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Effect of Different pH on *Alternaria* spp. and *Fusarium* spp. Pathogens of Potato Early Blight and *Fusarium* Wilt

Ravi Regar^{1*}, L.N.K. Singh¹, Bhuvaneswari V.¹ and Dinesh Kumar Meena²

¹Central Agricultural University, College of Agriculture, Imphal, Manipur

²Department of Plant Pathology, S.K.N. College of agriculture, Jobner, Jaipur.S

*Corresponding Author Email : raviregar4135@gmail.com

Abstract

Potato (*Solanum tuberosum* L.) is the most important vegetable crop in the world. It is also known as 'poor man's friend'. In Manipur during rabi season potato crop is the most widely cultivated vegetable. Potato is affected by many diseases like fungal, bacterial, viral, and also parasitic nematode. In potato 16% losses in yield due to microbial diseases and out of this 70-80% due to fungal affects. The present study was undertaken *in-vitro* condition. The mycelial growth of *Alternaria* spp. were studied at six different pH levels ranged from 4.0 to 9.0 on PDA medium and the results are presented in Table 2a. The Maximum radial growth of 8.5 cm was recorded at pH-7.0 at 7 days after inoculation. The Minimum radial growth of 6.1 cm was recorded at pH-4.0 at 7 days after inoculation. Also the mycelial growth of *Fusarium* spp. were studied at six different pH levels ranged from 4.0 to 9.0 on PDA medium and the results are presented in Table 2b. The Maximum radial growths of 8.5 cm were recorded at pH-6.0 at 7 days after inoculation. The Minimum radial growths of 5.7 cm were recorded at pH-4.0 at 7 days after inoculation. For both the pathogen *Alternaria* spp. and *Fusarium* spp. pH 6.1 and 5.7 were effective for mycelial growth under *in-vitro* conditions.

Key Words : *Alternaria* spp., *Fusarium* spp., pH, radial growths.

Introduction

Potato is a vegetable crop and non-grain food crop. Potato crop is also known as "poor man's friend". Botanical name is *Solanum tuberosum*. For vegetable purposes it is one of the most popular crop in India. In Manipur (Imphal East) potato cultivation area and production is 1.18 ha and 9.92 Mt (Agri. Manipur report 2017-18).

Major fungal pathogens causes different diseases in potato are late blight (*Phytophthora infestans*), early blight (*Alternaria solani*), wilt of potato (*Fusarium oxysporum*), powdery mildew (*Erysiphe cichoracearum*) and *Curvularia* diseases. In Manipur climatic condition mainly late and early blight, wilt diseases are occurred on potato crop.

Common symptom of Early blight caused by *Alternaria solani* appeared as small, irregular, dark brown to black spots and the size ranges from a pin point to ½ inch in diameter and also "appearance of concentric rings on older leaves. The lesion gives a characteristic "target-spot" or "bull's eye" appearance. Early blight is the major causes of defoliation of potatoes in the North Eastern States the increased disease severity is favored by alternating wet and dry conditions in the plant canopy (Franc, Harrison, and Lahman, 1988).

Symptoms of *Fusarium* wilt appeared as yellowing of the leaves, following by wilting, rolling or curling, sometimes affecting leaves on only one side of the plant.

The potatoes themselves may be blemished or decayed, often with sunken brown areas, especially at the stem end. Also plant growth stunted and developing of yellow leaves seeing in plant by Garibaldi *et al.* (2002).

Materials and methods

Isolation of fungal cultures : The diseased plants were collected from the potato grown in the experimental field. The early blight and wilt affected leaf and stem portions was cut into small pieces and surface sterilized with 0.1% sodium hypochlorite solution then afterward three times thoroughly washed with water. Potato dextrose agar (PDA) media were prepared and sterilized in an autoclave at 120°C, 15 lbs. pressure for 20 minutes. The media were poured into Petri plates and allowed to cool for sometimes. Then, the leaf pieces were inoculated into the media and kept for incubation. After seven to eight days the fungal tips were transferred to PDA slants in order to obtain pure cultures. The isolates were confirmed as *Alternaria* and *Fusarium* by microscopic observation of fungal culture. The slant culture was stored in BOD for future purposes.

Effect of pH on growth of fungal pathogens : The effect of various pH levels (hydrogen ion concentration) was studied using PDA as a basal medium. For the purpose, 400 ml PDA medium (in 500 ml capacity glass beaker) was poured in eight separate sterile glass beakers. pH concentration (4.0 to 9.0) of the PDA was measured using

pH meter and adjusted by adding 0.1 N HCL and NaOH solution, as required and adjusted the test pH concentration. After adjustment of the desired pH concentration of the medium, it was poured in sterile glass conical flasks (200 ml / 250 ml capacity flasks), plugged these flasks with non-absorbent cotton, wrapped with newspaper sheet, banded with rubber bands and autoclaved at 15 lbs. / inch² for 15 min. Autoclaved and cooled (45°C) PDA of various pH levels was poured (20 ml / plate) in sterile glass Petri plates by maintaining three plates / treatments. On solidification of PDA, these plates were inoculated separately by placing at the centre a single spore / a mycelium bit obtained from actively growing 3 days old pure culture of each isolate and incubated at 28±1°C. Radial growth of each isolate was recorded daily and the sporulation density was observed by using haemocytometer after 48 h. of inoculation.

Effect of different levels of pH on mycelial weight of fungal pathogens : Required quantity of potato dextrose broth (PDB) was prepared. The pH of the broth was adjusted to 4.0, 5.0, 6.0, 7.0, 8.0, and 9.0 with the help of digital pH meter using 0.1N HCL and 0.1N NaOH and sterilized. The 4 mm discs from actively growing three days old cultures of isolate were inoculated into the broth. The media dispensing and culturing activities were accomplished under laminar air flow cabinet. The broth was incubated at 25±2°C for 7 days, then the fresh and dry weight of the mycelial were recorded after filtering the mycelial mats on Whatman No.1 filter paper and dried at 60°C up to 24 hours in a hot air oven.

Estimation of fungal growth on dry weight basis by using the following formula: $W = W_2 - W_1$

W = Weight of the mycelial mat

W_1 = Weight of the filter paper

W_2 = Total weight of the fungal mycelial mat and filter paper

Results and Discussion

Effect of different pH on mycelial growth of *Alternaria* and *Fusarium* spp. : The mycelial growth of *Alternaria* spp. were studied at six different pH levels ranged from 4.0 to 9.0 on PDA medium and the results are presented in Table 2a. The Maximum radial growth of 8.5 cm was recorded at pH-7.0 at 7 days after inoculation. The Minimum radial growth of 6.1 cm was recorded at pH-4.0 at 7 days after inoculation. The *Alternaria* spp. produced dark black colony with cottony puffy growth with regular margin and very fast growth was observed in pH 7.

The mycelial growth of *Fusarium* spp. were studied at six different pH levels ranged from 4.0 to 9.0 on PDA medium and the results are presented in Table 2b. The

Maximum radial growths of 8.5 cm were recorded at pH-6.0 at 7 days after inoculation. The Minimum radial growths of 5.7 cm were recorded at pH-4.0 at 7 days after inoculation. The *Fusarium* spp. produced whitish puffy colony at initial stage later turns into straw colour mycelia with regular margin and also very fast growth observed in pH 7.

Effect of different pH on fresh and dry weight of *Alternaria* and *Fusarium* spp. : The fresh and dry weights of *Aternaria* spp. were studied at six different pH levels from 4.0 to 9.0 on PDB medium and the results are presented in Table 3a. The maximum (6.00 g) fresh weight was recorded in pH-7.0 after 7 days of inoculation. The minimum (2.53 g) fresh weight was recorded in pH-4.0. Highest (0.52 g) mycelial dry weight was obtained in pH-7.0 where the least (0.28 g) dry weight was observed in pH-4.0.

The fresh and dry weights of *Fusarium* spp. were studied at six different pH levels from 4.0 to 9.0 on PDB medium and the results are presented in Table 3b. The maximum (4.69 g) fresh weight was recorded in pH-7.0 after 7 days of inoculation. The minimum (2.71 g) fresh weight was recorded in pH-9.0. Highest (0.38 g) mycelial dry weight was obtained in pH-7.0 whereas the least (0.15 g) dry weight was observed in pH-4.0.

Effect of pH on growth and cultural characteristics of *Alternaria* and *Fusarium* spp. : According to Kiryu (1939) generally fungal pathogens utilize substrates in the form of solution only if reaction conducive to fungal metabolism and growth. For better fungal growth hydrogen ion concentration is very important. In the present study, all the six different pH levels viz., 4.0, 5.0, 6.0, 7.0, 8.0 and 9.0 were found to have influenced on production as well as the maximum of mean mycelial growth. The highest mean radial growths of 8.5 cm at pH-7.0 by *Alternaria* spp. after 7 days of inoculation were recorded. These findings are in supported of Gawai and Mangnalikar, (2018) and Chohan *et al.* (2015) who also found relatively similar types of results on average mycelial growth rate.

In *Fusarium* spp. also all the six pH levels viz., 4.0, 5.0, 6.0, 7.0, 8.0 and 9.0 were found to have influenced on production as well as the maximum of mean mycelial growth. The highest mean radial growth of 8.5 cm at pH-6.0 by *Fusarium* spp. after 7 days of inoculation was recorded. These findings are in accordance with Duarte *et al.* (2003), Tyagi, S. and Paudel, R (2014) and Jaruhar and Prasad (2011).

Effect of pH on fresh and dry weights of *Alternaria* and *Fusarium* spp. : The fungal pathogens *Alternaria* and *Fusarium* spp. had been tested at pH levels viz., 4.0, 5.0,

Table-1a : Effect of pH on growth characteristics of *Alternaria* spp.

Different pH	Mycelial growth in diameter (cm)						
	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	144 hrs	168 hrs
4.0	0.00 (0.71)	1.30 (1.34)	2.33 (1.68)	3.63 (2.03)	4.03 (2.13)	4.57 (2.25)	5.70 (2.49)
5.0	0.60 (1.05)	1.77 (1.51)	2.90 (1.84)	4.50 (2.24)	4.77 (2.30)	6.13 (2.56)	7.23 (2.78)
6.0	0.93 (1.20)	2.03 (1.59)	3.00 (1.87)	5.00 (2.35)	5.47 (2.44)	7.43 (2.82)	8.27 (2.96)
7.0	1.10 (1.27)	2.23 (1.65)	3.70 (2.05)	5.67 (2.48)	6.10 (2.57)	8.10 (2.93)	8.50 (3.00)
8.0	0.83 (1.15)	2.03 (1.59)	3.07 (1.89)	4.93 (2.33)	5.10 (2.37)	6.77 (2.70)	8.17 (2.94)
9.0	0.57 (1.03)	1.80 (1.52)	2.73 (1.80)	4.40 (2.21)	4.83 (2.31)	6.13 (2.58)	7.00 (2.74)
SE (d)	0.0881	0.1427	0.2494	0.1699	0.1539	0.1621	0.1885
CD at 5%	0.1921	0.3109	0.5434	0.3703	0.3354	0.3533	0.4108

*Mean of three replications, **Figures in the parenthesis are square root transformed values

Table-1b : Effect of pH on growth characteristics of *Fusarium* spp.

Different pH	Mycelial growth in diameter (cm)						
	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	144 hrs	168 hrs
4.0	0.67 (1.08)	1.17 (1.29)	1.53 (1.43)	3.17 (1.92)	4.23 (2.18)	5.20 (2.39)	6.10 (2.57)
5.0	1.27 (1.33)	2.80 (1.82)	4.03 (2.13)	5.07 (2.36)	6.60 (2.67)	7.37 (2.81)	7.83 (2.89)
6.0	1.47 (1.40)	3.10 (1.90)	4.43 (2.22)	5.23 (2.39)	7.47 (2.82)	8.13 (2.94)	8.50 (3.00)
7.0	1.37 (1.37)	2.90 (1.84)	4.17 (2.16)	4.80 (2.30)	6.77 (2.70)	7.93 (2.91)	8.23 (2.96)
8.0	1.00 (1.22)	2.50 (1.73)	3.43 (1.98)	4.50 (2.24)	6.33 (2.61)	7.63 (2.85)	8.03 (2.92)
9.0	0.93 (1.20)	2.43 (1.71)	3.30 (1.94)	4.07 (2.14)	5.73 (2.50)	6.77 (2.70)	7.10 (2.76)
SE (d)	0.1360	0.2741	0.4417	0.3150	0.1036	0.0860	0.0745
CD at 5%	0.2964	0.5974	0.9625	0.6864	0.2258	0.1875	0.1623

*Mean of three replications, **Figures in the parenthesis are square root transformed values

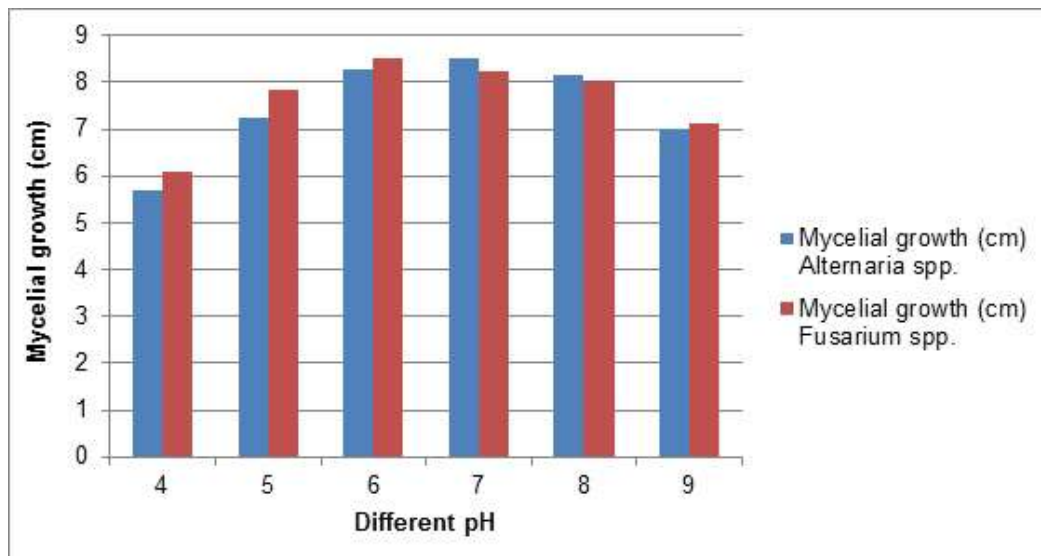
Fig-1 : Effect of different pH on growth of *Alternaria* and *Fusarium* spp.

Table-2a : Effect of pH on fresh and dry weight of *Alternaria* spp.

pH	Fresh weight (g)	Dry weight (g)
4.0	2.53*(1.74)**	0.28*(0.88)**
5.0	4.47(2.23)	0.48(0.99)
6.0	5.54(2.46)	0.49(1.00)
7.0	6.00(2.55)	0.52(1.01)
8.0	5.29(2.41)	0.46(0.98)
9.0	4.76 (2.29)	0.33(0.91)
SE (d)	0.4137	0.0460
CD at 5%	0.9015	0.1004

*Mean of three replications

**Figures in the parenthesis are square root transformed values.

Table-2b : Effect of pH on fresh and dry weight of *Fusarium* spp.

Different pH	Fresh weight (g)	Dry weight (g)
4.0	2.85*(1.83)**	0.15*(0.81)**
5.0	3.32(1.95)	0.25(0.87)
6.0	4.69(2.28)	0.38(0.94)
7.0	4.54(2.25)	0.36(0.93)
8.0	4.35(2.20)	0.33(0.91)
9.0	2.71(1.79)	0.20(0.84)
SE (d)	0.4137	0.0388
CD at 5%	0.9015	0.0846

spnum*Mean of three replications, **Figures in the parenthesis are square root transformed value

6.0, 7.0, 8.0 and 9.0 for analyzing their mycelial fresh weight and dry weight. The Maximum fresh weight of 6.00 g at pH 7 by *Alternaria* spp. after 7 days of inoculation where as the highest dry weight of 0.52 g of *Alternaria* spp. was found at pH 7. Similar results were obtained by Maheshwari *et al.* (2000) and Choudhary *et al.* (2017) in *Alternaria* and *Fusarium* spp. of fungi.

The maximum fresh weight of 4.69 g at pH 6 was obtained in case of *Fusarium* spp. after 7 days of inoculation. Accordingly highest dry weight of 0.38 g was recorded for *Fusarium* spp, pH 6. These findings were in accordance with earlier reported of Gupta *et al.* and (2010).

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Effect of Different Media on *Alternaria* spp. and *Fusarium* spp. Pathogens of Potato Early Blight and *Fusarium* Wilt

Ravi Regar*, L.N.K. Singh and Bhuvanewari V.

Central Agriculture University, College of Agriculture, Imphal, Manipur

*Corresponding Author Email : raviregar4135@gmail.com

Abstract

Solanum tuberosum is the most widely cultivated vegetable crop in Manipur during rabi season. India holds 2nd rank in potato production and 3rd in area under cultivation. In potato 16% losses in yield due to microbial diseases and out of this 70-80% due to fungal affects. The present study was undertaken *in-vitro* condition. The mycelial growth of *Alternaria* spp. was studied on five different media viz., potato dextrose agar, rose bengal agar, sabouraud agar, Richard synthetic agar, Malt extract agar. The Maximum radial growth of 8.5 cm was recorded in potato dextrose agar at 7 days after inoculation. The Minimum radial growth of 4.90 cm was recorded in rose bengal agar at 7 days after inoculation. *Alternaria* spp. showed dark black colony with cottony puffy growth white pigment with regular margin in potato dextrose agar cultural media used and slow to very fast growth were observed.

Also the mycelial growth of *Fusarium* spp. was studied on five different media. The Maximum radial growth of 8.5 cm was recorded in potato dextrose agar at 7 days after inoculation. The Minimum radial growth of 4.18 cm was recorded in rose bengal agar at 7 days after inoculation. *Fusarium* spp. showed whitish puffy colony at initial stage later turns into straw colour mycelia dark black colony with cottony puffy growth white pigment with regular margin in potato dextrose agar the cultural media used. Slow to very fast growth was observed. For both the pathogen *Alternaria* spp. and *Fusarium* spp. PDA media were effective for mycelial growth under *in-vitro* conditions.

Key Words : *Alternaria* spp., *Fusarium* spp., Media, potato dextrose agar, rose bengal agar, sabouraud agar, Richard synthetic agar, Malt extract agar, mycelial growth.

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important vegetable and non-grain food crop also known as “poor man’s friend”. It is one of the most popular crop in India for vegetable purposes. In Manipur (Imphal East) potato cultivation area and production is 1.18 ha and 9.92 Mt (Agri. Manipur report 2017-18) [5].

Major fungal diseases in potato are late blight (*Phytophthora infestans*), early blight (*Alternaria solani*), wilt of potato (*Fusarium oxysporum*), powdery mildew (*Erysiphe cichoracearum*) and *Curvularia* diseases. In Manipur climatic condition mainly late and early blight, wilt diseases are occurred on potato crop.

Symptom of Early blight caused by *Alternaria solani* appeared as small, irregular, dark brown to black spots and the size ranges from a pin point to ½ inch in diameter and also “appearance of concentric rings on older leaves. The lesion gives a characteristic “target-spot” or “bull’s eye” appearance. Early blight is the major causes of defoliation of potatoes in the North Eastern States the increased disease severity is favored by alternating wet and dry conditions in the plant canopy (Franc, Harrison, and Lahman, 1988) [1]. The disease initially appears on the older leaves causing premature senescence and leaf area reduction (Johnson and Teng, 1990) [7].

Symptoms of *Fusarium* wilt appeared as yellowing of the leaves, following by wilting, rolling or curling, sometimes affecting leaves on only one side of the plant. The potatoes themselves may be blemished or decayed, often with sunken brown areas, especially at the stem end. Also plant growth stunted and developing of yellow leaves seeing in plant by Garibaldi *et al.* (2002) [2].

Materials and Methods

Glassware clearing and cleaning : For all the laboratory experimental studies, Corning and Borosil glasswares were used. The glasswares were cleaned by keeping in solution of 60 g potassium dichromate solution, 60ml of concentrated sulphuric acid dissolved in a litre of distilled water for a day i.e., 24 h. Then the glasswares were washed with detergent solution followed by washing them under running tap water several times and finally they were washed with distilled water.

Sterilization : All the experimental materials, solid and liquid media were subjected to steam sterilization by autoclaving at 1.1 kg per cm² (i.e., 121.6°C) of pressure for 20 minutes. The plant tissues were surface sterilized in 1% sodium hypochlorite solution followed by three changes in sterile distilled water. All the cultural studies were performed in laminar flow where aseptic conditions prevailed, the tips of cork borers, forceps and inoculation

needles, loops were incinerated under flame of burner till their tips turn to red hot.

Isolation of fungal cultures : The diseased plants were collected from the potato grown in the experimental field. The early blight and wilt affected leaf and stem portions was cut into small pieces and surface sterilized with 0.1% sodium hypochlorite solution then afterward three times thoroughly washed with water. Potato dextrose agar (PDA) media were prepared and sterilized in an autoclave at 120°C, 15 lbs. pressure for 20 minutes. The media were poured into Petri plates and allowed to cool for sometimes. Then, the leaf pieces were inoculated into the media and kept for incubation. After seven to eight days the fungal tips were transferred to PDA slants in order to obtain pure cultures. The isolates were confirmed as *Alternaria* (Van Bruggen 1984)^[31] and *Fusarium* (Majumdar *et al.* 2008)^[20] by microscopic observation of fungal culture. The slant culture was stored in BOD for future purposes.

Effect of different media on pathogens : The cultural characteristics of pathogens were studied in five different media, viz., potato dextrose agar (PDA), rose bengal agar (RBA), sabouraud agar (SDA), malt extract agar (MEA) and Richard synthetic agar (RSA). Mycelial discs of (4 mm) of young actively growing culture of respective isolates of the pathogens were inoculated by placing at the centre of the petriplates containing the solidified media and incubated at 28±1°C for three days. Three plates were observed daily and all the distinguishing characters were recorded. The experiment was replicated three times. The cultural characters such as radial growth, colour, texture, margin, hyphal thickness, growth rate, zonation, odour and sporulation density were recorded.

The chemical compositions of different media were given below :

Potato Dextrose Agar Medium (PDA)

Potato – 200g
Dextrose – 20 g
Agar – 20 g
Distilled water – 1000 ml

Rose Bengal Agar Medium (RBA)

Potassium dihydrogen orthophosphate – 1.0 g
Magnesium sulphate – 0.5 g
Peptone – 5.0 g
Dextrose – 10.0 g
Rose Bengal – 0.033 g
Streptocycline – 0.03 g
Distilled water – 1000 ml

Sabouraud Agar Medium (SDA)

Dextrose – 40 g
Peptone – 10 g
Agar – 15 g
Distilled water – 1000 ml

Malt Extract Agar Medium (MEA)

Malt Extract – 20.0 g
Peptone – 1.0 g
Dextrose – 20.0 g
Agar – 20.0 g

Richard Synthetic Agar Medium (RSA)

Potassium Nitrate – 10.0 g
Monopotassium Dihydrogen Phosphate – 5 g
Magnesium Sulphate – 2.50 g
Ferric Chloride – 0.02 g
Sucrose – 50.0 g
Agar – 15.0 g

Results and Discussion

Effect of different media on the Growth of both Pathogens of Potato : The mycelial growth of *Alternaria* spp. was studied on five different media and the results are presented in Table – 3a. The maximum radial growth of 8.5 cm was recorded in potato dextrose agar at 7 days after inoculation. The minimum radial growth of 4.90 cm was recorded in rose bengal agar at 7 days after inoculation. *Alternaria* spp. showed dark black colony with cottony puffy growth white pigment with regular margin in potato dextrose agar the cultural media used. slow to very fast growth were observed (Table – 3a, Plate – 3a). These findings are supported by Shabana *et al.* (2015)^[13] and Koley and Mahapatra (2015)^[8] and Mishra and Versha (2012)^[9] and Somappa *et al.* (2013)^[14] who also performed test on growth performance, and other cultural characteristics of *Alternaria* spp. by using different nutrient media.

The mycelial growth of *Fusarium* spp. was studied on five different media and the results are presented in Table – 3b. The maximum radial growth of 8.5 cm was recorded in potato dextrose agar at 7 days after inoculation. The minimum radial growth of 4.18 cm was recorded in rose bengal agar at 7 days after inoculation. *Fusarium* spp. showed Whitish puffy colony at initial stage later turns into straw colour mycelia Dark black colony with cottony puffy growth white pigment with regular margin in potato dextrose agar the cultural media used. slow to very fast growth were observed (Table – 3b).

Table-3a : Effect of different media on growth characteristics of *Alternaria* spp.

Different media	Mycelial growth in diameter (cm)							Mycelial characteristics
	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	144 hrs	168 hrs	
RBA	0.15* (0.81)**	0.83 (1.15)	1.33 (1.53)	2.43 (1.71)	3.33 (1.96)	4.00 (2.12)	4.90 (2.32)	Thin, sparse mycelial growth
ME	1.05 (1.25)	2.28 (1.67)	2.85 (1.83)	4.03 (2.13)	4.90 (2.32)	6.15 (2.58)	7.40 (2.81)	Rigid, light brown to black colour, pluffy growth
PDA	1.58 (1.44)	2.70 (1.79)	3.35 (1.96)	4.58 (2.25)	5.45 (2.44)	7.00 (2.74)	8.50 (3.00)	Dark black colony with cottony pluffy growth
SA	0.73 (1.11)	1.93 (1.56)	2.58 (1.76)	3.38 (1.97)	4.13 (2.15)	5.65 (2.48)	7.15 (2.77)	Rigid, light brown to black colour, pluffy growth
RA	0.20 (0.84)	1.30 (1.34)	2.38 (1.70)	3.30 (1.95)	3.98 (2.12)	4.90 (2.32)	6.03 (2.56)	Whitish, thin, sparse mycelial growth
SE (d)	0.120	0.191	0.219	0.176	0.128	0.112	0.163	-
CD at 5%	0.256	0.408	0.467	0.375	0.273	0.239	0.347	-

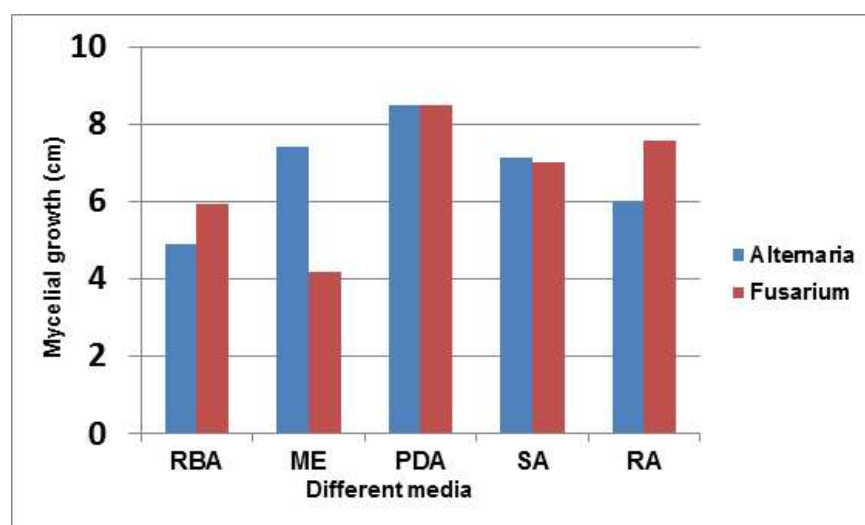
*Mean of four replications

**Figures in the parenthesis are square root transformed values.

Table-3b : Effect of different media on growth characteristics of *Fusarium* spp.

Different media	Mycelial growth in diameter (cm)							Mycelial characteristic
	24 hrs	48 hrs	72 hrs	96 hrs	120 hrs	144 hrs	168 hrs	
RA	0.63* (1.06)**	1.23 (1.32)	2.78 (1.81)	3.63 (2.03)	4.53 (2.24)	4.90 (2.32)	5.95 (2.47)	Very thin whitish mycelial growth
RBA	0.18 (0.83)	1.18 (1.30)	1.75 (1.50)	2.40 (1.70)	3.08 (1.89)	3.38 (1.97)	4.18 (2.16)	Very thin whitish mycelial growth
PDA	2.13 (1.62)	3.10 (1.90)	4.10 (2.15)	5.15 (2.38)	6.13 (2.58)	7.43 (2.82)	8.50 (3.00)	Whitish pluffy colony at initial stage later turns into straw color mycelia
SA	1.05 (1.25)	1.80 (1.52)	2.85 (1.83)	3.70 (2.05)	4.98 (2.34)	5.78 (2.51)	7.03 (2.74)	Whitish growth at peripheral region, light brownish yellow at center
ME	1.30 (1.34)	2.20 (1.64)	3.03 (1.88)	4.13 (2.15)	5.23 (2.39)	5.88 (2.53)	7.58 (2.84)	Cottony White growth
SE (d)	0.0987	0.1839	0.2217	0.2506	0.099	0.1449	0.1172	
CD at 5%	0.2104	0.3920	0.4726	0.5342	0.2122	0.3088	0.2499	

*Mean of four replications, **Figures in the parenthesis are square root transformed values.

Fig-2 : Effect of different media on growth of *Alternaria* and *Fusarium* spp.

These findings are supported by Gupta *et al.* (2010)^[4] and Pradeep *et al.* (2013)^[11] and Yadav *et al.* (2017)^[15] who also performed test on growth performance, and other cultural characteristics of *Fusarium* spp. by using different nutrient media. Againg, among the 5 media used, potato dextrose agar had shown best results.

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Efficacy of Certain Bioagents and Botanicals against Leaf Spot of Groundnut (*Arachis hypogaea* L.)

Pushpendar Singh Shekhawat*, Sunil Zacharia and Prdeep Singh Shekhawat

Department of Plant Pathology, Sam Higginbottom University of Agriculture, Technology and Sciences, Uttar Pradesh-211007

*Email : shekhawatpushpendar@gmail.com

Abstract

In-situ experiments were carried out in randomized block design with seven treatments and three replications. *Trichoderma viride* @ 5%, was found to be the most effective treatment and recorded minimum disease intensity (20.33 %) and better yield (0.920 t/ha) followed by *T. harzianum* @ 5%, *Pseudomonas fluorescens* @ 5%, neem leaf extract @ 20% and datura leaf extract @ 20%. Use of *T. viride* recorded maximum plant height 42.05 cm at 75 DAS.

Key words : Carbendazim, datura leaf extract, groundnut, neem leaf extract, *Pseudomonas fluorescens*, tikka disease, *Trichoderma harzianum* and *Trichoderma viride*.

Introduction

Earthnut (*Arachis hypogaea* L.) is one of the cardinal oil seed crops of the world. Earthnut is dictatorial among all the leguminous crops, envisaged as “poor man’s nut” and belongs to leguminous family. Earthnut has been the main oilseed crop in India and other evaluative countries for several decennary and was continue to be so in the future. Globally, earthnut (*Arachis hypogaea* L.) production and area till 2014-15 mean 17.8 million tonnes and 18.9 million hectare. In India, earthnut production, area and productivity during 2014-15 mean 9.67 million tonnes, 5.53 million hectare & 1750 kg/ha (Agriculture Statistics at Glance, 2014). In India, earthnut is cultivated more than 85% production of groundnut comes from five States namely Gujarat (38%), Andhra Pradesh (16%), Tamil Nadu (14%), Rajasthan (9%) and Karnataka (8%). *Cercospora* leaf spots of earthnut caused by *Cercospora arachidicola* (early leaf spot) and *Cercospora personata* (late leaf spot) are important diseases of earthnut in Nigeria and other regions of the world Subrahmanyam *et al.* (1980). It is the most important disease of earthnut in the Sudan savannas of Nigeria where the largest earthnut t production takes place. In addition to reduction in seed yield, it causes serious damage to the foliage which is a valuable fodder for livestock especially during a dry season. The 30-40% in USA yield losses of 50% was reported due to *Cercospora* leaf spot attack on earthnut.

Materials and Methods

Field experiment : Experiment was laid out in randomized block design (RBD) with seven treatments viz. *Trichoderma viride* @ 0.5%, *Pseudomonas fluorescens* @ 0.5%, *T. harzianum* @ 0.5%, botanicals viz. neem leaf extract @ 20%, datura leaf extract @ 20%

and fungicide viz. carbendazim @ 0.1% and three replications including untreated check in the experimental field of SHIATS, Allahabad in *kharif* season (August 2015). Each replication consisted of 21 plots of 2x2 m² each. The seeds cv. kushal was sown in August with a spacing of 30 x 10 cm. The bio-agents viz. *Trichoderma viride* @ 0.5%, *Pseudomonas fluorescens* @ 0.5%, *T. harzianum* @ 0.5%, botanicals viz. neem leaf extract @ 20%, datura leaf extract @ 20% and fungicide viz. carbendazim @ 5% were used as seed treatment and foliar spray. Observations were recorded in five selected tagged plants.

Symptoms : ELS are sub-circular to irregular 1 to 10 mm in diameter. Lesions are commonly dark (reddish) brown to black on the upper surface and light brown on the lower leaf surface. Leaf spot on upper surface is commonly surrounded by a yellow chlorotic halo. LLS are usually smaller and more nearly circular than early leaf spot lesions, 1 to 6 mm in diameter and are commonly dark gray or black on the lower leaf surface. There is no yellow halo around them. The LLS is usually more severe than ELS (Sharma, 2006). Fig.-1.

Results and Discussion

The result presented in Table-2 revealed that all the treatments were statistically significant and increased plant height as compared to untreated check. At 75 days after sowing, maximum plant height was recorded in T₂- *Trichoderma viride* (42.05 cm) followed by T₃- *T. harzianum* (41.88 cm), T₄- *Pseudomonas fluorescens* (41.80 cm), T₅- Neem leaf extract (41.28 cm), T₆- Datura leaf extract (40.68 cm), as compared to treated check T₁- Carbendazim (42.61 cm) and untreated check T₀- (40.18 cm).

Table-1 : Details of treatments.

Treatments	Treatment Name	References
T ₀	Control	-
T ₁	Carbendazim @ 50 %WP	Dubey <i>et al.</i> (1997)
T ₂	<i>Trichoderma viride</i>	Rakholiya and Jadeja (2010)
T ₃	<i>Trichoderma harzianum</i>	Rakholiya and Jadeja (2010)
T ₄	<i>Pseudomonas fluorescens</i>	Saravanakumar <i>et al.</i> (2007)
T ₅	Neem leaf extract	Hossain and Hossain (2013)
T ₆	Datura leaf extract	Hasan <i>et al.</i> (2014)



Figure-1 : (A) Conidiophore of *Cercospora* sp.
(B) Showing Earthnut plant infected with tikka disease.

The result presented in Table-2 revealed that all the treatments were statistically significant and increased plant leaf number as compared to untreated check. At 75 days after sowing, maximum plant leaf number was recorded in T₂- *Trichoderma viride* (131.67) followed by T₃- *T. harzianum* (130), T₄- *Pseudomonas fluorescens* (126), T₅- Neem leaf extract (118), T₆- Datura leaf extract (116), as compared to treated check T₁- Carbendazim (135) and untreated check T₀- (105).

The result presented in Table-3 revealed that all the treatments were statistically significant and increased disease intensity as compared to untreated check. At 60 days after sowing, maximum disease intensity was recorded in T₂- *Trichoderma viride* (20.33%) followed by T₃- *T. harzianum* (23.33%), T₄- *Pseudomonas fluorescens* (25%), T₅- Neem leaf extract (26.33%), T₆- Datura leaf extract (27.67%), as compared to treated check T₁- Carbendazim (18.33%) and untreated check T₀- (32%).

The result presented in Table 4 revealed that all the treatments were statistically significant and increased yield (g/plot) as compared to untreated check. Among the bio-agents and botanicals used the mean of maximum yield (g/plot) was recorded in T₂- *Trichoderma viride* (268.32g) followed by T₃- *T. harzianum* (235.12g), T₄- *Pseudomonas fluorescens* (209.20g), T₅- Neem leaf extract (186.91g), T₆- Datura leaf extract (174.36g), as compared to treated check T₁- Carbendazim (357.58g) and Untreated Check T₀- (162.67g).

Similar results were found by Hossain and Hossain (2013), Mane (2012) and Hasan *et al.* (2014) who found the boosting effect of Carbendazim 50 %WP @ 0.1% *Trichoderma viride*, *Trichoderma harzianum*, *Pseudomonas sp.*, Neem leaf extract (20%) and Datura leaf extract (20%) formulation on plant growth prove (evidenced) by the fact that the, Intensity of leaf spot/plant was also found to using bio-agents and botanicals was found to be the most effective in managing late leaf spot disease.

Table-2 : Effect of treatments on plant growth and total number of leaves of earthnut at 75 days after sowing under field conditions.

Treatments	Plant height (cm)	Total number of leaves
T0-Untreated check	40.18	105
T1-Carbendazim	42.61	135
T2- <i>Trichoderma viride</i>	42.05	131.67
T3- <i>Trichoderma harzianum</i>	41.88	130
T4- <i>Pseudomonas fluorescens</i>	41.80	126
T5-Neem leaf extract	41.28	118
T6-Datura leaf extract	40.68	116
C.D. (5%)	0.97	5.25
S.Ed.	0.44	2.41

Table-3 : Management of Tikka disease of earthnut (*Arachis hypogaea* L.) by bio-agents and botanicals at 60 DAS.

Treatments	Disease intensity %
T0-Untreated check	32.00
T1-Carbendazim	18.33
T2- <i>Trichoderma viride</i>	20.33
T3- <i>Trichoderma harzianum</i>	23.33
T4- <i>Pseudomonas fluorescens</i>	25.00
T5-Neem leaf extract	26.33
T6-Datura leaf extract	27.67
C.D. (5%)	1.895
S.Ed.	0.870

Table-4 : Effect bio-agents and botanicals on Yield (tonnes/ha).

Treatments	Yield (tonnes/ha)
T0-Untreated check	0.4625
T1-Carbendazim	1.143
T2- <i>Trichoderma viride</i>	0.920
T3- <i>Trichoderma harzianum</i>	0.851
T4- <i>Pseudomonas fluorescens</i>	0.725
T5-Neem leaf extract	0.533
T6-Datura leaf extract	0.505
C.D.	16.11
S.Ed.	7.39

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Efficacy of Bioagents and Botanical Extracts on the Disease Incidence (%) of *Sclerotium rolfsii* of Brinjal

Pajjuru Sujana Sri and Prdeep Singh Shekhawat

Department of Plant Pathology, Sam Higginbottom University of Agriculture, Technology and Sciences, Uttar Pradesh-211007

Abstract

Brinjal (*Solanum melongena* L.) known as the king of vegetables, It is a small short lived perennial herb belonging to the night shade family solanaceae of dicot angiosperm. Brinjal is often referred to as a poor man's vegetable because of seasonally low prices, but the fruits are nutritionally equivalent to tomatoes and represent an important source of vitamins. An experiment was conducted to manage brinjal collar rot in the fields of Keshvapuri village of Mehabubnagar district in Telangana during Rabi season of 2021 in the guidance of the Department of Plant Protection at Sam Higginbottom University of Agriculture, Technology and Science in Prayagraj. A Randomized Block Design was adopted with three replicates for seven environmentally friendly treatment by using *Trichoderma* sp. (4g/kg of seeds), *Pseudomonas fluorescences* (4g/ kg of seeds) neem oil (1%), mustard oil (1%), castor oil (1%), onion bulb (5%), tulsi leaf (5%) extracts, Among those treatments *Trichoderma* sp. (4g/kg of seeds) was found the most effective treatment and exhibited minimum percent disease incidence (18.8%)

Key words : Bio-agents, botanical extracts, collar rot, disease incidence, disease intensity, *Solanum melongena*, *Sclerotium rolfsii*.

Introduction

Brinjal (*Solanum melongena* L.) known as the king of vegetables, It is a small short lived perennial herb belonging to the night shade family solanaceae of dicot angiosperm (Siddique *et al.*, 2014). It is an important crop cultivated worldwide throughout the tropics and sub tropics. The brinjal, eggplant has originated in the Indian sub-continent and China (Thompson and Kelly, 1957).Where the major domestication of large fruited cultivars occurred. In "Origin of cultivated plants" published in (De Candolle, 1886) stated that the species *Solanum Melongena* has been known in India from ancient times and regarded it as a native of Asia (Lokesh and Kantharaju, 2018).

The leading brinjal producing countries in the order of importance are China, India, Japan, Italy and Spain. In India the major brinjal producing states in India are Andhra Pradesh, Maharashtra, Karnataka, Orissa, Madhya Pradesh and West Bengal. (Tabing and Tiwari, 2018). China is the largest producer of brinjal while, India occupies second position in production of brinjal in the world (13.15 MMT of world production). India ranks second in area (744 thousand/ha) and it is the fourth most important vegetable crop in India in terms of production contributing (12680 MT/ha) of total vegetable production. However, the productivity of brinjal is quite low (17.0) in India compared to that of other advance countries, where the productivity ranges from 17.8 - 35.9 MT/ha. Uttar Pradesh is largest producer with an average productivity of (35.24 MT/ha) (CMIE, 2019-2020).

Brinjal is often referred to as a poor man's vegetable because of seasonally low prices, but the fruits are nutritionally equivalent to tomatoes and represent an important source of vitamins. Nutritional value per 100 g, brinjal has a very low caloric value (24 K cal), protein (2%) and vitamin C (2.2 mg) but is a very good source of dietary fibre (3.4 g), potassium (230 mg), manganese (14 mg), calcium (9 mg), copper (0.082 mg) and thiamine (0.039 mg). (Singh *et al.*, 2014).

Brinjal is a hardy, long duration crop with high yielding, and is cultivated under a wide range of soils, well drained and fertile soil is preferred. It is grown as commercial crop throughout India. The most favourable temperature for its successful production on a daily basis is 13°C - 21°C.

The collar rot of brinjal caused by *Sclerotium rolfsii* commonly affects the plant population, yield and quality of the crop. *S. rolfsii* has an extensive host range at least 500 species in 100 families are susceptible including brinjal, Groundnut, Green bean, Lima bean, Onion, Pepper, Potato, Tomato, Sweet potato, and Watermelon, cucumber, soybean, maize, etc. It causes different types of diseases such as collar rot, sclerotium wilt, stem rot, charcoal rot, seedling blight, damping-off, foot-rot, stem blight and root-rot, sclerotium blight, sclerotium rot, southern blight, southern stem rot, and white mould in many economically valuable crops. (Suryawanshi *et al.*, 2015). Of these diseases, collar rot is becoming one of the threats both under nursery and field cultivation of brinjal. Infestation of the disease may start from sowing of the seeds on nursery beds to flowering of the crop in fields,

Table-1 : Disease incidence (%) at 45, 60 and 75 DAS as affected by treatments.

Treatments number	Treatments	Dosage	Disease incidence (%)		
			45 DAS*	60 DAS*	75 DAS*
T0	Control	-	46.63	59.96	83.3
T1	<i>Trichoderma</i> spp.	4g/kg (ST)	6.6	13.3	18.8
T2	<i>Pseudomonas fluorescens</i>	4g/kg (ST)	13.3 ^a	26.6 ^a	36.6
T3	Onion bulb extract (<i>Allium cepa</i>)	5% (ST)	19.96	28.8 ^a	46.6
T4	Tulsi leaf extract (<i>Ocimum sanctum</i>)	5% (S T)	39.9	53.3	73.3
T5	Neem oil (<i>Azadirachta indica</i>)	1% (S D)	11.06 ^a	19.9	26.6
T6	Mustard oil (<i>Brassica juncea</i>)	1% (S D)	33.3	46.63	66.6
T7	Castor oil (<i>Ricinus communis</i>)	1% (S D)	26.6	33.3	56.6
	C.D. (5%)		2.378	2.403	2.413
	S.E (m) ±		0.783	0.785	0.788

which may lead to heavy losses in the plant stand per unit area and ultimately the yield.

Sclerotium rolfsii is a soil-borne facultative, necrotrophic, pathogen, belonging to the division Basidiomycota. The sclerotia can survive in the soil from a few months to several years. After germination, *S. rolfsii* hyphae produce oxalic acid and pectinolytic and cellulolytic enzymes which kill and disintegrate host tissues, starting a new infection (Le. 2011). Clamp connection may be present in hyphae. It produces numerous small round, spherical sclerotia of 0.5 to 1.5mm diameter and of uniform size when immature, the sclerotia are white in colour and produce clear to pale yellowish coloured droplets. White coloured sclerotia later become dark brown in colour and resembled mustard seeds at mature stage. (Neelu *et al.*, 2019).

Materials and Methods

An experiment was conducted to manage brinjal collar rot in the fields of Keshvapour village of Mehabubnagar district in Telangana during Rabi season of 2021 in the guidance of the Department of Plant Protection at Sam Higginbottom University of Agriculture, Technology and Science in Prayagraj. This research project was conducted during the Rabi season, spanning from November 2021 to March 2022. In order to prepare the designated field for experimentation, the following steps were taken: removal of weeds, precise leveling of the terrain and thorough soil refinement. The entire experimental area was divided into 21 separate plots by using *Trichoderma* sp. (4g/kg of seeds), *Pseudomonas fluorescens* (4g/ kg of seeds) neem oil (1%), mustard oil (1%), castor oil (1%), onion bulb (5%), tulsi leaf (5%) extracts.

Nursery preparation : The selected field area was well prepared and plot marked as per the lay out plan. The selected field was ploughed, cleaned and the soil was well

pulverized after which the total area was divided into sub-plots.

Cultivation of Brinjal : Local susceptible variety was chosen for the experiment. All the package of practices was followed as per the general agronomic practices.

Seed Treatment : Seed treatment was done for seeds with *Trichoderma* sp. @4g/kg, *Pseudomonas fluorescens* @4g/kg of seeds, Onion bulb extract@5% and with Tulsi Leaf Extract@5%.

Seedling Dip Treatment : Seedling Dip Treatment was done for the seedlings before transplanting with Neem oil@1%, Castor oil@1%, and Mustard Oil@1.

Results and Discussion

Effect of Treatments on the Disease incidence (%) of Brinjal at 45, 60 and 75 DAS

Disease incidence (%) at 45 DAS : The data represented in table-1 reveals minimum average % disease incidence of *Sclerotium rolfsii* was observed in T1-*Trichoderma* sp. @ 4g/kg of seeds (6.6%) and T5- neem oil@ 1% (11.06%), Followed by T2-*Pseudomonas fluorescens*@ 4g/kg of seeds (13.3%), T3- Onion Bulb extract @ 5% (19.96%) and T7- Castor oil @ 1% (26.63%) as compared to T6- Mustard oil@ 1% (33.30%), T4- Tulsi leaf extract@ 5% (39.96%) and T0- untreated control (46.63%). All the treatments were significant to untreated control. Among the treatments (T5 and T2), were statistically non-significant to each other.

Disease incidence (%) at 60 DAS : The data represented in table-1 reveals the disease incidence (%) significantly decreased in T1-*Trichoderma* sp.@ 4g/kg of seeds (13.3%) followed by T5- neem oil@ 1% (19.96%), T2- *Pseudomonas fluorescens*@ 4g/kg of seeds (26.6%), T3- Onion Bulb Extract@ 5% (28.8%) and T7- Castor oil@ 1% (33.30%) as compared to T6- Mustard oil@ 1%

(46.63%), T4-Tulsi leaf extract @ 5% (53.3%) and T0-untreated control (59.96%). All the treatments were significant over untreated control. Among the treatments (T3 and T2) were statistically non significant to each other.

Disease incidence (%) at 75 DAS : The data represented in table-1 reveals the disease incidence (%) significantly decreased in T1-*Trichoderma sp.*@ 4g/kg of seeds (18.8%) followed by T5-neem oil@ 1% (26.6%), T2-*Pseudomonas fluorescens*@ 4g/kg of seeds (36.63%), T3- Onion Bulb Extract@ 5% (46.6%) and T7- Castor oil@ 1%(56.6%) as compared to T6- Mustard oil@ 1% (66.6%), T4- Tulsi leaf extract@ 5%(73.3%)and T0-untreated control (83.3%). All the treatments were significant over untreated control.

Field efficacy of Treatments on the disease incidence (%) of *Sclerotium rolfsii* of Brinjal at 45, 60 and 75 DAS : The similar findings was reported by Jadon *et al.* (2009) reported the soil and seedling dip treatment with *Trichoderma viride* @ 4g/kg of seedling and 50mg with 5g FYM/m² respectively was found most effective in reducing the % disease incidence. Meena *et al.* (2019) reported that different bio agents at the concentration of 1, 2.5 and 5% were tested. The results indicated that *T. harzianum*, *T. viride*, *P. fluorescens* and *B. subtilis*, potentially control the growth of *S. rolfsii*. Mahato *et al.* (2014) who found that *Trichoderma viride* and *Pseudomonas* showed highest inhibitory activity (68.28% and 74.25%) against *Sclerotium rolfsii* under in vitro conditions. Karthikeyan *et al.* (2006) tested the organic amendments tin greenhouse, mahua cake with *T. viride* each @5g/ kg of soil resulted in 3.75% stem rot incidence as against 39.98% in control. Enhanced activities of defence-related enzymes *viz.*, peroxidase (PO) and polyphenoloxidase (PPO) were noticed in infected plants rather than in healthy ones. Although induction of PO as well as PPO was observed in diseased plants, additional increase in activities of these enzymes were observed in plants treated with either *P. fluorescens* or *T. viride*. These results of the present study concedes with the reports of earlier workers who reported effectiveness of the bioagents (Biradar *et al* 2021, Patait N N 2021) And phytoextracts (biradar *et al* 2021).

Conclusions

From present study it was concluded that *Trichoderma sp.* was found highly effective in minimizing disease incidence. The results revealed that disease incidence (%) in brinjal at 45, 60 and 75 DAS significantly decreased by using *Trichoderma sp.* @ 4g/kg of seeds. They can be exploited for further experimentation to manage this disease. The findings of the present experiment are

limited to one crop season under Mahabubnagar agro-climatic conditions, as such to validate the present findings more such trials should be carried out in future.

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Productivity, Economic Efficiency and Energy Auditing of Rice Cultivation under Conservation Agriculture in the Vertisols of Central India

Anoop Kumar Rathore*, A.R. Sharma, M.C. Bhambri, Jitendra Marskole and Rituja Jain

ICAR-Directorate of Weed Research, Jabalpur, Madhya Pradesh-482004

*Corresponding Author Email : anprathore@gmail.com

Abstract

Conservation agriculture (CA)-based systems are known to be cost-effective and energy-use efficient besides being ecologically sustainable. However, research efforts are limited for rice cultivation in the vertisols of central India. We investigated the effects of different tillage-residue management practices (zero tillage with residue retention; zero tillage with residue burnt; conventional tillage with residue incorporation; conventional tillage with residue burnt), 2 N levels (100 and 125% recommended dose of N), and 3 weed management practices (unweeded, herbicide and integrated) on rice grown in sequence with wheat and greengram. The grain yield of ZT rice with residue retention was maximum and comparable with conventional tillage with residue incorporation in 2014 only. The ZT with residue retention was the most energy-efficient and profitable rice cultivation practice in terms of energy-use efficiency and net benefit: cost ratio. There was no significant influence of N levels on rice yields, energetic and economics. The highest grain yield was achieved with integrated weed management (IWM) involving *Sesbania* co-culture + pendimethalin 1000 g ha⁻¹ as pre-emergence fb 2, 4-D 500 g ha⁻¹ as post-emergence fb hand weeding. Energy-use efficiency was higher in IWM but it was not the cost effective practice. Most profitable practice in terms of B:C ratio was weed management through herbicides. It was concluded that zero tillage with residue retention along with recommended dose of N and weed management by herbicides was the most profitable and productivity in terms of B:C ratio and energy productivity. This could be a substitute for the energy-intensive conventional agricultural system for adoption in rice in the vertisol of central India.

Key words : Conservation agriculture, economic, energy, nitrogen management, direct seeded rice, weed management.

Introduction

Relationship between energy and agriculture is becoming more important under resource scarce situations (Chaudhary *et al.*, 2009). Energy consumption determines the productivity and profitability of agriculture production system. Energy-use efficiency and cost of cultivation of a production system are influenced by a range of factors, such as tillage, nutrients, pest management, harvesting and yields (Singh *et al.*, 1997). Increased use of energy in agriculture production system has led to higher cost of production and environmental problems (Nemecek *et al.*, 2011). In Madhya Pradesh, rice (*Oryza sativa*) is the one of important cereal crop cultivated on nearly 2.0 million ha, with a total production of 2.8 million tonnes (Agricultural Statistics at A Glance, 2014). It is an energy-intensive crop, and a major component of its use is through land preparation, fertilizers (Mandal *et al.*, 2015) and weed management. Conventional tillage is one of the most energy-consuming and high-priced operations in crop production system. Burning of preceding crop residue to clear the land for seedbed preparation is also a common practice associated with conventional tillage. The intensive use of energy in conventional tillage and burning of preceding crop residue are the concerns of the farmers as well as the environmentalists. Avoiding

unnecessary tillage may reduce energy use, labour and time requirement, and thus enhance energy-use efficiency of field operations compared with conventional tillage. Zero tillage is considered as an immediate response to ensure a reduction in energy consumption due to the negligible energy requirement for land preparation. Tillage and residue recycling affect N dynamics in soil. Nitrogen fertilizer contributes the highest share of energy consumption among all energy inputs used in most agricultural production systems (McLaughlin *et al.*, 2000). Weeds are a serious constraint in direct-seeded rice reducing yield up to 100%. Higher cost of cultivation relative to the lower returns from rice cultivation is a major concern among the rice farmers. Therefore, it is important to audit energy and cost in conventional and conservation agricultural practices. This study was planned to find out the energy- and cost-efficient cultivation system for sustainable direct-seeded rice production in the vertisols of central India.

Materials and Methods

Experimental Site and weather conditions : The field experiment was conducted on a fixed layout during rainy seasons of 2014 and 2015 at the Indian Council of Agricultural Research (ICAR)-Directorate of Weed Research (DWR), Jabalpur, Madhya Pradesh, India

(25°31' N, and 412 m above mean sea level). The patterns of rainfall and temperature during the cropping seasons of 2014 and 2015 are presented in Fig. 1. Rainfall during the rice growing season of 2014 (1180 mm) was relatively higher than 2015 (971 mm). Further, highly erratic pattern of rainfall distribution was observed in 2015. At vegetative growth stage of crop, the distribution of rainfall was quite similar during the each week of 2014 and 2015. However, the rice season of 2015 received the fraternal distributed and lower amount of rainfall (195.8 mm) during the critical period of reproduction as compared to 2014. Maximum weekly temperature of rice season 2015 was also slightly higher than of 2015 and long-term averages.

Experimental details : The field was under transplanted rice-wheat till 2012-13. It was laser levelled after wheat harvested and subsequently summer greengram (April-June) was grown in 2013. The experimental crop of rice was taken from 2013-14 in sequence with wheat and greengram. The experiment was conducted in a split-split plot design on a fixed layout. The main plot treatments comprised of four tillage-residue management practices, viz. zero tillage with residue retention (ZT+RR): the loose residues of preceding crop were manually spread uniformly over the plots before direct drilling of rice crop by using Happy seeder; zero tillage with residue burnt (ZT+RB): all loose residues of preceding crop were spread manually for uniform burning, and sowing was done by zero-till seed-cum-fertilizer drill after burning of residues; conventional tillage with residue incorporation (CT+RI): uniform spreading of preceding crop loose residues and incorporated with cultivator twice followed by (*fb*) rotavator twice; and conventional tillage with residue burnt (CT+RB): uniform spreading of preceding crop loose residues and burning following which the field was prepared with two passes each of cultivator *fb* rotavator. Two N-levels in sub-plots comprised of 100% recommended dose of N (RDN) and 125% RDN. The three weed management practices in sub-sub-plot comprised of unweeded (no weed management practice applied), herbicide (pendimethalin 1000 g ha⁻¹ as pre-emergence *fb* bispyribac-Na 25 g ha⁻¹ as post-emergence) and integrated weed management (IWM) (*Sesbania* co-culture with rice + pendimethalin 1000 g ha⁻¹ as pre-emergence *fb* 2,4-D 500 g ha⁻¹ as post-emergence *fb* hand weeding).

Crop establishment and management : Rice (*IR 64*) was sown mechanically at seed rate 25 kg ha⁻¹. Site-specific application of non-selective herbicide, i.e. glyphosate was sprayed @ 1.0 kg ha⁻¹ on unburned and green foliage of weeds under zero tillage plots and other weed management practices were applied as per the treatments. The recommended dose of N-P₂O₅-K₂O is

120-60-40 kg ha⁻¹. P₂O₅ and K₂O were applied as per the recommended rate and N was applied as per the treatments. Crop was raised with standard package of practices in all years.

Energy analysis : The parameters such as, energy input, energy output, net energy return, energy-use efficiency, energy profitability and energy productivity were calculated by converting the physical units of energy input-outputs to Mega Joule (energy unit) through the standardized conversion coefficient factors given in Table 1 and 2. All the inputs in the form of energy equivalents were summed to provide an estimate of input energy for crop cultivation. On the other hand, the energy output was estimated by multiplying energy equivalent to their corresponding grain and straw yield and expressed both input and output energy in terms of MJ ha⁻¹. All other parameters were calculated based on the standardized formulas (Mandal *et al.*, 2015).

Economic analysis : The economic analysis in terms of gross and net returns and benefit: cost ratio (returns per rupee invested) was done on the basis of existing rate of input and output. Total cost of cultivation of rice was calculated by summing the cost of all inputs (seeds, fertilizers, pesticides, fuel, labourers, etc.) and operating cost of machinery on per hour basis. Returns were calculated based on the standardized formulas (Gathala *et al.*, 2015).

Statistical analysis : Data were statistically analysed as per the standard analysis of variance (ANOVA) technique using the statistical software package SAS to compare the differences between means of different treatments at 5% level of significance ($p = 0.05$).

Results and Discussion

More favorable weather condition in 2014 led to better performance of crop than 2015 thus the yield was comparatively higher in 2014 than 2015. Initially (2014) ZT+RR gave significantly higher grain yield which was comparable with CT+RI, whereas at the next year (2015) which was a relatively low rainfall year, ZT+RR yielded significantly more than rest of tillage-residue management practices (Fig. 2a). Reduction in grain yield by 11-18% under residue burnt with CT and ZT in 2014 as compare to residue retention with ZT and incorporation with CT. Grain yield by 6-15% gain under ZT+RR over rest of tillage-residue management practices during 2015. No significant difference in grain yield was observed under both N-levels during both years. IWM produced significantly higher yield over other two weed management practices. Herbicide weed management also significantly increased grain yield over unweeded (Fig. 2a). Grain yield increased by 6-44% and 5-59%

Table-1 : Energy equivalent for different inputs and outputs.

Particulars	Unit	Equivalent energy (MJ)	Reference
A. Inputs			
1. Human labor			
(a) Adult man	MJ h ⁻¹	1.96	Mittal and Dhawan (1988)
(b) Adult women	MJ h ⁻¹	1.57	Mittal and Dhawan (1988)
2. Diesel including lube	MJ l ⁻¹	56.31	Mittal and Dhawan (1988)
3. Electricity	kWh	11.93	Mittal and Dhawan (1988)
4. Chemicals and fertilizers			
(a) Nitrogen	MJ kg ⁻¹	78.1*	Kitani (1999)
(b) Phosphorous (P ₂ O ₅)	MJ kg ⁻¹	17.4*	Kitani (1999)
(c) Potash (K ₂ O)	MJ kg ⁻¹	13.7*	Kitani (1999)
(d) Fungicide (kg a.i.)	MJ kg ⁻¹ a.i.	99	Strapatsa (2006)
(e) Herbicide (kg a.i.)	MJ kg ⁻¹ a.i.	287	Tzilivakis <i>et al.</i> (2005)
5. Machinery			
(a) Knapsack sprayer	MJ h ⁻¹	0.26	Mandal <i>et al.</i> (2015)
(b) Rotavator	MJ h ⁻¹	6.69	Mandal <i>et al.</i> (2015)
(c) Tractor	MJ h ⁻¹	16.42	Nassiri (2009)
(d) Combine harvester	MJ h ⁻¹	171	Nassiri (2009)
(e) Machinery	MJ kg ⁻¹	62.7	Sidhu <i>et al.</i> (2015)
6. Seed			
(a) <i>Sesbania</i>	MJ kg ⁻¹	14.7	Khan and Hossain (2007)
(b) Rice	MJ kg ⁻¹	14.7	West and Marland (2002)
7. Straw/stover			
(a) Rice straw (dry)	MJ kg ⁻¹	12.5	Kitani (1999)
(b) Greengram stover (dry)	MJ kg ⁻¹	12.5	Mittal and Dhawan (1988)
B. Outputs			
1. Grain/seed			
(a) Rice	MJ kg ⁻¹	14.7	West and Marland (2002)
2. Straw/stover			
(a) Rice straw (dry)	MJ kg ⁻¹	12.5	Kitani (1999)

*Production, packing, transportation and application.

Table-2 : Energy equivalent of machinery employed in different rice cultivation systems.

Machinery	Weight (kg)	Life (h)	Energy equivalent (MJ h ⁻¹)
Happy Seeder	595	1200	31.09
Zero till drill/Seed fertilizer drill	450	1200	23.5135
Cultivator	150	2500	3.762
Winnowing	100	2500	2.508

under IWM over rest of the weed management practices in 2014 and 2015, respectively. In 2014, rice grown in CT+RI yielded significantly higher biological yield than ZT+RB and CT+RB but on par with ZT+RR, while ZT+RR produced significantly higher biological yield over rest of the tillage-residue management practices in low rainfall year 2015. During 2014, 125% RDN recorded significantly higher biological yield but there was no significant difference in 2015 (Fig. 2b). Application of IWM practice significantly increased the biological yield than that of herbicide and unweeded practices during both years. The CT+RI was required more energy input in 2014, but CT+RB was consumed the highest energy input in 2015.

Between N-levels, lower energy input requirement was associated with 100% RDN. Among weed management practices, considerably higher energy input was required with *Sesbania* co-culture with application of herbicides *fb* hand weeding, while the less energy input requirement was recorded with unweeded. The significantly higher energy output was produced under CT+RI which were on par with ZT+RR, however ZT+RR performed better in 2015 and recorded significantly higher output energy (Table 3) and the lowest output energy noted under ZT+RB. Net energy return was also significantly lower in ZT+RB and CT+RB than ZT+RR and CT+RI. ZT+RR produced higher net energy return during both years

Table-3 : Input, output and net return of energy (MJ/ha) under tillage-residue, N-levels and weed management.

Treatment	Energy input (x 10 ³)*		Energy output (x 10 ³)		Net energy return (x 10 ³)	
	2014	2015	2014	2015	2014	2015
Tillage-residue management						
ZT+RR	48.82	52.95	130.13	111.10	81.31	58.15
ZT+RB	47.39	49.77	110.46	95.92	63.07	46.15
CT+RI	53.83	49.92	133.55	104.71	79.72	54.79
CT+RB	52.06	50.72	115.85	96.45	63.79	45.73
SEm±	-	-	1.88	1.04	1.88	1.04
CD (P=0.05)	-	-	6.49	3.59	6.49	3.59
N-levels						
100% RDN	48.67	48.98	120.60	100.63	71.93	51.65
125% RDN	52.38	52.70	124.40	103.47	72.01	50.77
SEm±	-	-	1.07	0.91	1.07	0.91
CD (P=0.05)	-	-	3.49	NS	NS	NS
Weed management						
Unweeded check	33.99	34.30	70.71	60.40	36.72	26.10
Herbicide	55.39	55.70	144.04	116.99	88.66	61.28
IWM	62.20	62.51	152.74	128.75	90.54	66.24
SEm±	-	-	1.60	1.33	1.60	1.33
e CD (P=0.05)	-	-	4.62	3.83	4.62	3.83

*Data was not statistically analyzed

Table-4 : Energy-use efficiency, energy profitability and energy productivity influenced by tillage-residue, N-levels and weed management in rice.

Treatment	Energy-use efficiency		Energy profitability (MJ/ha)		Energy productivity (MJ/ha)	
	2014	2015	2014	2015	2014	2015
Tillage-residue management						
ZT+RR	2.63	2.05	1.63	1.05	0.084	0.064
ZT+RB	2.27	1.91	1.27	0.91	0.071	0.061
CT+RI	2.45	2.08	1.45	1.08	0.077	0.065
CT+RB	2.18	1.87	1.18	0.87	0.070	0.059
SEm±	0.04	0.02	0.04	0.02	0.002	0.001
CD (P=0.05)	0.15	0.06	0.15	0.06	0.007	0.003
N-levels						
100% RDN	2.43	2.03	1.4	1.0	0.077	0.064
125% RDN	2.33	1.93	1.3	0.9	0.074	0.061
SEm±	0.02	0.02	0.0	0.0	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	0.002
Weed management						
Unweeded check	2.08	1.77	1.1	0.8	0.058	0.050
Herbicide	2.60	2.10	1.6	1.1	0.086	0.069
IWM	2.46	2.06	1.5	1.1	0.082	0.068
SEm±	0.03	0.03	0.0	0.0	0.001	0.001
CD (P=0.05)	0.09	0.07	0.1	0.1	0.004	0.002

which was statistically comparable with CT+RI in 2014 and significantly higher over rest of tillage-residue management practices in 2015. Maximum energy-use efficiency and energy profitability were recorded in ZT+RR while the lowest energy-use efficiency was estimated under residue burnt with ZT and CT during 2014 and 2015 (Table-4). The highest energy productivity and energy profitability were associated with ZT+RR and the lowest energy productivity was noted in ZT+RB and CT+RB in

2014 and 2015. In 2014 and 2015, 25% extra N over RDN was produced significantly higher energy output in 2014 but there was no significant difference between both N-levels in 2015. Net energy return was not significantly influenced by the N-levels. Statistically no difference in energy-use efficiency was noted under both N-levels. Both N-levels did not exerted any significant difference on energy productivity but numerically 125% RDN recorded slightly higher energy productivity than 100% RDN during

Table-5 : Tillage-residue, N-levels and weed management effects on economics of rice (/ha)

Treatment	Cost of cultivation ($\times 10^3$)		Gross return ($\times 10^3$)		Net return ($\times 10^3$)		B:C Ratio	
	2014	2015	2014	2015	2014	2015	2014	2015
Tillage and residue management								
ZT+RR	21.67	21.77	63.98	53.04	42.31	30.82	1.85	1.30
ZT+RB	21.11	21.56	52.65	46.93	31.53	25.48	1.40	1.13
CT+RI	24.62	24.31	64.13	50.01	39.50	25.80	1.55	1.01
CT+RB	24.35	24.53	56.90	46.33	32.55	22.08	1.26	0.87
SEm $\pm$	-	-	1.25	0.49	1.25	0.49	0.06	0.02
CD (P=0.05)	-	-	4.33	1.70	4.33	1.70	0.20	0.08
N-levels								
100% RDN	22.66	22.73	58.63	48.48	35.97	25.72	1.51	1.08
125% RDN	23.22	23.36	60.19	49.68	36.98	26.37	1.52	1.08
SEm $\pm$	-	-	0.73	0.38	0.73	0.38	0.03	0.02
CD (P=0.05)	-	-	NS	NS	NS	NS	NS	NS
Weed management								
Unweeded check	16.61	18.68	30.43	26.27	13.82	9.57	0.83	0.58
Chemical	23.62	23.12	71.47	57.41	47.85	33.70	2.03	1.43
IWM	28.59	27.32	76.34	63.55	47.75	34.87	1.68	1.22
SEm $\pm$	-	-	0.91	0.48	0.91	0.48	0.04	0.02
CD (P=0.05)	-	-	2.62	1.39	2.62	1.39	0.13	0.06

*Data was not statistically analyzed

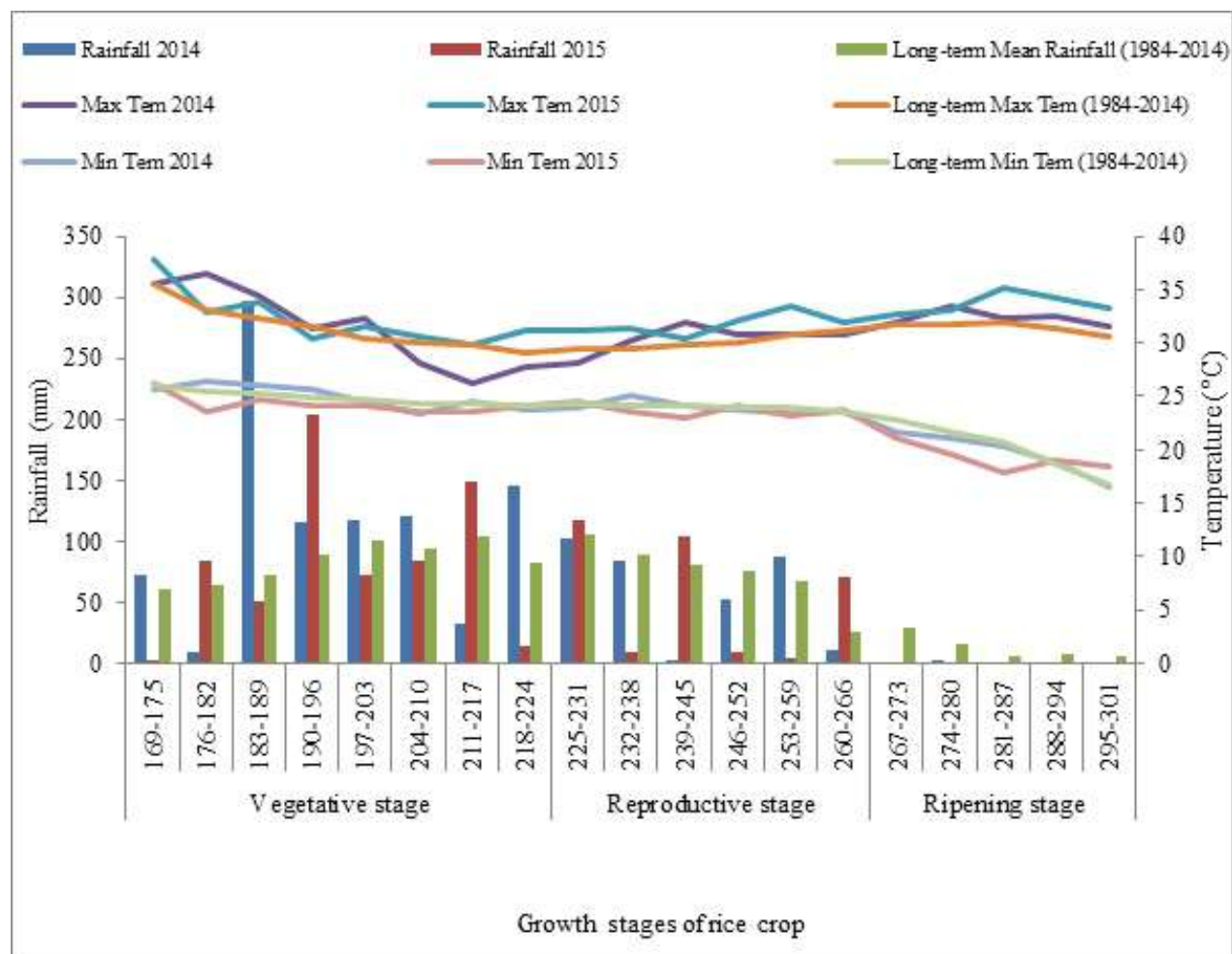


Fig-1 : Weather conditions during the crop season.

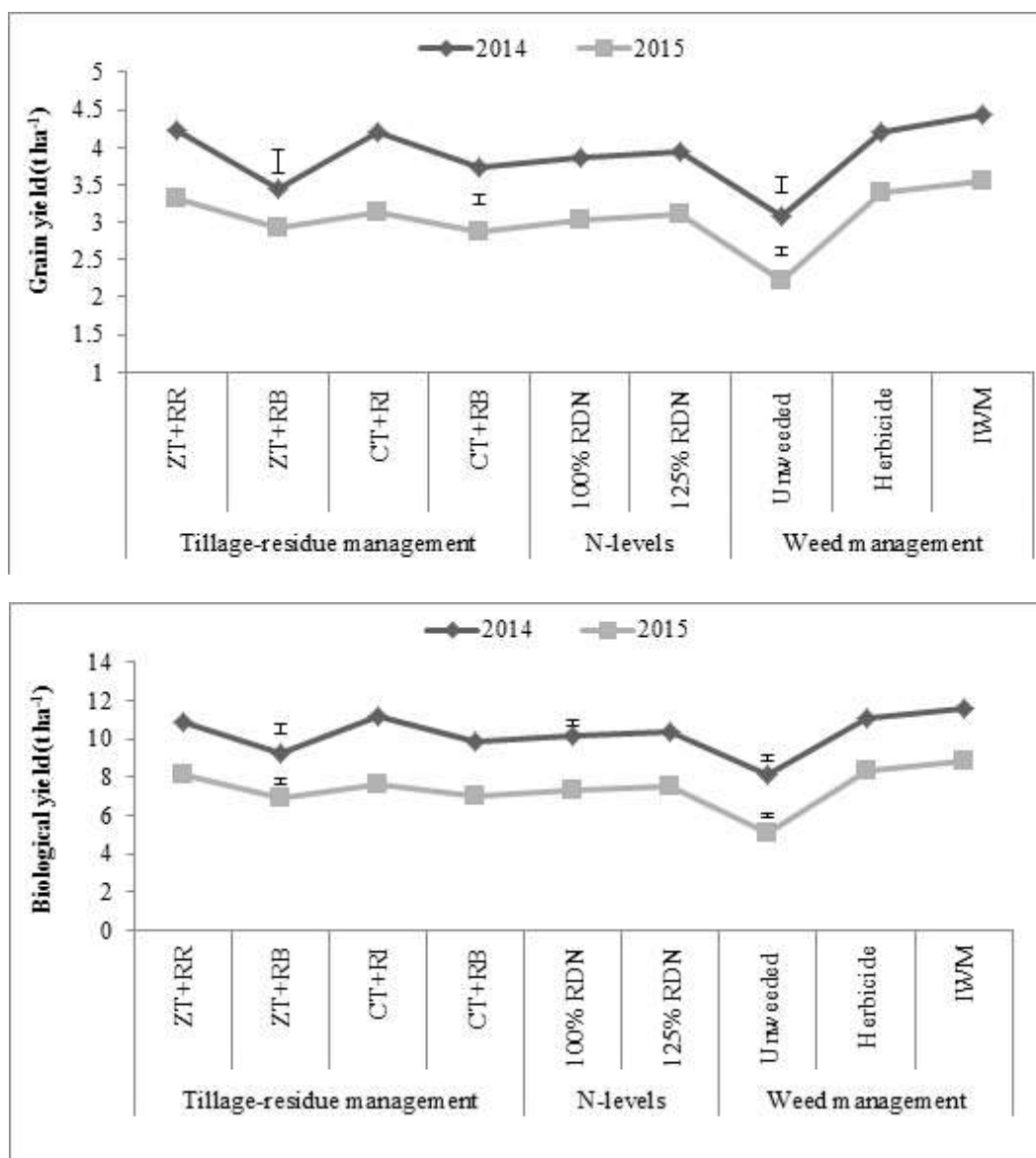


Fig-2 : Grain and biological yields under tillage-residue, N-levels and weed management.

(Vertical lines in the graph represent LSD bar at $p = 0.05$ and only those treatments varied significantly content LSD bar)

both years. IWM practice noted significantly energy output during both years (Table 3). IWM practice recorded higher net energy return and energy-use efficiency which was statistically superior over rest of weed management practices. In energy productivity, there was no significant difference between IWM and herbicide but both practices produced significantly higher energy productivity than unweeded (Table 4).

ZT+RR was the most cost-effective tillage-residue management practice. Cost of cultivation was recorded highest in conventional tillage with residue incorporation/burnt and least in zero-tillage with residue retention/burnt (Table-5). The gross and net returns were significantly higher in ZT+RR which was closely followed by CT+RI in 2014, while ZT+RR recorded significantly

maximum values of gross and net returns in 2015. The B:C ratio of ZT+RR was significantly higher than those of other tillage-residue management practices. There was no significant influence on gross and net returns as well as B:C ratio but numerically gross and net returns was faintly higher under 125% RDN. Intensive weed management practice, i.e. IWM recorded higher cost of cultivation followed by herbicide and unweeded practices. Gross return under IWM was significantly higher over herbicide and unweeded practices in both years. However, net return was higher with herbicide for weed management which was comparable with IWM practice in 2014 only. The lowest B:C ratio was noted under IWM practice followed by unweeded in 2014 and unweeded followed by IWM practice in 2015, however herbicide for

weed management recorded significantly superior in term of B:C ratio (Table 5).

Fully conservation agriculture based practice, i.e. zero tillage with residue retention produced higher yield due to the lesser weed problem, improved soil health and better moisture regimes than CT and ZT with residue burnt. The present results are well supported by Bhattacharyya *et al.* (2015). Energy consumed in conventional tillage with residue incorporation/ burnt was highest and least with zero tillage with residue retention/burnt. Energy consumed in the form of machinery and consequently use of fuel for land preparation and sowing was highest with conventional tillage with residue incorporation/burnt and least with zero-tillage with residue retention/burnt. Higher yield was recorded in IWM practice due to excellent control of weed growth during the critical period of crop-weed competition. The additional benefit was achieved due to inclusion of *Sesbania* which have competitive effect of weed growth and adding N to the soil. The same results were reported by Kumar and Mukherjee (2008). The energy input for land preparation and sowing was also the lowest for ZT (Bhushan *et al.*, 2007; Mandal *et al.*, 2015). CT+RI and CT+RB consumed highest energy input in 2014 and 2015, respectively as compared to other due to higher residue return from preceding crop, i.e. greengram and intensively machinery performed to prepared the land. Use of chemical fertilizers makes the cultivation system extremely energy-intensive therefore application of 125% RDN recorded higher energy input than 100% RDN. Choudhary and Behara (2013) also confirmed that input energy increased with increase in N levels. Higher energy input required for IWM practice because it was an intensive weed management practice which involved *Sesbania* co-culture with application of pre-and post-emergence herbicides *fb* manual weeding. Energy output is directly related to biological yield. CT+RI and ZT+RR recorded statistically comparable energy output in 2014 due to higher and comparable biological yield while ZT+RR performed better in low rainfall year 2015 and yielded significantly higher biological yield thus ZT+RR recorded higher energy output. Higher yield was produced under 125% RDN as compared to 100% RDN so the energy output higher under 125% RDN. IWM practice out yielded over other practices resulted higher energy output. Higher net energy return noted under CT+RI in 2014. This may be due to higher energy output as compared to other tillage-residue management practices. ZT+RR produced significantly higher net energy return in 2015 due to less energy input and higher energy output in comparison to other tillage-residue management practices. IWM produced higher biological yield resulted higher energy output thus higher net energy

return was associated with IWM practice. Mishra and Singh (2012) also found the similar results. Highest energy output and net energy return resulted the higher energy-use efficiency and energy profitability thus ZT+RR and IWM practice recorded the higher values of energy-use efficiency and energy profitability. Energy productivity is directly related to grain yield and input energy thus higher grain yield and lower input leads to higher energy productivity. Choudhary and Behara (2013) also have been reported significantly more energy-use efficiency and energy productivity under ZT than CT practices. ZT+RR recorded higher grain yield and lower input energy which made the ZT+RR more productivity in term of energy. Higher yield and input energy were associated with IWM, and herbicide recorded the lower grain yield and input energy as compared to IWM practice thus both IWM and herbicide practices had no significant difference in energy productive. The highest energy productivity was observed with herbicide weed management practice in rice crop (Tiwari *et al.*, 2013).

The gross return strongly depended on the grain and straw yields of crop in different treatments. In ZT+RR, gross return was significantly higher than those of tillage-residue management practices. Higher productivity in ZT+RR practice made this superior in terms of gross return in comparison to other practices. Cost of cultivation and gross return decided the net return. Among the tillage-residue management practices, minimum cost of cultivation and maximum gross return noted under ZT+RR. Minimum cost of cultivation with maximum net return increased the B:C ratio. The study of Jat *et al.* (2014) showed the positive effects of zero tillage and residue management on yield were well reflected into more favourable economics in rice crop. Gross return was higher in IWM practice due to higher productivity of rice during both years. The net return was lower under IWM practice due to higher cost of cultivation. Higher B:C ratio was found when weed control done by herbicide practice.

Conclusions

The results of the study show that yield, energy requirement and economics of rice respond to management strategies. Zero tillage with residue retention was superior in the point of view of the productively (grain and biological yield), organizationally (reducing machinery operations) and economically (cost effective). There was no need to apply N over 100 RDN to get maximum productivity and profitability in terms of yield, energy and economics. Inclusion of hand weeding with herbicide and *Sesbania* co-culture significantly increased the rice yield but weed management with herbicide practice was more profitable in terms of B:C ratio and energy productivity. Direct drilling of rice under zero-till in standing residue of

preceding crop alongwith recommended dose of N and effective weed management by herbicide practice appeared to be best technology for higher productivity and profitability in the vertisols of central India.

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Enhancing Productivity and Profitability of Soybean (*Glycine max* (L.) Merrill) through Different Agro Chemicals under Rainfed Conditions

Jitendra Marskole, V.D. Dwivedi, Anoop Kumar Rathore* and Rituja Jain

Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur-482004, M.P.

*Corresponding Author Email : anprathore@gmail.com

Introduction

Soybean (*Glycine max* L. Merrill) is one of the commercial crops in India. Soybean is a crop of multiple qualities, as it is both a pulse and oilseed crop. It contains 40 percent protein and 20 percent edible oil, besides minerals and vitamins. As per survey conducted by SOPA, the all India estimated production 12.98 million tonnes from an area of 12.03 million hectare with productivity of 1079 kg/ha. In Madhya Pradesh, the area under soybean cultivation is 6.26 million hectares with the production of 5.95 million tonnes. Although the ecological conditions of the state are congenial for soybean production, but the yield is substantially low (950 kg/ha), despite of the best management practices (SOPA, 2014).

Potassium (K) acts as a very essential and important nutrient for the plant growth and development. It is necessary in plants to improve the efficiency of photosynthesis and use of water. In soybean, deficiency of K causes so many problems and shows many deficiency symptoms in plants growth such as weaker straw, increased lodging and decrease in growth. Application of K to soybean plants under saline conditions enhances the growth of the plants and decreases the effect of salinity.

The effects of seed treatment (500 ppm) or foliar application of 1000 ppm thiourea (at 25 and 40 days after sowing) or a combination of these have been found effective on growth, yield, net photosynthesis and nitrogen metabolism of soybean (*Glycine max* L.) grown under rainfed conditions of the Indian arid zone. Thiourea application either as pre-sowing seed treatment or as foliar spray significantly increased plant height, leaf area, dry matter production and seed yield as compared to the untreated plants (Garg *et al.* 2006). However, maximum favorable effects were obtained with combined application of seed treatment and foliar spray. The beneficial effects of thiourea were attributed to its role in significantly increasing the net photosynthetic rates and the concentrations of total chlorophyll and starch in the leaves. Thiourea also reflected a positive role in enhancing nitrogen metabolism as it significantly increased nitrate reductase activity and concentration of

soluble protein in the treated plants. It has been found that seed treatment with thiourea followed by foliar spray could significantly improve growth, yield and water use efficiency of rainfed soybean under arid conditions due to enhanced photosynthesis and more efficient nitrogen metabolism (Garg *et al.* 2006). With this background an experiment was conducted to obtain an insight into the performance and economics of soybean under different chemical sprays.

Materials and Methods

A field experiment was conducted at AICRP for Dryland Agriculture, Kuthulia Farm College of Agriculture, Rewa (M.P.) during *Kharif* season 2015. A total of 8 treatment combinations, consisted of T₁: Control, T₂: two spray of water at 25-30 and 55-60 days after sowing (DAS), T₃: two foliar spray of 1% KNO₃ solution at 25-30 and 55-60 DAS, T₄: two foliar spray of 1% KCl solution at 25-30 and 55-60 DAS, T₅: two foliar spray of thiourea @ 250g ha⁻¹ dissolved in 500 liter of water at 25-30 and 55-60 DAS, T₆: spray of thiourea @ 250g ha⁻¹ and followed by spray of trizophos insecticide @ 600 ml ha⁻¹, T₇: spray of 1% KCL at 25-30 and 55-60 DAS followed by spray of trizophos insecticide @ 600 ml ha⁻¹, T₈: two spray of 1% KNO₃ solution at 25-30 and 55-60 DAS as well as trizophos insecticide @ 600 ml ha⁻¹.

These treatments were arranged in a randomized block design with three replications. The crop variety JS-20-29 was sown on 29th June and 2nd July 2015 with the seed rate of 75 kg/ha at a 30 cm wide rows. Soybean crop was fertilized with 30:60:30 kg NPK/ha as basal dose in the form of urea, single super phosphate and manure of potash, respectively. All the package of practices were followed as per the recommendations given by the university. The crop was harvested on 3rd October, manually with the help of sickles. Observations pertaining to pods/plant, seeds/pod and seed index as well as yields were recorded and statistically analyzed for interpretation of results. The amount of inputs and outputs per ha were multiplied with price of the unit to consolidate all of them in one unit (Rs/ha) to find out the economic indices viz. cost of cultivation, gross return, net return and benefit:cost ratio.

Results and Discussion

Yield attributing characters : Data of yield attributing characters as Influenced by different foliar spray of chemicals in soybean are given in Table-1. It is obvious from the data that number of pods plant⁻¹ varied significantly under different treatments. Among all the treatments, the minimum number of pods plant⁻¹ were recorded under control plot (23.60) which were increased significantly when foliar spray measure were adopted. The foliar spray of water at 25-30 DAS and 55-60 DAS enhanced the number of pods and significantly superior over control plot (23.60). The foliar spray of 1% KCl solution and thiourea @ 250g ha⁻¹ solution at 25-30 DAS and 55-60 DAS alone enhanced the number of pods appreciably in soybean plant, while the foliar spray of 1% KNO₃ solution at 25-30 DAS and 55-60 DAS was better than combined foliar spray of 1% KCl + trizophos 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS. But foliar spray of 1% KNO₃ + trizophos @ 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS (37.18) had more number of pods plants⁻¹ followed by foliar spray of thiourea@250g ha⁻¹ + trizophos 600 ml/ha solution at 25-30 DAS and 55-60 (35.51). However, these treatments significantly superior to control plots. It is obvious from the data that number of seeds pod⁻¹ varied significantly under different treatments. Among all the treatments, the minimum number of seeds pod⁻¹ were recorded under control plot (2.40) which were increased significantly when foliar spray measure were adopted. The foliar spray of water at 25-30 DAS and 55-60 DAS enhanced the number of seeds pod⁻¹ and significantly superior over control plot (2.40). The foliar spray of 1% KCl solution and thiourea@250g ha⁻¹ solution at 25-30 DAS and 55-60 DAS alone enhanced the number of seeds pod⁻¹ appreciably in soybean plant, while the foliar spray of 1% KNO₃ solution at 25-30 DAS and 55-60 DAS was better than combined foliar spray of 1% KCl + trizophos 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS. But foliar spray of 1%KNO₃+ trizophos @ 600ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS (3.13) had more number of seeds pod⁻¹ followed by foliar spray of thiourea@250g ha⁻¹ + Trizophos 600ml ha⁻¹ solution at 25-30 DAS and 55-60 (3.20). However, these treatments significantly superior to control plots. Data on seeds plant⁻¹ as Influenced by different foliar spray treatments are given in Table 1. It is obvious from the data that number of seeds plant⁻¹ varied significantly under different treatments. Among all the treatments, the minimum number of seeds plant⁻¹ were recorded under control plot (56.64) which were increased significantly when foliar spray measure were adopted. The foliar spray of water at 25-30 DAS and 55-60 DAS enhanced the number of seeds pod⁻¹ and significantly superior over control plot (56.64). The foliar

spray of 1% KCl solution and thiourea @ 250g ha⁻¹ solution at 25-30 DAS and 55-60 DAS alone enhanced the number of seeds plant⁻¹ appreciably in soybean plant, while the foliar spray of 1% KNO₃ solution at 25-30 DAS and 55-60 DAS was better than combined foliar spray of 1% KCl + trizophos 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS. But foliar spray of 1% KNO₃ + trizophos @ 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS (115.91) had more number of seeds plant⁻¹ followed by foliar spray of thiourea @ 250g ha⁻¹ + trizophos 60 0ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS (113.04). However, these treatments significantly superior to control plots. Data presented in Table 1 showed that seed index of soybean was affected due to foliar spray treatments. Among treatments, the minimum seed index (12.68) was recorded in control plot which was significantly increased when foliar spray measures were adopted. The foliar spray of 1% KNO₃ solution at 25-30 DAS and 55-60 DAS was produced higher seed index as compared to combined foliar spray of 1% KCl + trizophos 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS. Among the combined foliar spray of 1% KNO₃ + trizophos 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS (14.13) produced higher seed index as compared to other foliar spray treatments.

Yield parameters : Data pertaining to seed yield of soybean (kg ha⁻¹) under different foliar spray treatments are given in Table-2. It is evident from the data that seed yield significantly varied due to different foliar spray treatments. All the treated plots produced significantly more seed yields than control plots (679.65 kg ha⁻¹). Seed yield was increased with the foliar spray of 1% KNO₃ solution at 25-30 DAS and 55-60 DAS 1% KCl solution at 25-30 DAS and 55-60 DAS, and thiourea @ 250 gha⁻¹ and while the combined foliar spray of 1% KNO₃ + trizophos 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS (1390.94 kg ha⁻¹) seed yield was increased at higher magnitude. Data on straw yield (kg ha⁻¹) as affected by different foliar spray treatments are given in Table 2. It is evident from the data that straw yield significantly varied due to different foliar spray treatments. All the treated plots produced significantly more straw yield than control plot (2371.12 kg ha⁻¹). Straw yield was increased with the foliar spray of 1% KNO₃ solution at 25-30 DAS and 55-60 DAS 1% KCl solution at 25-30 DAS and 55-60 DAS, and thiourea @ 250g ha⁻¹ and while the combined foliar spray of 1% KNO₃ + trizophos 600 ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS (3170.22 kg ha⁻¹) straw yield was increased at higher magnitude. The ratio of economic yield and biological yield (HI) expressed in percentage was affected by various treatments Table 2. Among foliar spray treatments, the minimum harvest index was recorded in control plots (22.28) which was increased the

Table-1 : Influence of foliar spray of chemicals in soybean for mitigating drought effect on different yield attributing characters.

Treatment	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	Number of seeds plant ⁻¹	Seed index (g)
T ₁ : Control	23.60	2.40	56.64	12.68
T ₂ : Water spray at 25-30 and 55-60 DAS	29.98	2.53	75.40	12.78
T ₃ : Foliar spray of 1% KNO ₃ solution at 25-30 and 55-60 DAS	34.22	2.65	87.42	13.07
T ₄ : Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	32.30	2.63	84.90	13.40
T ₅ : Foliar spray of thiourea@ 250g ha ⁻¹ solution at 25-30 and 55-60 DAS	29.99	2.57	79.37	13.53
T ₆ : T ₅ + Trizophos insecticide@ 600 ml ha ⁻¹ tank mix	35.51	3.20	113.04	13.46
T ₇ : T ₄ + Trizophos insecticide@ 600 ml ha ⁻¹ tank mix	33.32	2.73	90.79	13.66
T ₈ : T ₃ + Trizophos insecticide@ 600 ml ha ⁻¹ tank mix	37.18	3.13	115.91	14.13
SEm±	1.50	0.13	1.86	0.29
CD (P=0.05)	4.65	0.39	5.77	0.88

Table-2 : Average seed and straw yields of soybean as influenced by foliar spray of chemicals for mitigating drought effect.

Treatment	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index (%)
T ₁ : Control	679.65	2371.12	22.28
T ₂ : Water spray at 25-30 and 55-60 DAS	904.76	2876.57	23.92
T ₃ : Foliar spray of 1% KNO ₃ solution at 25-30 and 55-60 DAS	1049.06	3390.39	23.65
T ₄ : Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	1018.76	2932.23	25.80
T ₅ : Foliar spray of thiourea@250g ha ⁻¹ solution at 25-30 and 55-60 DAS	952.38	2975.91	24.24
T ₆ : T ₅ + Trizophos insecticide@600 ml ha ⁻¹ tank mix	1356.42	2953.96	31.46
T ₇ : T ₄ + Trizophos insecticide@600 ml ha ⁻¹ tank mix	1089.47	3145.85	25.72
T ₈ : T ₃ + Trizophos insecticide@600 ml ha ⁻¹ tank mix	1390.94	3170.22	30.47
SEm±	8.11	17.32	0.46
CD (P=0.05)	25.12*	53.68*	NS

Table-3 : Gross and net returns of soybean as influenced by foliar spray of chemicals for mitigating drought effect.

Treatment	GMR (Rs ha ⁻¹)	Cost of cultivation (Rs ha ⁻¹)	NMR (Rs ha ⁻¹)	B:C ratio
T ₁ : Control	31596.23	15515.80	16080.43	2.04
T ₂ : Water spray at 25-30 and 55-60 DAS	41781.33	16015.80	25765.53	2.61
T ₃ : Foliar spray of 1% KNO ₃ solution at 25-30 and 55-60 DAS	48500.05	15715.80	32784.25	3.09
T ₄ :Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS	46738.86	15755.80	30983.06	2.97
T ₅ :Foliar spray of thiourea@250g ha ⁻¹ solution at 25-30 and 55-60 DAS	43928.29	15795.80	28132.49	2.78
T ₆ :T ₅ + Trizophos insecticide@600 ml ha ⁻¹ tank mix	61280.08	17265.80	44014.28	3.55
T ₇ :T ₄ + Trizophos insecticide@600 ml ha ⁻¹ tank mix	49992.89	17455.80	32537.09	2.86
T ₈ :T ₃ + Trizophos insecticide@600 ml ha ⁻¹ tank mix	62980.80	17645.80	45335.00	3.57
SEm±	-	-	-	-
CD (P=0.05)	-	-	-	-

foliar spray of 1% KNO₃ solution at 25-30 DAS and 55-60 DAS, 1% KCl solution at 25-30 DAS and 55-60 DAS and thiourea@250g ha⁻¹ being highest (30.47) under combined foliar spray of 1% KNO₃ + trizophos 600ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS and proved superior over rest of the treatments.

Economic analysis of the treatments : The economic analysis of foliar spray treatments was determined on per hectare area basis, which includes cost of cultivation, gross monetary returns, net monetary returns and benefit

cost ratio (profitability per rupee of investment) under different treatments. Cost of cultivation was determined treatment wise on the basis of market price of various common and variable agro-inputs used. The values thus obtained are presented in Table 3. Control plot treatment had the lowest cost of cultivation (Rs 15515.80 ha⁻¹), but it increased in a range of Rs 15795.80 to Rs 16015.80 ha⁻¹ and range of Rs 17265.80 to 17645.80 ha⁻¹ with the foliar spray of treatment T₂, T₃, T₄ and T₅ and increased in a range of Rs 17265.80 to 17645.80 ha⁻¹ with the increase in

combined foliar spray of T₆, T₇, and T₈. As where, it was maximum under T₈ (Rs 17645.80 ha⁻¹). The value of seed and straw yields, depending on the existing market rate of each produce was taken into consideration for determining gross monetary returns (GR) under particular treatment Table 3. The GR was minimum in control plots (Rs 31596.23 ha⁻¹) which increased remarkably under all the plots receiving foliar spray and being maximum under T₃ (1% KNO₃ solution at 25-30 DAS and 55-60 DAS, Rs 48500.05 ha⁻¹). Among the foliar spray treatments, combined foliar spray of treatment T₈ (1% KNO₃+ trizophos @ 600ml ha⁻¹ solution at 25-30 DAS and 55-60 DAS) (Rs 62980.80 ha⁻¹) fetched the highest GR followed by T₆, T₇, T₃, T₄, T₅, T₂ and T₁. The net monetary returns (NMR) under each treatment was determined by subtracting the cost of cultivation from GR of the particular treatment. The treatment wise values, thus obtained, are given in Table 3. It was obvious from the data that there

was marginal profit of Rs 16080.43 ha⁻¹ when crop sown in control plots (T₁) throughout the crop season while maximum NMR was gained from T₈ (Rs 45335.00 ha⁻¹) followed by T₆, T₃, T₇, T₄, T₅, T₂, and T₁. It refers to net monetary gain under a particular treatment with each rupee of investment. The benefit cost indices as affected by different treatments are given in Table 3. It is evident from the data that B:C ratio was maximum under T₈ (3.57) followed by T₆ (3.55), T₃ (3.09), T₄ (2.97), T₇ (2.86), T₅ (2.78), T₂ (2.61), and minimum in T₁ (2.04).

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Analyzing Pathways, Exploring Associations and Investigating Variability in Fenugreek (*Trigonella foenum-graecum* L.)

Guman Singh^{1*}, R.K. Kakani² and R.K. Solanki²

¹Mahatma Jyoti Rao Phoole College of Agriculture, Talamod, (Mahatma Jyoti Rao Phoole, University, Jaipur-302001 Rajasthan)

²ICAR-National Research Center of Seed Spices, Tabiji, Ajmer-305206 Rajasthan

*Correspondence Author Email : gsgurjar111@gmail.com

Abstract

Fifty germplasms of fenugreek (*Trigonella foenum-graecum* L.) were assessed using Augmented Block Design in five blocks during Rabi 2013-2014 at the research farm of the National Research Centre on Seed Spices, Tabiji, Ajmer (Rajasthan). Five checks, Hisar Suvarna, Hisar Sonali, RMT-361, RMT-1, and AFG-3, were also included in the evaluation. The objective was to determine the variability, character association, and path analysis among the contributing traits and seed yield. An examination of variance unveiled substantial variability across the majority of the characteristics. For days to fifty per cent flowering and seed yield per plant, high estimates of phenotypic coefficient of variance, genotypic coefficient of variance, broad sense heritability, genetic advance, and genetic advance as a percentage of mean were observed. There was a significant and positive correlation observed between seed yield per plant and plant height, number of seeds per pod, and number of pods per plant. However, the correlation was not statistically significant but positive with respect to test weight, days to 50 per cent flowering, primary and secondary branches per plant, the number of pods on the main stem, pod length, and shelling per cent. The results of the path analysis indicated that several characteristics—test weight, number of seeds per pod, number of pods per plant, number of pods on main stem and secondary branches per plant—had a direct and positive impact on seed yield per plant, making them crucial for the selection of a high-yielding germplasm line.

Key words : Fenugreek, variability, character association, path coefficient.

Introduction

Fenugreek (*Trigonella foenum-graecum* L.), an annual diploid species commonly referred to as “methi,” is classified within the “Fabaceae” subfamily “Papilionaceae.” The Latin word “Trigonella” derives its name from a small triangle, alluding to the flower’s triangular shape. The species name “foenum-graecum,” which translates to “Greek hay,” suggests that it was formerly cultivated as a forage crop (Petropoulos, 2002). Fenugreek is indigenous to the nations extending from the eastern borders of the Mediterranean to Central Asia. It has chromosome number $2n=16$ and is a self-pollinating crop (Frayer, 1930). It is a significant condiment crop that is primarily cultivated in North India during the Rabi season, being utilised for both its seeds and leaves. Fenugreek exhibits adaptability to a diverse array of climatic conditions. It requires a mild, arid climate during its maturation period. Fenugreek is cultivated on an approximate area of 81,200 hectares in India. The average yield is 1,18,400 tonnes, and the efficacy per hectare is 1,458 kilogrammes (Anon., 2014). The provinces of Andhra Pradesh, Rajasthan, Gujarat, Tamil Nadu, and Uttar Pradesh are the primary producers of fenugreek. Fenugreek is a significant spice crop owing to its extensive range of applications. Fresh leaves (green leafy vegetable), shredded leaves (flavouring agent),

sprouts (salad), microgreens (salad), pot herbs (decoration), seeds (spice, condiments, or medicines), extracts, and granules (medicines) are all common applications for fenugreek. The culinary attributes attributed to the seeds and foliage of fenugreek are well-known; they are utilised to impart flavour to meat, poultry, and vegetables. In the preparation of parantha, khakra, herbal tea, and injera/taita, fenugreek leaves are utilised. Additionally, fenugreek seeds are a primary component of curry powder. Flatulence, gastroenteritis, liver span enlargement, gout, headache, tinnitus, baldness, vata disease, leucorrhoea, back pain, mouth ulcer, abdominal pain, kidney problem, hernia, beri-beri, parched lips, diabetes, dyspepsia, dropsy, spleen, heart disease, obesity, and leucorrhoea are among the ailments that can be treated with fenugreek seeds. It is believed that seeds have restorative, menstruation-easing, lactation-promoting, and aphrodisiac properties. Laboratory investigations have demonstrated the inhibitory effect of fenugreek on the proliferation of breast cancer and leukaemia cells.

Grain yield is a multifaceted attribute that is influenced by an abundance of factors. The selection process for desirable varieties should not be limited to cereal yield alone; additional factors associated with grain yield should be taken into account as well. Additionally, the correlation coefficient can be utilised to determine

which characteristics are inconsequential or unimportant to the selection procedure. The correlation between variables may be ascribed to various factors, including the existence of linkage, pleiotropic effects of genes, physiological and developmental relationships, environmental influences, or a combination of these. Path coefficient analysis is a statistical method utilised to partition correlation coefficients into their direct and indirect effects (Dewey and Lu, 1959). This process enables the estimation of the contribution of each character to produce. It is utilised in plant breeding programmes to ascertain the characteristics of the correlations between yield and yield components, which can subsequently be utilised as selection criteria to enhance the overall crop yield. Accepting descriptions of the correlation between traits according to a cause-and-effect model and estimating the significance of influencing traits on particular traits are the objectives of path analysis. Aiming to determine the degree of association between yield and yield contributing traits and to estimate the variability present in active germplasm of fenugreek, the current study was conducted at NRCSS, Ajmer.

Materials and Methods

Fifty distinct genotypes of varying genetic and geographic origin comprised the experimental material for the current study, in addition to five control strains: Hisar Suvarna, Hisar Sonali, RMt-1, RMt-361, and AFG3. In Augmented Design, the experiment was divided into five sections, each containing five checks and ten test entries. Plant to plant spacing was 5-10 cm and row to row spacing was 50 cm. The dimensions of the plot were 0.5 m x 2 m. Adherence to all prescribed agronomic techniques and plant protection protocols in a timely manner facilitated the successful cultivation of the crop. Characteristic observations were made on five plants selected at random from each experimental germplasm at the moment of maturation, with the exception of the days to 50% blossoming and days to 75% maturity, which were recorded for the entire plot. The phenotypic and genotypic coefficient of variation, broad sense heritability, expected genetic advance at 5% selection intensity, correlation coefficient, and path coefficient were all estimated utilising these quantitative characteristics in accordance with established statistical procedures (Singh and Chaudhary, 1979).

Results and Discussion

The results of the analysis of variance indicated that germplasm lines exhibited a substantial degree of variability in nearly all morphological traits that were examined (including days to 50 per cent flowering, number

of pods on main stem, number of pods per plant, pod length, shelling per cent, number of seeds per pod, test-weight, and seed yield per plant). However, days to 75 per cent maturity, plant height, primary branches, and number of secondary branches per plant did not demonstrate a significant amount of variability. Hariharan and Vijayakumar (1996) and Gangopadhyay *et al.* (2009) reported on the variability of characters suitable for selection. The current findings validate those findings.

The following exhibited higher genotypic coefficient of variation values : yield per plant (26.08), number of secondary branches per plant (12.97), test weight (13.79), shelling percentage (10.68), and number of seeds per pod (9.88). It signifies the genuine genetic capacity, suggesting a considerable degree of genetic variability for these traits. Consequently, since the response to selection is directly proportional to the component of variability, selection may be more efficacious for these traits. In a similar vein, the yield per plant (29.14), number of secondary branches per plant (21.16), number of pods per plant (15.23), number of primary branches per plant (13.21), test weight (14.38), and number of seeds per pod (11.25) exhibited higher phenotypic coefficient of variation values (Table-2).

As predicted by augmented design, the results demonstrated that the disparities between genotypic and phenotypic variations were minimal. The error component utilised in an augmented design is composed of tests that are iterated within blocks. This is frequently extremely limited; consequently, the distinction is also extremely limited. The similarity between the genotypic and phenotypic coefficient of variation estimates suggests that the environment has the least impact on these characteristics.

The broad sense heritability estimates, expressed as a percentage, were high for the following traits: days to 50 per cent flowering, number of pods per plant, seed yield per plant, test weight, shelling per cent, and the number of seeds per pod. This suggests that these traits are relatively unaffected by environmental factors, suggesting that future yield improvements could be achieved through direct selection for these yield-enhancing traits. The outcomes reported by Meena *et al.* (2011), Naik *et al.* (2012), Verma and Ali (2012), and Pushpa (2012) were comparable. The genetic progress of the traits, expressed as a percentage of the mean, varied between 0.00 (days to 75% maturity) and 48.10 (yield per plant). An estimated high magnitude of genetic advance was observed in the days to 50 per cent flowering and yield per plant as a percentage of the mean.

In the majority of the characters, the phenotypic correlation coefficient was greater than their genotypic

Table-1 : Analysis of variance for different characters.

Sources of variation	Df	Days to 50% flowering	Days to 75% maturity	Plant height	Primary branches per plant	Secondary branches per plant	No. of pods on main stem	No. of pods per plant	Pod length	Shelling %	No. of seeds per pod	Test weight	Yield per plant
Block (Eliminating check + Var.)	4	0.554	0.302	41.331	0.829	1.572	0.430	2.393	0.169	6.526	0.320	0.152	0.245
Entries (Ignoring Block)	54	14.97***	2.072	50.202	0.572	2.769	3.008*	99.288***	0.229*	73.855***	3.454***	5.301***	9.374***
Checks	4	36.59***	2.1	49.690	1.169*	2.396	9.698**	91.071***	0.006	64.617**	7.463***	2.260**	21.996***
Germplasm	49	13.508***	2.101	48.898	0.520	2.704	2.396	84.80***	0.238*	73.957***	3.197***	5.641***	7.165***
Checks vs. Germplasm	1	0.24	0.54	116.124	0.721	7.437*	6.242*	842.061***	0.7004**	105.856*	0.035	0.837	67.160***
Error	16	1.085	2.524	47.826	0.381	1.453	1.343	7.944	0.0805	12.755	0.547	0.320	1.060

** Significant at p = 0.01, * Significant at p = 0.05

Table-2 : Overall mean values of genotypes, their range, genotypic and phenotypic coefficient of variation, heritability in broad sense, genetic advance and genetic advance as % of mean for different characters in fenugreek.

Characters	Mean	Range (min.-max.) (adjusted value)	Genotypic coefficient of variation (GCV %)	Phenotypic coefficient of variation (PCV %)	Heritability in broad sense (%)	Genetic advance	Genetic advance as % of mean
Days to 50 per cent flowering	54.97	48.88-70.28	5.366	5.691	88.91	5.72	40.4222
Day of 75% maturity	133.96	132-136.20	0.000	1.114	0.00	0.000	0.00
Plant height	87.18	66.32-101.43	0.996	8.017	1.55	0.2225	0.2552
No. of primary branches	5.26	3.97-7.09	5.957	13.209	20.34	0.2900	5.5351
No of secondary branches	7.27	4.84-10.64	12.977	21.160	37.61	1.1824	16.3948
No. of pods on main stem	13.14	9.70-16.18	6.563	11.025	35.44	1.0531	8.0487
No. of pods per plant	52.24	25.66-64.50	14.216	15.229	87.13	14.1042	27.3359
Pod length	10.88	9.40-11.81	3.063	4.027	57.85	0.5211	4.7991
Shelling (%)	61.03	34.52-94.35	10.685	12.172	77.06	11.8360	19.3223
No. of seeds per pod	13.78	8.16-19.70	9.887	11.253	77.2	2.4648	17.8948
Test weight	14.01	9.30-19.09	13.798	14.379	92.08	3.8149	27.2744
Yield per plant	8.10	1.99-12.26	26.088	29.145	80.12	3.8119	48.1051

[illegible]

Table-4 : Direct (diagonal) and indirect effects of different characters on seed yield per plant in fenugreek at genotypic and phenotypic level.

Characters	G/P	Days to 50 % flowering	Days to 75% maturity	Plant height (cm)	Primary branches per plant	Secondary branches per plant	No. of pods on main axis	No. of pods per plant	No. of seed per pod	Test weight
Days to 50% flowering	G	0.037	-0.002	-0.011	0.041	-0.000	0.003	0.152	0.018	-0.035
	P	-0.001	-0.001	0.003	0.066	-0.007	0.008	0.140	0.019	-0.038
Days to 75% maturity	G	0.004	-0.019	-0.013	0.062	-0.006	-0.019	-0.025	-0.004	-0.049
	P	-0.000	-0.015	0.006	0.035	0.006	-0.021	-0.009	-0.009	-0.057
Plant height (cm)	G	-0.009	0.005	0.043	-0.030	0.008	0.027	0.178	0.015	0.050
	P	0.000	0.004	-0.022	-0.014	0.000	0.040	0.201	0.025	0.050
Primary branches per plant	G	-0.008	0.006	0.007	-0.174	0.003	0.032	0.131	-0.004	0.022
	P	0.000	0.002	-0.001	-0.189	0.032	0.025	0.145	-0.011	0.012
Secondary branches per plant	G	-0.000	0.002	0.006	-0.012	0.056	0.000	0.103	-0.008	0.015
	P	0.000	-0.000	-0.000	-0.053	0.115	-0.005	0.102	-0.011	0.009
No. of pods on main stem	G	0.001	0.002	0.009	-0.046	0.000	0.123	0.056	0.017	0.020
	P	-0.000	0.002	-0.007	-0.038	-0.005	0.128	0.077	0.023	0.018
No. of Pods Per plant	G	0.007	0.000	0.009	-0.028	0.007	0.008	0.801	0.025	-0.002
	P	-0.000	0.000	-0.005	-0.033	0.014	0.012	0.816	0.025	-0.003
No. of seeds per pod	G	0.007	0.000	0.007	0.008	-0.004	0.021	0.206	0.097	-0.026
	P	-0.000	0.001	-0.005	0.019	-0.012	0.028	0.195	0.104	-0.026
Test weight	G	-0.009	0.006	0.015	-0.028	0.006	0.018	-0.012	-0.018	0.138
	P	0.000	0.005	-0.007	-0.015	0.007	0.015	-0.019	-0.018	0.154

correlation coefficient counterparts. This implies that environmental factors influence the values of genotypic correlation due to the influence of non-genetic causes. The results of the association analysis, which considered both genotypic and phenotypic factors, indicated a significant and positive correlation between seed yield per plant and plant height, number of seeds per pod, and number of pods per plant. Although not statistically significant, the relationships between seed yield per plant and days to 50 per cent flowering, primary and secondary branches per plant, number of pods on main stem, pod length, shelling per cent, and test weight were all positive (Table 3). The current results validate the conclusions drawn by Prajapati *et al.* (2010) and Ayanoglu *et al.* (2004).

Path analysis demonstrated that the influence of direct effects was more pronounced than that of indirect effects, with infrequent observations of changes in either direction between the genotypic and phenotypic path coefficients. Path coefficient analysis, employing genotypic and phenotypic correlations, identified several significant characteristics that influenced seed yield per plant in a direct and positive manner: test weight, number of seeds per pod, number of pods per plant, number of pods on main stem, and number of secondary branches per plant. The correlation coefficient between an effect and a causal factor is nearly proportional in magnitude to the effect's direct effect. Thus, the actual interrelationship was elucidated by correlations, which also indicated that a direct selection of these characteristics would be fruitful (Table-4). The results presented here are consistent with the studies conducted by Dash and Kole (2000), Datta *et al.* (2005), Gangopadhyay *et al.* (2009), Prajapati *et al.* (2010), Million *et al.* (2012), and Kole and Saha (2013). Specifically, the number of primary branches per plant and days to 75 per cent maturity had both a direct and negative impact on seed yield per plant. On the other hand, days to 50 per cent flowering exhibited a genotypically positive effect on seed yield, but a phenotypic effect was found to be negatively direct on seed yield. Significant findings from the correlation and path coefficient analysis studies indicate that the most influential yield contributing traits for seed yield per plant are plant height, number of pods per plant, and number of pods on the main stem. Furthermore, these traits were found to account for the observed relationship between various morphological characteristics and seed yield per plant. Therefore, when striving to enhance yield, the number of seeds per pod, pod length, days to 50 per cent blossoming, and branches per plant should be duly considered.

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Heat Stress Effects and Heterosis Studies in Bread Wheat (*Triticum aestivum* L. Em. Thell)

Guman Singh*, Dharendra Singh and D.K. Gothwal

Department of Plant Breeding and Genetics, S.K.N. Agriculture University, Jobner, Jaipur-303329

*Corresponding Author Email : gsgurjar111@gmail.com

Abstract

An attempt was made to determine desirable cross combinations under conditions of high temperature stress for the following traits: days to heading, grain filling duration, days to maturity, plant height, number of tillers per plant, flag leaf area, number of grains per spike, peduncle length, spike length, 1000-grain weight, harvest index, and biological yield per plant. This was accomplished through the estimation of relative heterosis and heterobeltiosis in wheat genotypes. The F₁ crosses were conducted using ten genotypes in a half-diallel fashion. During the academic year 2016-17, the experiment was carried out using a randomised block design with three replications. All the examined characters exhibited an adequate degree of heterosis and heterobeltiosis, as indicated by the results. The highest observed heterosis over the mid-parent was 34.22 percent (Raj 3765xRaj 3777) in a high temperature stress environment, based on a global evaluation of heterosis for cereal yield per plant across environments. A maximal heterosis of 33.15% was observed over the superior progenitor (Raj 3765xRaj 3777) under conditions of high temperature stress. Consequently, cereal yield per plant was observed to be more heterogeneous in these combinations when subjected to high temperature conditions. As a result, it is possible to deduce that future breeding programmes may utilise these cross combinations to develop a heterogeneous gene pool in wheat, thereby increasing cereal yield and other characteristics that contribute to the plant's resistance to thermal stress.

Key words : Wheat, heterosis, heterobeltiosis, high temperature stress.

Introduction

Bread wheat (*Triticum aestivum*), which ranks second only to rice in India, is the most significant edible grain crop among cereals. Since the advent of civilization, this cereal commodity has been a fundamental source of sustenance for human beings. It is renowned for its ability to safeguard individuals from starvation. It is classified as a self-pollinating Poaceae family legume. It is a hexaploid species with 21 pairs of chromosomes (2n=6x=42: AABBDD genomes). It has made a substantial contribution to the success of the "Green Revolution" and has assisted in transforming our nation from one of reliance on imports to one that is now self-sufficient.

It is cultivated on an estimated 215.44 million hectares of land worldwide, yielding 731.7 million tonnes at an average productivity of 3490 kilogrammes per hectare (Anonymous, 2019). Wheat cultivation is predominant in Australia, Europe, Russia, North and South America, and China. The wheat production and area in India for the 2018-19 fiscal year were documented as 29.8 million hectares and 101.2 million tonnes, respectively. The average wheat yield per hectare was estimated to be 3390 kg (Anonymous, 2019). Uttar Pradesh has documented the maximum production in India, amounting to 30.24 million tonnes. Subsequently, Bihar has produced 5.08 million tonnes, followed by Madhya Pradesh at 13.93 million tonnes, Haryana at

11.80 million tonnes, and Rajasthan at 11.20 million tonnes. Collectively, these six states accounted for approximately 90% of the nation's wheat production.

Wheat cultivation in Northern India during the late-sowing period is subjected to extremely low temperatures until the booting stage. Subsequently, during the later phases, the crop is exposed to mild temperatures, which forces it to mature under high temperature conditions, ultimately resulting in suboptimal cereal yield. Consequently, the reproductive (spike initiation to anthesis) and maturation (anthesis to maturity) stages of development of wheat crops planted late are typically subjected to elevated temperatures stress from March to April, when ambient temperatures hover between 35 and 40 degrees Celsius. For distinct growth stages, individual genotypes within a given plant species require specific temperature ranges to flourish. For instance, wheat requires 20-23°C for kernel formation, 16-20°C for tillering, and 20-25°C for germination. Wheat is particularly vulnerable to temperatures that surpass 32-33°C for an extended duration; elevated temperatures can cause damage to plants during seedling emergence, reproductive development, stem elongation, heading, and blossoming.

Enhanced agricultural productivity had been the primary objective of breeding initiatives. For this objective, wheat cultivators across the globe have been employing

the genetic resources at their disposal. It is essential to comprehend the genetic factors that regulate the yield components, as breeding for yield is predominately dependent on genetic manipulation of those components in addition to yield. These traits are polygenic and demonstrate both additive and non-additive genetic variation. Parents exhibiting noteworthy GCA effects are valuable for exploitation via conventional crossing programmes, while parents with noteworthy SCA effects are well-suited for the production of desirable transgressive segregants in wheat. Presently, there is abundant evidence to suggest that self-pollinated crops are capable of displaying a comparable degree of heterosis to cross-pollinated crops (Larik *et al.*, 1995). This endeavour is the subject of the present investigation in this context.

Materials and Methods

The experimental material utilised in this research consisted of ten wheat genotypes that were genetically diverse. These genotypes were obtained from the Rajasthan Agricultural Research Institute in Durgapura, Jaipur, through the All India Coordinated Wheat and Barley Improvement Project (AICW&BIP), along with their 45 F₁ varieties. A half-diallel cross was conducted between ten different barley genotypes (Raj 1482, Raj 3765, Raj 3077, Raj 3777, Raj MR-1, Raj 4238, Raj 4079, Raj 4120, DPW 621-50, and WH 1105) at the Agronomy Farm, S.K.N. College of Agriculture, Jobner, during the academic year 2015-16. Agronomy farm, S.K.N. College of Agriculture, Jobner, cultivated ten progenitors and the 45 F₁ offspring that resulted from them using a randomised block design with three replications and high temperature conditions during the 2016-17 academic year. This resulted in a high-temperature stress environment at post-anthesis, which occurred approximately 30 days later than normal. The progenitors and F₁ offspring were cultivated in a two-row, two-meter-long tract with a 30-centimeter row-to-row separation and a 10-centimeter plant-to-plant separation. A total of ten competitive plants, including both parents and F₁s, were selected at random to participate in the recording of observations on thirteen different characteristics. These characteristics included the number of grains per spike, peduncle length (cm), 1000-grain weight (g), harvest index, days to heading, grain filling duration, days to maturity, plant height (cm), number of tillers per plant, flag leaf area (cm²), and peduncle length (cm).

The researchers conducted analysis of variance for each of the characters in accordance with the method proposed by Panse and Sukhatme (1985). As proposed by Fonseca and Patterson (1968), the heterosis (H%)

and heterobeltiosis (HB%) were calculated as the deviation of the F₁ value from the mid-parent and better-parent values, respectively.

Results and Discussion

The analysis of variance conducted in a heat stress environment unveiled statistically significant variations among parents with the exception of the following traits: days to heading, grain filling duration, peduncle length, and 1000 grain weight. F₁'s also revealed substantial variations across all the examined characters. All traits were found to have substantial mean squares when comparing F₁'s to parents, with the exception of grain filling duration, plant height, peduncle length, and biological yield per plant. The significance of the differences between the parents and F₁ in nearly all characteristics suggests the presence of heterosis.

Additionally, this research may aid in the identification of promising crossbreed combinations for conventional breeding programmes. In his seminal work, Mackey (1976) expounded upon the genetic principles governing the expression of heterosis superior to that of the superior parent. This superiority can arise from two possible scenarios: (i) dominance, which occurs when advantageous dominant or semi-dominant genes accumulate and are dispersed across two parents; (ii) non-allelic interaction or epistasis, which occurs when advantageous alleles collaborate at different loci; and (iii) favourable interaction between two alleles at the same locus. If either or both of the first two circumstances induce heterosis, it will be feasible to recover homozygous lines to the same extent as heterotic hybrids. However, the extent to which such lines can be recovered will be contingent on the linkage relationships between the involved genes and the capability to detect recombinants as they emerge. This will be especially challenging in cases involving close linkage and heterosis manifested as a marginal enhancement in each of the principal yield components. When interallelic interactions among dominant types are the cause of heterosis, it becomes unfeasible to rectify such heterosis in successive generations through homozygosity. The application of heterosis for commercial purposes is considered an exemplary application of genetics in plant breeding. The extent of heterosis in a given crop is determined by factors such as hybrid seed production feasibility, utilisation, and exploitation. The significance and utility of hybrid superiority, specifically in comparison to heterobeltiosis, which involves the superior parent, are greater when assessing the commercial viability of heterosis and identifying parental combinations that yield the greatest quantity of transgressive segregants.

Due to the highly adapted varieties used as parents

Table-1 : Estimates of heterosis (H) and heterobeltiosis (HB) for grain yield per plant for high temperature stress.

Character	Grain yield per plant (g)	
Cross	H	HB
Raj 1482x Raj 3765	12.60**	12.16*
Raj 1482x Raj 3077	2.41	1.95
Raj 1482x Raj 3777	22.07**	20.62**
Raj 1482x Raj MR-1	9.38	0.99
Raj 1482x Raj 4238	20.66**	14.25**
Raj 1482x Raj 4079	12.75**	8.38
Raj 1482x Raj 4120	3.68	2.62
Raj 1482x DPW 621-50	2.11	-7.22
Raj 1482x WH 1105	5.57	0.45
Raj 3765x Raj 3077	19.35**	19.28**
Raj 3765x Raj 3777	34.22**	33.15**
Raj 3765x Raj MR-1	0.40	-6.97
Raj 3765x Raj 4238	10.85*	5.35
Raj 3765x Raj 4079	24.18**	19.82**
Raj 3765x Raj 4120	18.25**	17.51**
Raj 3765x DPW 621-50	5.49	-3.81
Raj 3765x WH 1105	3.78	-0.88
Raj 3077x Raj 3777	-6.08	-6.77
Raj 3077x Raj MR-1	-6.48	-13.29**
Raj 3077x Raj 4238	-4.54	-9.22
Raj 3077x Raj 4079	23.75**	19.47**
Raj 3077x Raj 4120	0.29	-0.28
Raj 3077x DPW 621-50	-7.08	-15.23**
Raj 3077x WH 1105	1.64	-2.88
Raj 3777x Raj MR-1	1.55	-5.20
Raj 3777x Raj 4238	0.86	-3.41
Raj 3777x Raj 4079	9.58*	6.56
Raj 3777x Raj 4120	-8.83	-8.98
Raj 3777x DPW 621-50	1.26	-6.99
Raj 3777x WH 1105	17.92**	13.49**
Raj MR-1x Raj 4238	-4.13	-6.66
Raj MR-1x Raj 4079	2.31	-1.90
Raj MR-1x Raj 4120	17.39**	9.42
Raj MR-1x DPW 621-50	9.26	7.36
Raj MR-1x WH 1105	7.19	3.84
Raj 4238x Raj 4079	13.11**	11.35*
Raj 4238x Raj 4120	3.54	-1.01
Raj 4238x DPW 621-50	12.18*	7.39
Raj 4238x WH 1105	8.65	8.09
Raj 4079x Raj 4120	15.65**	12.27*
Raj 4079x DPW 621-50	14.84**	8.29
Raj 4079x WH 1105	2.33	1.25
Raj 4120x DPW 621-50	-8.01	-15.63**
Raj 4120x WH 1105	4.41	0.32
DPW 621-50x WH 1105	-2.07	-6.72
SE	0.51	0.59

*, **Significant at 5 per cent and 1 per cent levels, respectively.

Table-2 : Top three crosses for their heterosis and heterobeltiosis estimates in high temperature stress environment for different characters.

Characters	Heterosis	Heterobeltiosis
Days to heading	Raj 3765xWH 1105	Raj 3765xWH 1105
	Raj MR-1xRaj 4120	Raj 3077xRaj 4238
	Raj 3077xRaj 4238	Raj 4238xRaj 4079
Gain filling duration (days)	Raj 4238xRaj 4079	-
	Raj 3777xWH 1105	-
	Raj MR-1xWH 1105	-
Days to maturity	Raj 3077xDPW 621-50	Raj 3077xDPW 621-50
	Raj 3077xRaj 4238	Raj 3765xRaj 4079
	Raj 3777xRaj MR-1	Raj 3777xRaj MR-1
Plant height (cm)	Raj 3765xRaj 4079	DPW 621-50xWH 1105
	Raj 3765xWH 1105	Raj 4079xDPW 621-50
	-	Raj 3077xRaj MR-1
Number of tillers per plant	Raj 3765xRaj 3777	Raj 3765xRaj 3777
	Raj 4079xDPW 621-50	Raj 1482xRaj 3777
	Raj 3077xRaj 4079	-
Flag leaf area (cm ²)	Raj 3777xRaj 4238	-
	Raj 3777xRaj 4120	-
	Raj 4120xDPW 621-50	-
Peduncle length (cm)	Raj MR-1xRaj 4079	-
	Raj 1482xRaj MR-1	-
	Raj 3765xRaj 4120	-
Spike length (cm)	Raj MR-1xRaj 4120	Raj MR-1xRaj 4120
	Raj 3777xRaj 4238	Raj 3765xRaj 3777
	Raj 3765xRaj 3777	Raj 4079xRaj 4120
Number of grains per spike	Raj MR-1xRaj 4120	Raj 3765xRaj 3777
	Raj 3765xRaj 3777	Raj 1482xRaj 3765
	Raj 3777xRaj 4238	Raj MR-1xRaj 4120
1000-grain Weight (g)	Raj 3765xRaj 4079	Raj 3765xRaj 4079
	Raj 3077xRaj 4079	Raj 3765xRaj 4120
	Raj 3765xRaj 4120	Raj 3077xRaj 4079
Biological yield per plant (g)	Raj 3765xRaj 4238	Raj 3077xRaj 4079
	Raj 3077xRaj 4079	Raj 3777xWH 1105
	Raj 3777xWH 1105	Raj 3765xRaj 4238
Grain yield per plant (g)	Raj 3765xRaj 3777	Raj 3765xRaj 3777
	Raj 3765xRaj 4079	Raj 1482xRaj 3777
	Raj 3077xRaj 4079	Raj 3765xRaj 4079
Harvest index (%)	Raj 3077xRaj 4120	Raj 1482xRaj 4238
	Raj 3077xRaj MR-1	Raj 3077xRaj 4120
	Raj 3077xRaj 3777	Raj 4238xRaj 4120

Table-3 : Crosses possessing with high heterosis (H) and heterobeltiosis (HB) for grain yield per plant (g) along with desirable (+) heterotic expression for other characters in high temperature stress environment.

Particulars	Crosses possessing high heterosis and heterobeltiosis for grain yield per plant	Days to heading	Grain filling duration	Days to maturity	Plant height	Number of tillers per plant	Flag leaf area	Peduncle length	Spike length	Number of grains per spike	1000-grain weight	Biological yield per plant	Harvest index
Heterosis	Raj 3765xRaj 3777	-	-	-	-	+	-	-	+	+	-	+	+
	Raj 3765xRaj 4079	-	-	+	+	+	-	-	-	-	+	+	-
	Raj 3077xRaj 4079	-	-	+	-	+	-	-	+	+	+	+	-
Heterobeltiosis	Raj 3765xRaj 3777	-	-	+	-	+	-	-	-	+	-	+	+
	Raj 1482xRaj 3777	-	-	-	-	+	-	-	-	-	-	-	-
	Raj 3765xRaj 4079	-	-	+	+	-	-	-	-	-	+	+	-

in this investigation, heterosis over the intermediate parent and over the superior parent has substantial practical implications. Nonetheless, research into the extent of heterosis is crucial, as it may prove useful in determining the course of future breeding initiatives. Histories have been conducted on both heterosis and heterobeltiosis in the current investigations. The pursuit of increased cereal yield is evidenced by the presence of positive heterosis. The heterosis estimates indicated that the responses of crosses to heterosis varied from one character to the next and from cross to cross when subjected to high temperature stress environment. The range of heterosis under high temperature stress environment varied from -4.99 (Raj 3765xWH 1105) to 12.12% (Raj 3777xRaj 4079) for days to heading; -19.47 (Raj 3077xDPW 621-50) to 13.36% (Raj 4238xRaj 4079) for grain filling duration; -7.18 (Raj 3077xDPW 621-50) to 2.65% (Raj 3777xWH 1105) for days to maturity; -5.89 (Raj 3765xRaj 4079) to 8.47% (Raj 3077xWH 1105) for plant height; -13.58 (Raj 3777xRaj 4238) to 26.95% (Raj 3765xRaj 3777) for number of tillers per plant; -18.96 (Raj 3077xWH 1105) to 19.84% (Raj 3777xRaj 4238) for flag leaf area; 19.31 (Raj 3777xRaj 4238) to 21.78% (Raj MR-1xRaj 4079) for peduncle length; and -12.50 (Raj 3765xRaj 4079) to 22.64% (Raj MR-1xRaj 4120) for spike length; -3.58 (Raj 3777xEaj 4120) to 24.46% (Raj MR-1xRaj 4120) for number of grains per spike; -7.39 (Raj 1482xWH 1105) to 18.15% (Raj 3765xRaj 4079) for 1000-grain weight; -2.36 (Raj 3077xRaj MR-1) to 30.49% (Raj 3777xRaj 4120) for biological yield per plant; -0.02 (Raj MR-1xRaj 4238) to 21.11% (Raj MR-1xRaj 4120) for grain yield per plant; -15.04 (Raj 3765xRaj 4238) to 28.22% (Raj 3077xRaj 4120) for harvest index.

Grain yield per plant is a critical attribute in the pursuit of enhancing agricultural productivity. An exhaustive examination of grain yield per plant for heterosis revealed that seventeen of the forty-five crosses subjected to high temperature stress exhibited noteworthy positive heterosis. Conversely, eleven of the crosses subjected to high temperature stress demonstrated significant positive heterobeltiosis; thus, these crosses were deemed favourable for this characteristic when subjected to high temperature stress. The crosses Raj 3765xRaj 3777, Raj 1482xRaj 3777, and Raj 3077xRaj 4079 exhibited the greatest positive significant value of heterosis. Furthermore, Raj 3765xRaj 3777, Raj 3765xRaj 4079, and Raj 1482xRaj 3777 all possessed the highest positive significant value of heterobeltiosis. Consequently, these cross combinations were identified as the most desirable under high temperature stress conditions (Table 1). Under high temperature stress, maximum heterosis was recorded as 34.22% (Raj 3765xRaj 3777), and maximum heterobeltiosis was

recorded as 33.15% (Raj 3765xRaj 3777). As a result, cereal yield per plant was observed to be more heterogeneous in these hybrids subjected to high temperature stress conditions.

In a high temperature stress environment, the crosses Raj 3765xRaj 3777 and Raj 3765xRaj 4079 demonstrated favourable cereal yield per plant in terms of per se performance, heterosis, and heterobeltiosis.

The significance and utility of hybrid superiority, specifically in comparison to heterobeltiosis, which involves the superior parent, are greater when assessing the commercial viability of heterosis and identifying parental combinations that yield the greatest quantity of transgressive segregants.

Table 2 lists the three most productive heterotic and heterobeltiotic crosses for various yield-attributing characteristics. The crosses Raj 3765xRaj 3777, Raj 3077xRaj 4079, and Raj 3077xRaj 4079 exhibited the most desirable heterosis in a heat stress environment, and the crosses Raj 3765xRaj 3777, Raj 1482xRaj 3777, and Raj 3765xRaj 4079 have high heterobeltiosis for four or more yield attributing traits, according to an intriguing relationship between heterosis and heterobeltiosis for grain yield per plant and other yield attributing traits.

Under conditions of elevated temperature stress, the current experiment revealed significant heterosis in the following variables: grain yield per plant (34.22%), biological yield per plant (30.49%), harvest index (28.22%), number of tillers per plant (26.75%), and number of grains per spike 24364%.

The current study observed that the progenitors, which demonstrated favourable heterosis and heterobeltiosis in terms of grain yield per plant, also demonstrated these traits in at least one or more yield-attributing characteristics. For example, heterosis for grain yield per plant was primarily influenced by days to maturity, number of tillers per plant, spike length, number of grains per spike, and biological yield per plant, whereas heterobeltiosis was influenced by days to heading, biological yield, and harvest index in both environments. The results of this inquiry corroborated the assertions made by Grafius (1959), which posit that yield cannot be attributed to a distinct gene system in and of itself, but rather results from the multiplicative interactions of its constituent qualities. Therefore, heterobeltiosis for grain yield could potentially derive from heterobeltiosis for numerous yield-contributing characteristics. Nevertheless, not all the traits exhibited heterotic expression in the crosses that demonstrated heterotic cereal yield per plant. It was also observed that the

environments affected the manifestation of heterosis and heterobeltiosis in the majority of the characters. This was the result of a substantial G x E interaction. Consistent with Joshi *et al.* (2003.b), Singh *et al.* (2004), Pancholi *et al.* (2012), and Raj and Kandalkar (2013), the findings support this conclusion.

Conclusions

A satisfactory level of heterosis and heterobeltiosis was observed in every character that was investigated. In a thermal stress environment, the crosses Raj 3765xRaj 3777, Raj 3077xRaj 4079, and Raj 3077xRaj 4079 displayed the most desirable heterosis. Furthermore, the crosses Raj 3765xRaj 3777, Raj 1482xRaj 3777, and Raj 3765xRaj 4079 exhibited high heterobeltiosis for at least four yield-attributing traits. As a result, the aforementioned hybrids may be regarded as potentially fruitful varieties for enhancing the yield potential of barley grown under heat stress conditions. A comprehensive assessment of heterosis in relation to cereal yield per plant indicated that under conditions of elevated temperature stress, the maximum heterosis observed was 34.22% (Raj 3765xRaj 3777), and the maximum heterobeltiosis was 33.15% (Raj 3765xRaj 3777). As a result, cereal yield per plant was observed to be more heterogeneous in these hybrids subjected to high temperature stress conditions.

The degree of heterosis was determined to be 34.22% for grain yield per plant, 30.49% for biological yield per plant, 28.22% for harvest index, 26.95% for number of tillers per plant, and 24364% for number of grains per spike when subjected to high temperature stress. In a high temperature stress environment, the crosses Raj 3765xRaj 3777 and Raj 3765xRaj 4079 emerged as favourable crosses for cereal yield per plant based on per se performance, heterosis, and heterobeltiosis. The present investigation reveals an ample scope for exploitation of hybrid vigour for commercial production as well as isolation of pure lines among the progenies of heterotic F₁ for demonstrable advancement of cereal yield in wheat under high-temperature stress environment.

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ICT-Based Best Practices in College Libraries : A Comprehensive Review

Jitendra Singh Choudhary and Laxmi Choudhary

University of Technology, Jaipur, Rajasthan

Abstract

This abstract provides an overview of the research study focused on Information and Communication Technology (ICT) based best practices implemented in college libraries. In today's rapidly evolving digital landscape, libraries are challenged to adapt and innovate to meet the diverse information needs of students and faculty. This study investigates the integration of ICT tools and strategies in college libraries to enhance accessibility, facilitate effective information retrieval, and promote a dynamic learning environment. The research employs a mixed-methods approach, combining a thorough literature review with case studies and surveys of selected college libraries renowned for their successful ICT implementations. The analysis encompasses various facets of ICT integration, including digitization of resources, implementation of library management systems, utilization of digital repositories, and the integration of interactive platforms for user engagement. In conclusion, this research provides valuable insights into the successful integration of ICT in college libraries, demonstrating its transformative potential in enriching the learning environment. The identified best practices offer a roadmap for colleges seeking to harness the power of technology to meet the evolving information needs of their academic community. This study contributes to the ongoing discourse on the modernization of libraries and underscores the pivotal role of ICT in shaping the future of academic resource centers.

Introduction

In today's rapidly evolving educational landscape, the integration of Information and Communication Technology (ICT) has become a driving force, reshaping conventional approaches across various sectors, including higher education. College libraries, as critical repositories of knowledge, have undergone substantial transformations owing to the adoption of ICT. This comprehensive review aims to critically assess the innovative approaches and best practices that have emerged in college libraries as a consequence of ICT incorporation. Through an examination of empirical data, scholarly publications, and case studies, this review seeks to provide valuable insights into how ICT has revolutionized library services, ultimately augmenting the learning experiences of students in higher education institutions.

In this digital era, the effective integration of ICT in college libraries has proven instrumental in meeting the evolving information needs of students, faculty, and researchers (Smith, 2018). The implementation of state-of-the-art technologies, such as online databases, e-books, and digital repositories, has propelled libraries from static physical repositories to dynamic, accessible virtual spaces (Johnson et al., 2020). This transition has not only widened the scope of available resources but has also transcended geographical boundaries, ensuring inclusivity in education.

Moreover, the adoption of ICT has transformed library cataloging and retrieval systems, enabling users to efficiently locate and access resources (Kumar & Sahoo,

2019). Advanced search algorithms and metadata tagging have streamlined the search process, allowing users to navigate vast digital collections with precision and ease. Additionally, the integration of Artificial Intelligence (AI) and Machine Learning (ML) algorithms has empowered libraries to offer personalized recommendations, aligning content with individual preferences and research interests (Wang *et al.*, 2021).

One of the most revolutionary aspects of ICT in college libraries has been the emergence of virtual learning environments and collaborative platforms. Integrated learning management systems and online discussion forums have facilitated dynamic interactions among students, faculty, and library resources (Alabi & Oyewusi, 2018). This collaborative approach nurtures a culture of active learning, encouraging students to engage with information resources in a multifaceted manner, ultimately enriching their educational journey.

The integration of ICT in college libraries has ushered in an era of unprecedented progress, redefining the role of libraries in higher education. This review will delve deeper into specific best practices, analyzing case studies and empirical evidence to provide a comprehensive understanding of the transformative impact of ICT on college libraries.

Digital Repositories and Open Access: Enabling Seamless Integration with E-learning and Virtual Classrooms

: The shift towards online education and research in the digital age has been significantly influenced by the emergence of digital repositories and

open-access resources. These platforms provide a wealth of educational material and research findings, readily available to a global audience. Simultaneously, the integration of e-learning platforms and virtual classrooms has transformed the delivery and accessibility of education. This article will delve into the seamless integration of digital repositories, open access, and e-learning environments, examining the advantages and challenges associated with their convergence.

Digital Repositories: A Vault of Knowledge : Digital repositories function as centralized hubs for managing and disseminating diverse digital content, including scholarly articles, datasets, multimedia resources, and more. These repositories have revolutionized access to knowledge, enabling researchers, students, and educators worldwide to explore a vast array of academic material. Noteworthy examples encompass institutional repositories hosted by universities and organizations, as well as specialized repositories like arXiv, PubMed Central, and DSpace.

Open Access: Fostering Accessibility to Knowledge : Open access (OA) publishing has emerged as a vital element in the scholarly communication landscape. It champions the unhindered availability of research outputs, enabling anyone with an internet connection to peruse, download, and utilize scholarly articles, often without charge. This model amplifies the visibility and impact of research while promoting collaboration and innovation. Prominent OA initiatives include the Directory of Open Access Journals (DOAJ) and the Public Library of Science (PLOS).

Integration of Digital Repositories and Open Access : The amalgamation of digital repositories and open access platforms synergistically expands the reach and impact of academic work. When researchers deposit their work in institutional repositories, they can opt for open access, making their findings instantly accessible to a global audience. This integration bridges the gap between researchers and the broader community, cultivating a culture of knowledge sharing and collaboration.

E-learning and Virtual Classrooms: A Paradigm Shift in Education : E-learning platforms and virtual classrooms have revolutionized education delivery, offering flexible and accessible learning opportunities. These platforms leverage technology to create interactive and engaging learning environments, allowing students to participate in courses from any location globally. Prominent examples encompass Learning Management Systems (LMS) like Moodle, and virtual classroom platforms such as Zoom and Microsoft Teams (Anderson, T., & Dron, 2011).

Seamless Integration: Augmenting the Learning Experience : The integration of digital repositories and open-access resources with e-learning platforms provides numerous advantages to both educators and learners. Educators can enhance their courses with a diverse range of open-access materials, including peer-reviewed articles, case studies, and multimedia content. This not only enriches the quality of educational content but also exposes students to a broader spectrum of knowledge sources.

Furthermore, students benefit from direct access to authoritative and up-to-date research, enabling them to engage critically with course material. They can explore supplementary resources and delve deeper into topics of interest, fostering independent learning and research skills Smith, J. (2018).

Challenges and Considerations : While the integration of digital repositories, open access, and e-learning platforms holds immense potential, it is not without challenges. These include issues related to copyright and licensing, ensuring the quality and reliability of open-access resources, and the need for technical infrastructure to support seamless integration.

The convergence of digital repositories, open access, and e-learning platforms stands as a powerful junction in modern education and research. It democratizes access to knowledge, enhances the quality of educational content, and fosters a culture of collaboration and innovation. As the digital landscape continues to evolve, this integration will play a pivotal role in shaping the future of education and research.

Mobile Accessibility and Responsive Design: Enhancing User Experience : In today's technology-driven world, prioritizing mobile accessibility and employing responsive design is crucial for creating inclusive and user-friendly digital experiences. This article delves into the importance of mobile accessibility and responsive design, emphasizing their pivotal role in enhancing user experience European Commission. (2018).

Mobile Accessibility: Bridging the Digital Divide : Mobile accessibility pertains to the development of digital content and applications that cater to individuals with disabilities, encompassing visual, auditory, cognitive, or motor impairments. With more than a billion people globally living with some form of disability, it's imperative to address this diverse user base. By ensuring accessible mobile interfaces, we ensure that everyone, regardless of their abilities, can access and interact with digital content seamlessly.

Responsive Design: Adapting Across Devices :

Responsive design stands as a critical element of mobile accessibility. It involves crafting web pages that dynamically adjust and adapt to various screen sizes and orientations, allowing optimal viewing and interaction across a spectrum of devices, including smartphones, tablets, and desktop computers. This adaptability is achieved through the use of flexible grids, images, and media queries, allowing content to be presented in a user-friendly format regardless of the device being used.

Research indicates that responsive design significantly enhances user engagement and satisfaction. According to a report by Google, websites with mobile-friendly designs are more likely to rank higher in search results, underscoring the importance of responsive design not just for user experience, but also for search engine visibility.

Furthermore, studies conducted by the Nielsen Norman Group have found that a considerable portion of users won't recommend a business with a poorly designed mobile site, underscoring the impact of responsive design on brand perception and customer loyalty Nielsen Norman Group. (2018).

Data Management and Research Support: Empowering Informed Decision-Making : Effective data management and research support are essential components of any successful organization or academic institution. These practices involve the systematic collection, organization, and analysis of data to derive meaningful insights and inform decision-making processes.

Ensuring Data Integrity and Security : Robust data management practices prioritize the integrity and security of information. This encompasses the implementation of encryption protocols, access controls, and regular audits to safeguard against unauthorized access, data breaches, and loss. Moreover, adherence to data protection regulations such as GDPR (General Data Protection Regulation) and HIPAA (Health Insurance Portability and Accountability Act) is crucial in maintaining the trust of stakeholders and clients.

Supporting Research through Technology : Institutions and organizations rely on advanced technological tools to facilitate research endeavors. This includes databases, statistical software, and data visualization platforms. These tools not only streamline data collection and analysis but also enable researchers to draw meaningful conclusions from complex datasets. Additionally, cloud-based solutions have emerged as a crucial resource, allowing for collaborative research

efforts and secure storage of large volumes of data World Health Organization. (2021).

Conclusions

The integration of ICT-based best practices has ushered in a new era of accessibility, collaboration, and innovation within these academic environments. Through the adoption of state-of-the-art technologies such as integrated library systems, digital repositories, and virtual learning environments, college libraries have been able to cater to the diverse needs of their user base. This evolution has not only streamlined access to vast repositories of knowledge but has also empowered students and faculty with tools for effective research, critical thinking, and lifelong learning. Moreover, the incorporation of ICT tools like data analytics, artificial intelligence, and machine learning has revolutionized library services by enabling personalized recommendations, predictive analytics, and enhanced user experiences. This, in turn, has significantly improved information retrieval processes and promoted a culture of data-driven decision-making.

Mobile accessibility and responsive design are foundational principles in creating inclusive digital experiences, ensuring that content is accessible to users of all abilities and across various devices. Concurrently, robust data management and research support are essential for organizations and academic institutions to make informed decisions and advance knowledge. By prioritizing these aspects, businesses and institutions can not only enhance user satisfaction and engagement but also demonstrate a commitment to inclusivity and responsible data handling.

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Empowering Agriculture through Artificial Intelligence : A Review of Current Applications and Future Prospects

Jitendra Singh Choudhary, Laxmi Choudhary

University of Technology, Jaipur, Rajasthan

Abstract

Artificial Intelligence (AI) has emerged as a transformative force in the agricultural sector, revolutionizing various aspects of farming operations. This review provides an extensive overview of the current state of AI applications in agriculture, encompassing precision agriculture, crop monitoring, pest and disease management, yield prediction, and autonomous machinery. The integration of AI technologies has led to significant improvements in resource utilization, yield optimization, and sustainability. Furthermore, this paper discusses the challenges and opportunities in the adoption of AI in agriculture and envisions the future prospects of this rapidly evolving field.

Empowering Agriculture through Artificial Intelligence : A Review of Current Applications and Future Prospects explores the transformative potential of AI in agriculture, highlighting key advancements and outlining future possibilities. The main points of this review include:

- I. Precision Agriculture and Smart Farming
- II. Crop Monitoring and Disease Detection
- III. Predictive Analytics for Weather and Climate
- IV. Crop Yield Prediction and Optimization
- V. Supply Chain Optimization
- VI. Market Analysis and Price Forecasting
- VII. Robotic Automation and Autonomous Machinery
- VIII. Soil Health Management
- IX. Empowering Smallholder Farmers and Global Food Security
- X. Challenges and Ethical Considerations

Precision Agriculture: Revolutionizing Farming through Technology : Precision agriculture, also known as precision farming, is a modern approach to farming that leverages technology to optimize crop yields, minimize resource use, and enhance overall profitability. This methodology relies on data-driven decision-making, enabling farmers to precisely manage resources such as water, fertilizers, and pesticides. Through the integration of various technologies, precision agriculture has ushered in a transformation of traditional farming practices.

Technologies in Precision Agriculture

1. Global Positioning System (GPS) : The utilization of GPS technology plays a pivotal role in precision agriculture, offering accurate and real-time location data. This allows farmers to create detailed field maps,

facilitating precise planting, fertilizing, and harvesting operations. For example, GPS-guided tractors can navigate through fields with unparalleled accuracy, minimizing overlap and reducing resource wastage (Smith, 2018).

2. Remote Sensing : Remote sensing encompasses the use of drones, satellites, and other aerial devices to capture high-resolution images of fields. These images provide valuable insights into crop health, soil conditions, and pest infestations. By employing specialized software, farmers can analyze this data to make informed decisions about irrigation, pest control, and fertilization (Anderson, 2019).

3. Variable Rate Technology (VRT) : VRT empowers farmers to apply inputs at variable rates across a field, rather than using a uniform approach. This technology takes into account the specific needs of each area within a field, optimizing resource allocation. For instance, VRT can adjust the amount of fertilizer based on soil nutrient levels, leading to improved yields and cost savings (Johnson, 2020).

Benefits of Precision Agriculture

1. Increased Yield and Profitability : By precisely managing resources, farmers can achieve higher crop yields and, consequently, greater profits. Studies have shown that precision agriculture practices can lead to yield increases of up to 25% while reducing input costs by 10-20% (Black et al., 2017).

2. Environmental Sustainability : Precision agriculture promotes sustainable farming practices by minimizing the use of inputs like water, fertilizers, and pesticides. This reduces the environmental impact of agriculture, contributing to soil and water conservation efforts (Zhang et al., 2019).

Precision agriculture represents a significant

advancement in modern farming practices. By harnessing the power of technology, farmers can achieve higher yields, reduce environmental impact, and enhance overall profitability. Embracing precision agriculture is not only beneficial for individual farmers but also crucial for achieving global food security in an increasingly populated world.

Smart Farming & Crop Monitoring: A Technological Paradigm Shift

Smart farming, also known as digital agriculture, leverages cutting-edge technologies to optimize various aspects of farming operations. One key component of smart farming is crop monitoring, which involves the use of sensors, drones, and data analytics to track the health and growth of crops in real-time.

Technologies in Smart Farming & Crop Monitoring

1. Internet of Things (IoT) Sensors : IoT sensors are deployed in fields to monitor crucial parameters such as soil moisture levels, temperature, humidity, and nutrient content. This data is transmitted to a centralized system, providing farmers with insights into the conditions that affect crop growth (Li et al., 2018).

2. Drones for Aerial Imaging : Drones equipped with high-resolution cameras are used for aerial imaging, enabling farmers to obtain detailed visual information about their fields. This technology is instrumental in identifying areas of stress, pest infestations, and assessing overall crop health (Torres-Sánchez et al., 2018).

3. Data Analytics and Machine Learning : Advanced analytics and machine learning algorithms process the data collected from various sensors and imaging devices. These technologies can provide predictive insights, helping farmers make informed decisions about irrigation schedules, pest control measures, and crop harvesting times (Mulla, 2020).

Benefits of Smart Farming & Crop Monitoring

1. Increased Efficiency and Productivity : By harnessing real-time data, farmers can make timely interventions to address issues affecting crop health. This leads to increased productivity and higher-quality yields (Wang et al., 2019).

2. Resource Optimization : Smart farming technologies enable precise resource allocation, minimizing wastage of water, fertilizers, and pesticides. This results in cost savings and reduces the environmental impact of farming operations (Wolfert et al., 2017).

Predictive Analytics for Weather and Climate

The integration of predictive analytics into weather and

climate studies has greatly enhanced our ability to anticipate and prepare for changing environmental conditions. By harnessing advanced computational methods and statistical techniques, meteorologists and scientists can now offer more accurate forecasts, enabling communities to better adapt to evolving weather patterns.

Understanding Predictive Analytics for Weather and Climate

Predictive analytics for weather and climate entails the utilization of historical weather data, atmospheric models, and machine learning algorithms to formulate precise forecasts. This approach enables scientists to not only predict short-term weather fluctuations but also discern long-term climate trends.

Central to this process is data assimilation, which involves merging observational data from diverse sources such as satellites, ground-based stations, and aircraft with model simulations. This integration aids in mitigating uncertainties and refining the accuracy of forecasts.

Applications of Predictive Analytics in Weather and Climate

Predictive analytics in weather and climate extends its utility across a broad spectrum of applications :

Natural Disaster Preparedness: Accurate predictions of extreme weather events such as hurricanes, floods, and heatwaves empower communities to take preemptive measures, thus minimizing damage and safeguarding lives.

Agricultural Planning: Farmers can optimize planting and harvesting schedules based on weather forecasts, ultimately maximizing crop yields and minimizing losses.

Energy Management: Power companies can anticipate energy demands more effectively, resulting in more efficient energy production and distribution.

Environmental Policy: Governments can formulate policies related to resource management, urban planning, and disaster resilience informed by climate predictions.

Challenges and Limitations

While predictive analytics has significantly advanced weather and climate forecasting, certain challenges persist. Accurately modeling intricate climate interactions and comprehending regional disparities remains a formidable task. Additionally, the availability of high-quality observational data remains pivotal for precise predictions. Predictive analytics for weather and climate has revolutionized our capacity to anticipate and respond to shifting environmental conditions. With ongoing advancements in data assimilation techniques and the integration of cutting-edge technology, we anticipate even more precise and dependable predictions in the future.

Crop Yield Prediction and Optimization

The accurate prediction and optimization of crop yields are imperative for ensuring food security in a world with an ever-expanding population. The amalgamation of predictive analytics with agricultural science has played a pivotal role in refining crop management practices and maximizing agricultural productivity.

Leveraging Predictive Analytics for Crop Yield Prediction

The application of predictive analytics in agriculture encompasses the integration of data from diverse sources, encompassing weather patterns, soil conditions, and historical crop yields. Machine learning algorithms are subsequently deployed to identify patterns and make precise predictions concerning future yields.

Moreover, remote sensing technologies, including drones and satellites, offer invaluable data for monitoring crop health and growth, enabling timely interventions.

Applications of Crop Yield Prediction and Optimization

Precision Agriculture : Farmers can utilize predictive analytics to tailor their practices to specific areas of their fields, optimizing irrigation, fertilization, and pest control. **Supply Chain Management:** Accurate yield predictions facilitate better planning with regards to storage, transportation, and distribution of agricultural products. **Risk Mitigation:** Predictive analytics aids farmers in preparing for adverse weather events or other factors that may impact crop yields.

Supply Chain Optimization

Supply chain optimization is crucial in today's globalized business environment. It involves streamlining the flow of goods and services from the supplier to the end consumer. **Efficiency through Technology:** Utilizing advanced technologies like IoT sensors, AI-driven demand forecasting, and blockchain for transparent transactions enhances supply chain efficiency (Choi et al., 2020; Ivanov & Dolgui, 2020). **Risk Management:** Implementing strategies to mitigate risks associated with disruptions, such as natural disasters or geopolitical tensions, is vital (Zsidisin et al., 2018). **Sustainability Integration:** Embracing sustainable practices not only reduces environmental impact but also aligns with consumers' increasing demand for eco-friendly products (Sarkis et al., 2019). **Collaborative Networks:** Building strong relationships with suppliers, distributors, and logistics partners fosters trust and enables a more agile and responsive supply chain (Lamming et al., 2017).

Market Analysis and Price Forecasting

Introduction: Market analysis and price forecasting are

crucial components of any business strategy. They involve assessing market trends, consumer behavior, and competition to make informed pricing decisions. **Data-Driven Insights:** Utilizing big data analytics and machine learning models can provide accurate market predictions (O'Hara & Zhong, 2019). **Consumer Behavior Understanding:** Conducting surveys, analyzing social media trends, and studying purchasing patterns helps in comprehending consumer preferences (Sun et al., 2019). **Competitor Analysis:** Keeping a close eye on competitors' pricing strategies and market positioning is essential for staying competitive (Wagner & Hinz, 2016). **Regulatory Impact:** Understanding how government policies and regulations affect pricing and market dynamics is crucial (Gadenne et al., 2019).

Robotic Automation and Autonomous Machinery

Introduction: Robotic automation and autonomous machinery are revolutionizing industries by enhancing productivity and efficiency through the use of intelligent machines. **Increased Productivity:** Robots and autonomous machinery can perform repetitive tasks at a much higher speed and accuracy than humans. **Safety and Reliability:** Robots can handle dangerous tasks in hazardous environments, reducing the risk to human workers. **Skill Augmentation:** While robots handle routine tasks, human workers can focus on more complex, creative, and strategic activities. **Cost Savings:** Although initial investment costs can be high, over time, the cost per unit of production tends to decrease due to increased efficiency.

Soil Health Management

Introduction: Soil health management is essential for sustainable agriculture and environmental conservation. It involves practices that maintain or improve soil quality for optimal plant growth. **Crop Rotation and Diversification:** Rotating crops and diversifying plant species helps in preventing soil degradation and maintaining nutrient balance. **Conservation Tillage:** Reduced or no-till practices minimize soil disturbance, preserving soil structure and reducing erosion. **Organic Matter Addition:** Incorporating organic matter through composting or cover cropping enhances soil fertility, structure, and microbial activity. **Monitoring and Testing:** Regular soil testing and monitoring help in assessing nutrient levels and pH, allowing for precise fertilizer application.

Empowering Smallholder Farmers and Global Food Security

Empowering smallholder farmers is crucial for achieving global food security. These farmers, who cultivate small plots of land, play a significant role in feeding the world's population. **Access to Resources:** Providing smallholder

farmers with improved access to seeds, fertilizers, and modern farming techniques can significantly increase their productivity (IFAD, 2019).

Training and Education: Offering training programs on sustainable farming practices, financial literacy, and market access helps smallholders improve their yields and income (FAO, 2020). Market Linkages: Facilitating connections between smallholder farmers and markets, including local and international markets, can increase their income and overall food security (World Bank, 2019). Policy Support: Implementing policies that protect the rights and interests of smallholder farmers, such as land tenure and access to credit, is essential for their empowerment.

Challenges and Ethical Considerations

In any of the aforementioned areas, there are challenges and ethical considerations that need to be addressed for sustainable and responsible practices. Environmental Impact: Implementing advanced technologies like automation and robotics must be done with careful consideration of their environmental footprint (Huang et al., 2019). Equity and Access: Ensuring that the benefits of supply chain optimization, automation, and empowerment reach all stakeholders, including marginalized groups, is critical. Ethical Sourcing: In market analysis and supply chain optimization, businesses should be vigilant about sourcing practices to avoid exploitation and promote fair trade (Stewart & Luckin, 2019). Regulatory Compliance: Adhering to local and international regulations is crucial to ensure that advancements in these areas are ethical and sustainable.

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Effect of Casing Materials on Contaminant of *Trichoderma harzanium* and also the Cultivation Process of White Button Mushroom [*Agaricus bisporus* (Lange) Imbach]

Prdeep Singh Shekhawat¹, Kharapude Pragati¹, Chandrakant¹, Pajjuru Sujana Sri¹ and Solanke Krushna Mohanrao²

¹Department of Plant Pathology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh

²Department of Entomology, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan

Abstract

Button mushroom (*Agaricus bisporus*) cultivation is a significant aspect of the global mushroom industry. In this study, research was conducted to explore the effects of different casing materials on button mushroom growth and yield. Additionally, a lab experiment was carried out to evaluate the compatibility of various botanicals with *Agaricus bisporus*. Botanicals, such as plant extracts, have been reported to possess various bioactive compounds with potential benefits for mushroom growth and disease control. However, the limiting factor for its successful cultivation is the occurrence of weeds and competitor moulds. An experiment was conducted at the Mushroom Crop Room, Department of Plant Pathology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. The main objectives were to check the effect of casing materials on contaminant of *Trichoderma harzanium* and also the cultivation process of white button mushroom. The study was conducted in Completely Randomised Design under the agro-climatic conditions of Prayagraj (2021-22). The results revealed that the treatment minimum contaminant of *Trichoderma harzanium* was recorded in T₄ [Cocopeat + Garlic leaf (3:1)] followed by T₃ [Cocopeat + Turmeric leaf (3:1)], T₅ [Cocopeat+ Pomegranate skin waste (3:1)], T₁ [Cocopeat + Drumstick leaf (3:1)], T₂ [Cocopeat + Tea waste (3:1)], as compared to T₀.

Key words : *Agaricus bisporus*, long method composting, compost preparation, botanicals.

Introduction

White button mushroom, scientifically called as *Agaricus bisporus* is an edible basidiomycetes fungus that belongs to the genus *Agaricus*. Globally, China is the largest producer of mushrooms in the world followed by USA, Netherlands, Poland and Spain (FAO, 2021). During the period between 2021- 2022, Bihar tops the list followed by Maharashtra, Orissa, Haryana, Uttarakhand in the top mushroom producing states in India [Agricultural and processed food products export development authority of India (APEDA), 2021].

Farm yard manure (FYM) has become the standard substrate for casing under Indian conditions. But the major problem with this conventionally used casing material is the procurement of farmyard manure, due to which many materials are being tested as its alternative for casing the mushroom beds. Vermicompost is rich in NKP (nitrogen 2-3%, potassium 1.85-2.25% and phosphorus 1.55-2.25%), micronutrients, beneficial soil microbes and also contain plant growth hormones and enzymes (RK *et al.*, 2009). It is scientifically proven as miracle growth promoter and also plant protector from pests and diseases. Vermicomposts are rich in macro and micro nutrients, beneficial microflora besides containing growth promoting substances (OA *et al.*, 2015). nutrients for growth of vegetative mycelium and basidiomes (Carrasco *et al.*, 2018).

Mushrooms are highly proteinaceous and have emerged as a source of nutraceuticals due to the presence of medicinal components (Banik, 2010). These are heterotrophic organisms which require external nutrients for growth of vegetative mycelium and basidiomes (Carrasco *et al.*, 2018). Some human related diseases like hyperlipidemia and diabetes have been treated by use of mushrooms which increased the role of mushrooms as food stuff (Omowumi and Kadir, 2013). Though vermicompost has been used as a casing material, but it has a limited use as a substrate. Vermicompost supplementation accelerated the growth of mycelium, which resulted shorter duration of spawn run and quicker pin head initiation in both wheat and rice straw (Sarker *et al.*, 2020).

Agaricus bisporus is one of the most important mushrooms that cultivated in the world (Toker *et al.*, 2007). The white button mushroom (*Agaricus bisporus*) is very popular throughout the world and is the most important mushroom of commercial significance in India (Maheshwari, 2013).

Light brown colored compost having no smell of ammonia should be allowed to cool down before spawning (Netam *et al.*, 2018). In phase III during spawn run there is decrease in Actinobacteria and Firmicutes and increase in Proteobacteria (Kertesz *et al.*, 2016); (Carrasco *et al.*, 2019).

Cocopeat has been regarded as the most suitable and more ideal for casing (Kaur and Rampal, 2017). Various agro-industrial residues have been used as alternatives or as additives to loam soil, such as composted vine shoots, spent mushroom substrate and coconut fiber pith, waste paper, and many others. The use of Sewage sludge in *Agaricus bisporus* production was first reported by Block, Sewage sludge is known as valuable organic manure rich in recycled nitrogen and phosphorus and is characterized by a relatively low C:N ratio, ranging between 6 and 9, high bulk density, and low air-filled porosity (Kumar *et al.*, 2022)

Materials and Methods

In-vivo experiment was conducted in the mushroom crop room and laboratory Department of Plant Pathology, SHUATS, Prayagraj. The area is situated on the right bank of Yamuna River at Rewa road and at a distance of about 6 km away from the city. Geographical location is 25.8° N latitude and 81.5° E longitude at an altitude of 90 meter above sea level.

Wheat straw was selected as substrate for composting. Long method composting was followed which took 35 days to complete where 2 additional turnings were given due to the presence of ammonia smell. Spawn of *Agaricus bisporus* was procured from the Directorate of Mushroom Research, Solan, Himachal Pradesh, India. Spawn strain was DMR - A 121. Spawn was applied @7.5g/kg compost (Kapoor, 2004). Four kilograms of compost was filled in each bag. A total of six treatments replicated four times including a control were taken up under Completely Randomized Design.

Cultivation technique : The cultivation process of white button mushroom can be divided into four major steps that include composting, spawning, casing, harvesting.

Compost preparation : Long method composting was followed which took 35 days to complete where 2 additional turnings were given due to the presence of ammonia smell.

Ingredients used for compost preparation :

Ingredients	Quantity
Wheat straw	300 kg
Wheat bran	15 kg
Single super phosphate (SSP)	03 kg
Muriate of potash (MOP)	03 kg
Urea	06 kg
Calcium sulphate	09 kg
Gypsum	30 kg

For the basic materials for compost, wheat straw, wheat bran, urea, potassium (Muriate of Potash), phosphorus (Single Super Phosphate), gypsum, and were procured from prayagraj market.

The compost was prepared by long method of composting (LMC), Wetted wheat straw was spread thinly over entire floor of the composting yard and then gradually wetted by sprinkling water, till the straw was taking no more water.

The straw was then turned for even wetting at this stage and water content was maintained at 75%. The moist straw was mixed with wheat bran and fertilizers uniformly scattered over the straw. A heap was made after each turning but not compressed tightly so as to maintain the aerobic condition in the compost heap. Gypsum was mixed at the third turning. Total eighth turnings were done, first three turnings at three days interval and last four turnings were done at three days interval. The compost was then ready for spawning that it was dark brown in colour and without any smell of ammonia and had sufficient moisture content (68-70%) when pressed between the palms. Two additional turnings were given on day 31 and 34 as there is smell of ammonia.

Composting schedule followed :

Day	Work done
Day 0	Mixing of straw and other ingredients except gypsum.
Day 1-5	Water was sprinkled regularly to maintain moisture content.
Day 6	First turning was given to the pile with addition of water.
Day 9	Second turning was given same as first turning.
Day 13	Third turning was given and gypsum was added.
Day 16	Fourth turning
Day 19	Fifth turning
Day 22	Sixth turning
Day 25	Seventh turning
Day 28	Eighth turning

Two additional turnings were given on day 31 and 34 as there is smell of ammonia.

Sterilization of Mushroom crop room : Cleaned with water and then, the dirt on the wall was scrapped with sand paper. Crop room was then coated with calcium carbonate (CaCO₃), cropping room was pre-sterilized by spraying formaldehyde solution (0.2%) with the help of foot sprayer. After spraying room was kept air tight for 48 hrs and after 48 hrs fresh air was introduced by air circulation duct then room was used for cropping purpose.

The spawn was mixed with compost at the rate of 7.5 g/1 kg compost (30 g/ bag) in a cylindrical polythene bag. Compost filled bags were then covered with well sterilized newspaper on the top. The bags were then shifted to the crop room where temperature was maintained between 20±2°.

Spawning : The process of mixing spawn with compost is called spawning, both surface and layer spawning were

done, when the bags were be completely colonized by the mushroom mycelium (complete spawn run), the polythene bags were be cut and removed. The substrates were be sprayed with water 3-4 times per day. After 3-5 days of removal of polythene bags small pin heads were appear on all sides of bags. At this time, little amount of light will be provided inside the crop room. The spawned bags will be kept in the well sterilized crop room. The temperature in the crop room will be maintained between 20 - 30°C and relative humidity at 75-85%. To regulate the oxygen and carbon dioxide levels, the crop room were be opened for 1-2 hours every day.

Sterilization of casing materials : Sterilization of the casing materials is much important in order to prevent the diseases and insect incidence. It was done by sun drying the selected materials and then spraying them with formaldehyde solution and covered with a fine polythene sheet in order to facilitate fumigation so that the gases do not escape out of the sheet and thereby providing good sterilization.

Preparation of botanical : All the Four substrates (Pomegranate pear, Drumstick leaves, Turmeric leaf, Garlic leaves) and, Tea waste, was collect from different localities of Prayagraj. It will be weighed, washed, sterilised with formalin and dried after which it will be powdered and packed in polypropylene bags and sealed. The prepared botanical leaf powder was mixed into the substrate at the rate of 40g per 4kg wet substrate around 25-30%. The spawn were be thoroughly mixed with the compost and were be pressed moderately. Later the bags were be kept open on the top end and are kept in the dark room for spawn run. 15-16 holes were be made with the help of sterilized needle to facilitate good aeration inside the bag. After complete spawn run, the bags are to be filled with casing layer.

Casing : After full spawn run or full mycelia colonization of the compost, the casing materials were applied on top of the compost at a uniform thickness of one inch. Each of the casing materials was applied to four uniform bags (replicates) containing 15 cm deep of spawned compost. The twenty four bags were arranged in a Completely Randomized Design (CRD) in a covered mushroom growing room. Each bag received 0.5 to 1.0 litre of water as irrigation once every other day, the rate being based on the relative dryness of the casing material. Mushroom beds were sprayed regularly with water to keep the casing soil adequately moist. The recorded temperature of cropping room was ranged 18-24 °C during harvesting period.

The compost beds after complete spawn run, should be covered with a layer of soil (casing) about 3-4 cm thick to induce fruiting. The casing material should be having

high porosity, water holding capacity and the pH should range between 7-7.5.

The casing materials were include Cocopeat, Pomegranate pear powder, Drumstick leaf powder, Tea waste, Turmeric leaf powder and Garlic leaf powder of the treatments.

After casing is done the temperature of the room is again maintained at $23 \pm 2^\circ$ and relative humidity of 85-90% for another 8-10 days. Low CO₂ concentration is favorable for reproductive growth at this stage.

Fruiting : Under favorable environmental condition viz. temperature (initially $23 \pm 20^\circ\text{C}$ for about week and then $16 \pm 2^\circ\text{C}$), moisture, (2-3 light sprays per day for moistening the casing layer) humidity (about 85%) proper ventilation and CO₂ concentration (0.08-0.15%) the fruit body initials which appear in the form of pin heads start growing and gradually develop into button stage.

Harvesting : Harvesting was done after the pinheads started turning into button sized fruiting bodies just before the cap expands and gills are exposed and are about to bulge. Harvesting was done by holding them gently and twisting them in clockwise and anti- clockwise directions without any residues of stub and without disturbing the other fruiting bodies.

Table-1 : Effect of cocopeat with agrowaste as casing materials on the days of contaminant of *Trichoderma harzanium*.

Symbols	Treatment	No. of days after casing contaminant of <i>Trichoderma harzanium</i> in bags
T ₀	Cocopeat	14
T ₁	Cocopeat + Drumstick leaf (3:1)	20
T ₂	Cocopeat + Tea waste (3:1)	16
T ₃	Cocopeat + Turmeric leaf (3:1)	23
T ₄	Cocopeat + Garlic leaf (3:1)	0
T ₅	Cocopeat + Pomegranate peel powder (3:1)	23

The data presented in Table-1 revealed that all the treatments were significantly superior to untreated (control), Minimum contaminant of *Trichoderma harzanium* was recorded in T₄ [Cocopeat + Garlic leaf (3:1)] followed by T₃ [Cocopeat + Turmeric leaf (3:1)], T₅ [Cocopeat+ Pomegranate skin waste (3:1)], T₁ [Cocopeat + Drumstick leaf (3:1)], T₂ [Cocopeat + Tea waste (3:1)], as compared to T₀.

The probable reasons of these findings may be due to the fact that garlic leaf powder contains sulphur-containing compounds, such as allicin, alliin and ajoene,

enzymes, which have anti-microbial properties including anti-fungal property. This inhibits the growth of the fungal contaminants. Turmeric leaf powder contains curcumin which have anti-microbial properties including anti-fungal property. This inhibits the growth of the fungal contaminants.

Conclusions

During this study, it was evident that the presence of cocopeat + garlic leaf powder in the treatments showed significant reduced in the disease as compared to control. cocopeat with pomegranate peel powder, turmeric leaf powder or tea waste powder are good for the casing and garlic leaf powder contains sulphur- containing compounds, such as allicin, alliin and ajoene, enzymes, which have anti-microbial properties including anti-fungal property. This inhibits the growth of the fungal contaminants. However, the present study only was limited to one rabi season 2021-22 under prayagraj conditions, therefore, to substantiate the present result more trials are needed for 2-3 seasons for further research. The highest yield was recorded in Cocopeat + Pomegranate skin waste contains potassium, sodium, iron and zinc which favours the better growth of mycelium

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Effect of Levels of Phosphorus and Potassium on Nutrient Content of Wheat (*Triticum aestivum* L.)

Amarjeet Singh*, P.K. Sharma and Rahul Sharma

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : choudharyanuj9529@gmail.com

Abstract

A field experimentation was conducted at Kharar Alipur village in Hisar district of Haryana under the supervision of Department of Agriculture, Vivekananda Global University, Jaipur during rabi seasons of the years 2022-23. The objectives were to study the "Response of Wheat (*Triticum aestivum* L.) under Varying Levels of Phosphorus and Potassium under Irrigated Conditions". The experiment consisted of 12 treatment combinations comprising four levels of phosphorus (control, 40, 60 and 80 kg/ha,) with three levels of potassium (20, 40 and 60 kg/ha). The experiment was laid out in Factorial Randomized Block Design and replicated thrice. Application of phosphorus @ 80 kg ha⁻¹ recorded maximum nutrient content in grain and straw (N, P and K).

Key Words : Wheat, Phosphorus, Potassium and Nutrient Content.

Introduction

Wheat [*Triticum aestivum* (L.)] is the most important widely cultivated staple food crop of world due to its adaptability under diversified climatic conditions. Wheat play a major role towards meeting 40 % of world global food demand of world population and act as a boon for mankind to provide half of the dietary protein as well as more than half of the calories

India contributes highest wheat cultivated area (31.45 million hectares) in the world while acquired second position with respect to production (107.59 million tonnes) after china with the average productivity of 3.42 tonnes ha⁻¹ (Anonymous, 2020a).

The N and P balance represents a big challenge in optimizing local crop production. On the one hand, fertilization increases production costs, but on the other hand, the correct amount of fertilizer distributed at the right moment can enhance both wheat quality and quantity. Better matching of N and P fertilizers at rates suitable to the local climate and soil type can increase the productivity of wheat.

Materials and Methods

Experimental site : The experiment was laid out at Khara Alipur, Hisar, Haryana, India. Geographically, the study area is located at 75° 87' East longitudes, at 29° 11' North latitude and at altitude of 215 m above mean sea level (AMSL). Khara Alipur is a village in Hisar Tehsil in Hisar district of Haryana State, India.

Climate and weather conditions : The climate of this location is semi-arid characterized by aridity of the atmosphere and extremity of temperature during both

summers (40.6° C) and winters (2.7° C). The average rainfall is 557 mm per annum, which is mostly received during July to September. The sporadic showers during winters are also common, which are probably observed during this period. The standard meteorological weekly data for temperature, relative humidity, total rainfall, rainy days, wind speed, evaporation and bright sunshine hours for the crop seasons are presented in Table 3.1 and graphically represented in Fig. 3.1. The mean relative humidity fluctuated from 63.50 to 91 per cent during the crop season. The mean maximum temperature during the crop growth period of mustard ranged between 11.9 °C to 29.2 °C, while minimum temperature ranged from 2.8 °C to 15.0 °C during the crop season.

Experimental details : The experiment comprised 4 levels of phosphorus and 3 levels of potassium, thereby making twelve treatment combinations that were laid out in Factorial Randomized Block Design (FRBD) and replicated three times.

S. No.	Treatments	Symbols
A.	Phosphorus levels (kg/ha)	
1.	Control	P ₀
2.	40 kg /ha	P ₁
3.	60 kg/ha	P ₂
4.	80 kg/ha	P ₃
B.	Potassium level (kg/ha)	
1	20 kg /ha	K ₁
2	40 kg/ha	K ₂
3	60 kg /ha	K ₃

Nutrient content (%) : The nitrogen, phosphorus and potassium contents in grain of wheat were estimated at maturity. The grain sample of crop was collected separately as per treatment at harvest. These samples

Table-1 : Effect of phosphorus and potassium on nitrogen content by grain, straw of wheat.

Treatments	Nitrogen content (%)	
	Grain	Straw
Phosphorus (kg ha⁻¹)		
Control	1.70	0.60
40 kg/ha	1.78	0.65
60 kg/ha	1.91	0.70
80 kg/ha	2.02	0.72
S.Em.±	0.05	0.01
C.D. at 5%	0.14	0.04
Potassium (kg ha⁻¹)		
20 kg/ha	1.77	0.62
40 kg/ha	1.86	0.68
60 kg/ha	1.93	0.71
S.Em.±	0.04	0.01
C.D. at 5%	0.12	0.04
C.V. %	7.90	6.35

Table-2 : Effect of phosphorus and potassium on phosphorus content by grain, straw of wheat.

Treatments	Phosphorus content (%)	
	Grain	Straw
Phosphorus (kg ha⁻¹)		
Control	0.32	0.09
40 kg/ha	0.35	0.11
60 kg/ha	0.36	0.13
80 kg/ha	0.38	0.14
S.Em.±	0.01	0.01
C.D. at 5%	0.02	0.01
Potassium (kg ha⁻¹)		
20 kg/ha	0.34	0.11
40 kg/ha	0.36	0.12
60 kg/ha	0.37	0.13
S.Em.±	0.01	0.01
C.D. at 5%	0.02	0.01
C.V. %	5.11	6.78

Table-3 : Effect of phosphorus and potassium on potassium content by grain, straw of wheat.

Treatments	Potassium content (%)	
	Grain	Straw
Phosphorus (kg ha⁻¹)		
Control	0.32	0.49
40 kg/ha	0.34	0.50
60 kg/ha	0.35	0.51
80 kg/ha	0.36	0.52
S.Em.±	0.01	0.01
C.D. at 5%	0.02	NS
Potassium (kg ha⁻¹)		
20 kg/ha	0.33	0.50
40 kg/ha	0.34	0.51
60 kg/ha	0.35	0.52
S.Em.±	0.01	0.01
C.D. at 5%	NS	NS
C.V. %	6.27	4.19

were ground in the grinder after drying in oven at 70°C temperatures for 48 hours. Thus, the ground plant materials passed through 30-mesh sieve, and these materials used for determination of nitrogen, phosphorus and potassium content.

Results and Discussion

Nitrogen content in grain and stover (%)

Effect of phosphorus : Application of phosphorus @ 80 kg P₂O₅ ha⁻¹ recorded significantly the higher nitrogen content in grain (2.02 %) and straw (0.72 %).

Effect of potassium : Application of 60 kg K₂O ha⁻¹ recorded significantly the higher nitrogen content in grain (1.93 %) and straw (0.71 %).

Phosphorus content in grain and stover

Effect of phosphorus : Among the various phosphorus levels, application of phosphorus @ 80 kg P₂O₅ ha⁻¹ recorded significantly the higher phosphorus content in grain (0.38 %) and straw (0.14 %).

Effect of potassium : Application of 60 kg K₂O ha⁻¹ recorded significantly the higher phosphorus content in grain (0.37 %) and straw (0.13 %).

Potassium content in grain and stover (%)

Effect of phosphorus : Significantly maximum potassium content in grain (0.36 %) was observed when crop received 80 kg P₂O₅ ha⁻¹ (P₃) which was closely followed by 60 kg P₂O₅ ha⁻¹ (P₂).

Effect of potassium : The different levels of potassium failed to exert their significantly effect on potassium content in grain and straw.

The nitrogen content in grain and straw, phosphorus content in grain and straw, potassium content in grain, potassium content in grain and straw and protein content in grain were recorded significantly the higher with phosphorus @ 80 kg P₂O₅ ha⁻¹. These finding are in accordance with those reported by Liscano *et al.* (2000), Mehta *et al.* (2019), Neelam *et al.* (2013), Obaid *et al.* (2019).

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Effect of Integrated Nutrient Management on Yield Attributes and Yield of Cumin (*Cuminum cyminum* L.)

Anil Bharnanga*, P.K. Sharma and Ranveer Badiyasar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : ajat00218@gmail.com

Abstract

A field experiment was carried out at Village- Indawar, Merta, Nagaur during rabi season of 2022-23 to study the "Effect of Integrated Nutrient Management on Growth, Yield and Quality of Cumin (*Cuminum cyminum* L.)". The experiment consisting of nine treatments i.e., Control, N:P (30:20 kg/ha), N:P (30:20 kg/ha) + Azotobacter + PSB, FYM @ 5 t/ha, Vermicompost @ 5 t/ha, N:P (30:20 kg/ha) + FYM @ 5 t/ha, N:P (30:20 kg/ha) + FYM @ 5 t/ha, N:P (30:20 kg/ha) + VC @ 2.5 t/ha, N:P (30:20 kg/ha) + Azotobacter + PSB + FYM @ 5 t/ha, N:P (30:20 kg/ha) + Azotobacter + PSB + VC @ 2.5 t/ha was laid out in randomized block design with three replications on loamy sand soil. Application of N:P (30 : 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T₉) also gave highest grain, straw yields, test weight and harvest index of 740 kg ha⁻¹, 1450 kg ha⁻¹, 5.02g and 0.49, respectively and found significantly superior over control.

Key Words : Integrated Nutrient Management, Azotobacter, FYM and Vermicompost

Introduction

Seed spices are known as an integral part of Indian culture that's why India is known as home of spices. Among all the major seed spices, cumin (*Cuminum cyminum* L.) locally known as "Jeera" is one of the important spice crop.

Adequate mineral fertilization is one of the most important pre-requisites with respect to plant nutrients for better growth and development of a plant. The gap between the nutrient removal and supply cannot be bridge up by the application of any single nutrient but this has to be achieved with balanced use of fertilizers. Indian farmers pay reasonable attention to cultivation, especially in respect of seedbed preparation, manuring and irrigation, however sufficient attention has not been paid to nutrient management aspect which remains one of the constraints in boosting up the production. Organic manure and bio-fertilizer play important role in crop production. It acts on the soil physical properties, organic matter promotes formation of soil crumb, thus makes the soil friable and thereby, facilitates the proper movement of air and water as well as absorption of rain water. It also adds plant nutrients to the soil and organic acid during dry matter decomposition which act on the insoluble nutrients reserve in the soil and make them available. Inoculation of seed with Rhizobium recorded higher protein content due to more nitrogen fixation and better utilization by plants. As nitrogen is an integral part of protein, higher availability and uptake of nitrogen under Rhizobium inoculation resulted in higher protein content in seed.

Materials and Methods

Experimental site : The experiment was carried out at

Village-Indawar, Merta City, Nagaur (Rajasthan) which is situated at a distance of about 24 km from Merta road railway station. Geographically, it is located between 26° 55' N to 26° 78' North latitude and 73° 66' E to latitude 73° 95' East longitude at an altitude of 322 meter above mean sea level. This region falls under agro-climatic zone II a (Transtional Plan of Inland Drainage) of Rajasthan.

Climate and weather conditions : The climate of Nagaur is typically arid with hot dry summers. The average annual rainfall is about 367 mm (CV 52%) and bulk of it (85 to 90%) is received from June to September (kharif season) by the southwest monsoon. The normal time of onset of monsoon is the last week of June to first week of July, but weather aberrations are quite common with respect to late arrival and early withdrawal of monsoon that resulted dry spells and high temperature during kharif season. The other distinct climatic features of this region are low relative humidity (15 to 30%) with high wind velocity (30 to 40 km hour⁻¹), solar incidence (520 cal cm⁻²), potential evapotranspiration (1843 mm year⁻¹) and wide range of maximum (24.6oC in January to 41.6o C in May) and minimum (9.6 in January to 27.7o C in June) temperatures.

Weather acts as an input that influencing the growth and quality of crop as well as biotic phase of soil during season. Hence, it is necessary to illustrate climatic variables and their relation in this context.

Experimental details : The experiment consisting of 9 treatment and was carried out in Randomized Block Design (RBD).

Umbels/plant : The umbels of five casually selected

plants from separately plot were counted at harvest and average number of umbels/plant was worked out.

S. No.	Treatments	Symbols
1.	Control	T ₁
2.	N:P (30:20 kg/ha)	T ₂
3.	N:P (30:20 kg/ha) + Azotobacter + PSB	T ₃
4.	FYM @ 10 t/ha	T ₄
5.	Vermicompost @ 5 t/ha	T ₅
6.	N:P (30:20 kg/ha) + FYM @ 5 t/ha	T ₆
7.	N:P (30:20 kg/ha) + Vermicompost @ 2.5 t/ha	T ₇
8.	N:P (30 : 20 kg/ha) + Azotobacter + PSB + FYM 5 t/ha	T ₈
9.	N:P (30 : 20 kg/ha) + Azotobacter + PSB + Vermicompost @ 2.5 t/ha	T ₉

Umbellets/umbel : Number of umbellate/umbe was recorded at harvest by counting the umbellets of the five randomly collected umbels from every plot and the average value was calculated.

Number of seeds/umbellate : At the time of threshing, umbels Five tagged plants were randomly selected in every plot and their total seeds were counted to record the average number of seeds/umbellate.

Results and Discussion

Number of umbels/plant : The maximum number of umbels per plant (20.25) was recorded with application of N:P (30 : 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T₉) which was closely followed by application of T₈ (19.25) and T₆ (19.75) and significantly higher over control. The minimum number of umbels per plant was recorded with Control treatment (T₁) was 17.11 cm. The enhancement in number of umbels per plant due to application of N: P (30 : 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T₉) was 18.34 per cent higher over control.

Number of umbellets per umbel : Application of N:P (30 : 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T₉) being remained at par with application of N:P (30 : 20 kg/ha) + Azotobacter + PSB + FYM @ 5 t/ha (T₈) and application of N:P (30:20 kg/ha) + VC @ 2.5 t/ha (T₇) recorded maximum number of umbellets per umbel of cumint. The minimum number of umbellets per umbel was obtained with Control (T₁). Application of N:P (30 : 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T₉) increased the number of umbellets per umbel by 42.43 per cent over control.

Table-1 : Effect of Integrated Nutrient Management on umbels and umbellets of cumint.

Treatment No.	Treatment details	No. of umbels per plant	No. of umbellets per umbel
T ₁	Control	17.11	5.02
T ₂	N:P (30:20 kg/ha)	17.63	5.60
T ₃	N:P (30: 20 kg/ha) + Azotobacter + PSB	18.62	6.25
T ₄	FYM @ 10 t/ha	17.96	5.50
T ₅	Vermicompost @ 5 t/ha	18.40	5.70
T ₆	N:P (30:20 kg/ha) + FYM @ 5 t/ha	19.75	6.40
T ₇	N:P (30:20 kg/ha) + VC @ 2.5 t/ha	18.90	6.80
T ₈	N:P (30: 20 kg/ha) + Azotobacter + PSB + FYM 5 t/ha	19.25	7.06
T ₉	N:P (30: 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha	20.25	7.15
	S.Em±	0.73	0.07
	CD (P=0.05)	2.22	0.19

Table-2 : Effect of Integrated Nutrient Management on seeds and test weight of cumint.

Treatment No.	Treatment details	No. of seeds per umbel	Test weight (g)
T ₁	Control	18.25	4.46
T ₂	N:P (30:20 kg/ha)	20.14	4.96
T ₃	N:P (30: 20 kg/ha) + Azotobacter + PSB	21.25	4.91
T ₄	FYM @ 10 t/ha	22.45	4.78
T ₅	Vermicompost @ 5 t/ha	21.14	4.86
T ₆	N:P (30:20 kg/ha) + FYM @ 5 t/ha	20.85	4.97
T ₇	N:P (30:20 kg/ha) + VC @ 2.5 t/ha	22.81	4.98
T ₈	N:P (30: 20 kg/ha) + Azotobacter + PSB + FYM 5 t/ha	23.09	4.93
T ₉	N:P (30: 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha	23.14	5.20
	S.Em±	0.07	0.06
	CD (P=0.05)	0.19	0.16

Number of seeds per umbel : The maximum number of seed per umbel (23.14) was obtained with Application of N:P (30 : 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T_9) which was closely followed by application N:P (30 : 20 kg/ha) + Azotobacter + PSB + FYM @ 5 t/ha (T_8) and application of N:P (30:20 kg/ha) + VC @ 2.5 t/ha (T_7) and significantly higher over all other remaining treatments. While, minimum number of seed per umbel of cumin was found with control treatment (T_1). Application of N:P (30 : 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T_9) increased the seeds per umbel by 26.79 per cent under control.

The highest number of umbels per plant (29.15) was achieved by applying N:P (30: 20 kg/ha) + Azotobacter + PSB+VC @ 2.5 t/ha (T_9). It was on par with the treatment of N:P (30 : 20 KG/HA) + AZOTOBACTER + PSB kg/ha + FYM @ 5 t/ha (T_8), as well as N:P (30:20 kg/ha) + VC @ 2.5 t/ha (T_7), and (T_6) N:P 30:20 kg/ha + FYM @ 5 t/ha with the number of umbels per plant recorded as 27.70, 27.55, and 27.00, respectively. More or less similar findings were reported by Yadav *et al.* (2005) and Choudhary and Jat (2004). Thus present results are strongly substantiated.

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Effect of Liquid Formulations on Yield Attributes and Yield of Barley (*Hordeum vulgare* L.)

Govind Mahawar*, P.K. Sharma, Lavinder Singh Mahawar and Manish Koli

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : govindmahawar61@gmail.com

Abstract

Barley (*Hordeum vulgare* L.) is an important *rabi* cereal crop grown throughout the temperate and tropical regions of the world. foliar sprays of Jeevamrit (10%) + Vermiwash (10%) Spray spray recorded the significantly highest total number of tillers, effective tillers, grains per spike, spike length, test weight, seed yield, straw yield, biological yield and harvest index. T₉-Vermiwash (10%) Spray +Jeevamrit (10%) + Panchgavya (10%) recorded significantly the highest seed (4965 kg/ha), straw (6862 kg/ha) and biological yield (11827 kg/ha) among all the treatments.

Key words : Barley, jeevamrit, panchgavya, vermiwash and yield.

Introduction

Barley (*Hordeum vulgare* L.) is an important *rabi* cereal crop grown throughout the temperate and tropical regions of the world. It is a most important cereal crop and is considered as the first cereal domesticated for use by man as food and feed (Potla *et al.*, 2013). Barley belongs to the family *Poaceae* (formerly called *Graminae* or grass family). It is a self-pollinating, diploid species with 14 chromosomes and comprised of 32 species. It assumes the fourth position in total cereal production in the world after barley, rice and maize (FAOSTAT, 2020). Barley is grown on 51.60 million hectares with a production of 157.03 million tonnes, and its productivity is 3043 kg ha⁻¹ in the world (FAOSTAT, 2020). Organic farming aims for human welfare without harming the environment and it follows the principles of ecology, health, fairness and care for all including soil.

To achieve sustainable crop production and soil fertility, the role of organic manures and other nutrient management practices such as use of fermented organic manures viz., panchgavya, jeevamrit, vermiwash, beejamrit, sasyamrit *etc.*, are becoming popular among farmers nowadays.

Keeping above facts in view, the present study was done during *Rabi* season of 2022-23 at research farm, Vivekananda Global University, Jaipur.

Materials and Methods

Experimental site : The experiment was laid out at Agronomy Farm, Vevakananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5' North latitude and 75° 28' East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this

region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this zone is typically semi-arid characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 46°C, while, in winters, it may fall as low as 1.0 °C. The rainfall of this tract varies from 400-500 mm. The mean maximum relative humidity fluctuated from 35 to 69 per cent and mean minimum relative humidity fluctuated from 0 to 46 per cent during the crop season. The mean maximum temperature during the crop growth period of mustard ranged between 20.1 °C to 35.0 °C, while minimum temperature ranged from -0.5 °C to 17 °C during the crop season. The total rainfall received during the crop season was 78.3 mm.

Preparation of liquid manures

Panchgavya : The formulation of panchgavya was prepared in earthen container by mixing cow dung, cow ghee, cow urine, cow milk and cow curd in a proportion through the procedure mentioned below and was placed in a shady and open place. The mouth of earthen pot was kept covered with clean fine cotton cloth for ensuring aeration for fermenting and check common fly on it. The entire concentration is stirred well, using a neem stick twice a day morning and evening. In an earthen container, first mix 7 kg fresh cow dung and 1 kg cow ghee thoroughly and keep it for 3 days. Mix it twice daily (morning/evening) at least for 15 minutes. Add 10 litres cow urine and 10 litres water and mix thoroughly. Keep it for 15 days with regular mixing in morning and evening hours. Add 3 litres cow milk, 2 kg cow curd and also 500 gm jaggery as additive and mix them completely. The experiment was conducted in a Split Plot Design (SPD)

Table-1 : Effect of liquid organic formulations on number of effective tillers, grains per spike, spike length and test weight of barley.

Treatments	Number of effective tillers per plant	Spike length (cm)	Grains per spike	Grain weight spike ⁻¹	Test weight (g)
T ₁ -Control (No Spray)	66.12	6.65	36.16	2.31	33.12
T ₂ -Water Spray	66.71	6.69	36.36	2.32	33.19
T ₃ -Jeevamrit (10%) Spray	75.62	7.65	38.95	2.79	37.92
T ₄ -Panchgavya (10%) Spray	76.47	7.69	39.15	2.80	38.00
T ₅ -Vermi-Vash (10%) Spray	76.82	7.92	39.22	2.81	38.12
T ₆ -Vermiwash (10%) Spray + Panchgavya (10%) Spray	77.24	8.12	39.65	2.84	38.41
T ₇ -Jeevamrit (10%) + Vermiwash (10%) Spray	78.14	8.45	39.71	2.92	39.15
T ₈ -Jeevamrit (10%) + Panchgavya (10%) Spray	78.45	8.69	39.92	3.22	42.21
T ₉ -Vermiwash (10%) Spray +Jeevamrit (10%) + Panchgavya (10%)	79.62	8.77	40.12	3.41	44.14
SEm±	2.92	0.27	0.85	0.27	1.37
CD (P=0.05)	8.74	0.80	2.53	0.80	4.11
CV (%)	6.73	5.90	3.77	6.20	6.20

Table-2 : Effect of liquid organic formulations on grain, straw, biological yield and harvest index of barley.

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
T ₁ -Control (No Spray)	2526	3995	6521	38.74
T ₂ -Water Spray	2594	4098	6692	38.76
T ₃ -Jeevamrit (10%) Spray	3425	5112	8537	40.12
T ₄ -Panchgavya (10%) Spray	3472	5194	8666	40.06
T ₅ -Vermi-Vash (10%) Spray	3645	5464	9109	40.02
T ₆ -Vermiwash (10%) Spray + Panchgavya (10%) Spray	3665	5554	9219	39.75
T ₇ -Jeevamrit (10%) + Vermiwash (10%) Spray	3895	5894	9789	39.79
T ₈ -Jeevamrit (10%) + Panchgavya (10%) Spray	4062	6021	10083	40.29
T ₉ -Vermiwash (10%) Spray +Jeevamrit (10%) + Panchgavya (10%)	4965	6862	11827	41.98
SEm±	148	210	352	1.37
CD (P=0.05)	444	630	1054	4.11
CV (%)	7.16	6.80	6.81	5.94

with three replications for each treatment. the data were statistically analysed as described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means, wherever the 'f' test was found significant at 5 per cent level of probability.

Jeevamrit : Mix cow urine (10 liter) + cow dung (10 kg) + pulses floor (2 kg) + jaggery (2 kg dissolved in 10 litres water) + a handful of soil in a separate container and mix this mixture very well. In a non-metallic barrel of 200 litres capacity, fill water and pour the prepared mixture of cow dung, cow urine, pulses floor, jaggery and soil in the barrel. With the help of wooden stick stir the mixture in the barrel clockwise and anticlockwise. The experiment was conducted in a Randomized Block Design (RBD) with three replications for each treatment. the data were statistically analysed as described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means, wherever

the 'f' test was found significant at 5 per cent level of probability.

Results and Discussion

The results pertaining to total number of tillers, effective tillers, grains per spike, spike length, test weight, seed yield, straw yield, biological yield and harvest index (table-1 and 2) indicated that foliar application of different liquid formulations were significantly better than control and water spray treatment in increasing yield attributes and yield of barley. The result showed that foliar sprays of Jeevamrit (10%) + Vermiwash (10%) Spray recorded the significantly highest total number of tillers, effective tillers, grains per spike, spike length, test weight, seed yield, straw yield, biological yield and harvest index. However, these were found at par with each other and accompanied by rest of the treatments. T₉-Vermiwash (10%) Spray +Jeevamrit (10%) + Panchgavya (10%) recorded significantly the highest seed (4965 kg/ha),

straw (6862 kg/ha) and biological yield (11827 kg/ha) among all the treatments.

Foliar application of 10% Jeevamrit + panchgavya + vermiwash maximized the various yield attributes of barley viz., effective tillers, grains per spike, spike length and test weight. The highest seed, straw and biological yields of barley (4965, 6862 and 11827 kg/ha) were obtained under the treatment of sprays of 10% Jeevamrit + panchgavya + vermiwash which was significantly superior over rest of the treatments. More or less similar findings were reported by Nekar *et al.* (2009), Munji *et al.* (2010), Ali *et al.* (2011) and Patel *et al.*, (2013). Thus present results are strongly substantiated

Acknowledgments

A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Agriculture, faculty members and non-teaching staff of Department of Agriculture, Vivekananda Global University, Jaipur for providing me the necessary help and suggestions during the course of the study.

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Effect of Nitrogen and Nano-Urea Spray Level on Nutrient Content of Wheat (*Triticum aestivum* L.)

Harish Saini*, P.K. Sharma and Rahul Sharma

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : harishsaini4465@gmail.com

Abstract

Field experimentation was conducted during *rabi* season of 2022-23 at Nangal Sumer Singh village in Dausa district of Rajasthan under the supervision of Department of Agriculture, Vivekananda Global University, Jaipur to study the Response of Wheat (*Triticum aestivum* L.) under varying levels of Nitrogen and Nano-Urea Spray. The experiment consisted of 12 treatment combinations comprising four levels of nitrogen (control, 50 per cent RDN, 75 per cent RDN and 100 per cent RDN) with three levels of nano urea spray (control, Nano-Urea Spray @ 1000 ml ha⁻¹ and Nano-Urea Spray @ 2000 ml ha⁻¹). The experiment was laid out in Factorial Randomized Block Design and replicated thrice. 100 per cent RDN recorded significant improvement in NPK content in grain and straw.

Key Words : Wheat, Nitrogen, Nutrient Content and Nano-Urea

Introduction

Wheat (*Triticum aestivum* L.) is an important cereal crop belongs to family "Poaceae" and genus "Triticum". Wheat is an important source of carbohydrates (Shewry and Hey, 2015). Globally, it is the leading source of vegetal protein in human food, having a protein content of about 13 per cent, which is relatively high compared to other major cereals, but relatively low in protein quality for supplying essential amino acids.

In terms of area, India contributes highest wheat cultivated area (31.61 million hectares) in the world while acquired second position with respect to production (109.52 million tonnes) after china with the average productivity of 3.46 tonnes ha⁻¹ (Anonymous, 2021a).

Nitrogen is essential nutrient for plant growth and involved in important synthesis and formation of many important substances and compounds in plant such as amino acids, enzymes, DNA, RNA and chlorophyll. It is responsible for greenness, vigorous growth and overall crop development; therefore it must be available for plants in adequate amounts.

Nano fertilizers have emerged as a promising alternative for ensuring high crop yield while remaining environmentally friendly. There are lots of advantages of nano-fertilizers, like they increase three times in nutrient use efficiency, 55-60 times less requirement to chemical fertilizer, 10-12 time more stress tolerant by the crops, complete bio-source so eco-friendly, 30-35% more nutrient mobilization by the plants, 18-54% improvement in the crop yield.

Materials and Methods

Experimental site : The experiment was laid out at Nangal Sumer Singh village in Dausa district of Rajasthan during *rabi* season of 2022-23. Dausa is situated at 26° 53" North latitude and 76° 19" East longitudes at an altitude of 333 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this location is semi-arid characterized by aridity of the atmosphere and extremity of temperature during both summers (40.6° C) and winters (2.7° C). The average rainfall is 557 mm per annum, which is mostly received during July to September. The sporadic showers during winters are also common, which are probably observed during this period. The standard meteorological weekly data for temperature, relative humidity, total rainfall, rainy days, wind speed, evaporation and bright sunshine hours for the crop seasons are presented in Table 3.1 and graphically represented in Fig. 3.1. There was an average rainfall is 69.8 mm during the cropping seasons. The mean relative humidity fluctuated from 59.0 to 85.0 per cent during the crop season.

A. Nitrogen levels (kg ha ⁻¹)	Symbol used
1. Control	N ₀
2. 50 per cent RDN	N ₁
3. 75 per cent RDN	N ₂
4. 100 per cent RDN	N ₃
B. Nano-Urea Spray	
1. Control	S ₀
2. Nano-Urea Spray @ 1000 ml ha ⁻¹ at 40-45 DAS	S ₁
3. Nano-Urea Spray @2000 ml ha ⁻¹ at 40-45 DAS	S ₂

Table-1 : Effect of nitrogen and nano urea spray on N content in grain and straw of wheat.

Treatments	N content (%)	
	Grain	Straw
Nitrogen levels (kg ha⁻¹)		
N ₀ -Control	1.620	0.465
N ₁ -50 per cent RDN	1.646	0.479
N ₂ -75 per cent RDN	1.651	0.481
N ₃ -100 per cent RDN	1.714	0.500
SEm+	0.020	0.004
CD (P=0.05)	0.057	0.012
Nano urea spray (ML ha⁻¹)		
S ₀ -Control	1.629	0.468
S ₁ -Nano-Urea Spray @ 1000 ml ha ⁻¹	1.647	0.481
S ₂ -Nano-Urea Spray @ 2000 ml ha ⁻¹	1.697	0.495
SEm+	0.017	0.003
CD (P=0.05)	0.049	0.010
OCV (%)	3.54	2.49

Table-2 : Effect of nitrogen and nano urea spray on P content in grain and straw of wheat.

Treatments	P content (%)	
	Grain	Straw
Nitrogen levels (kg ha⁻¹)		
N ₀ -Control	0.320	0.117
N ₁ -50 per cent RDN	0.346	0.124
N ₂ -75 per cent RDN	0.349	0.125
N ₃ -100 per cent RDN	0.369	0.130
SEm+	0.005	0.002
CD (P=0.05)	0.014	0.005
Nano urea spray (ML ha⁻¹)		
S ₀ -Control	0.323	0.118
S ₁ -Nano-Urea Spray @ 1000 ml ha ⁻¹	0.347	0.124
S ₂ -Nano-Urea Spray @ 2000 ml ha ⁻¹	0.367	0.129
SEm+	0.004	0.001
CD (P=0.05)	0.012	0.004
CV (%)	4.14	3.82

Table-3 : Effect of nitrogen and nano urea spray on K content in grain and straw of wheat.

Treatments	K content (%)	
	Grain	Straw
Nitrogen levels (kg ha⁻¹)		
N ₀ -Control	0.435	1.506
N ₁ -50 per cent RDN	0.458	1.599
N ₂ -75 per cent RDN	0.460	1.614
N ₃ -100 per cent RDN	0.487	1.690
SEm+	0.007	0.020
CD (P=0.05)	0.020	0.059
Nano urea spray (ML ha⁻¹)		
S ₀ -Control	0.438	1.515
S ₁ -Nano-Urea Spray @ 1000 ml ha ⁻¹	0.459	1.610
S ₂ -Nano-Urea Spray @ 2000 ml ha ⁻¹	0.483	1.682
SEm+	0.006	0.018
CD (P=0.05)	0.017	0.051
CV (%)	4.55	3.81

Experimental details : The experiment comprised 4 levels of nitrogen and 3 levels of nano-urea spray, thereby making twelve treatment combinations that were laid out in Factorial Randomized Block Design (FRBD) and replicated three times.

Nutrient content (%) : The nitrogen, phosphorus and potassium contents in grain of wheat were estimated at maturity. The grain sample of crop was collected separately as per treatment at harvest. These samples were ground in the grinder after drying in oven at 70°C temperatures for 48 hours. Thus, the ground plant materials passed through 30-mesh sieve, and these materials used for determination of nitrogen, phosphorus and potassium content.

Results and Discussion

Nitrogen content in grain and stover (%)

Effect of nitrogen levels : The increase in N content in grain and straw of wheat due to N₃- 100 per cent RDN was 5.80 per cent in grain and 7.73 per cent in straw over control, respectively.

Effect of nano urea spray : The improvement in N content of wheat by S₂ (%Nano-Urea Spray @ 2000 ml ha⁻¹) was 4.17 and 3.04 per cent and 5.77 and 2.91 per cent in grain and straw over (control (S₀) and S₁ Nano-Urea Spray @ 1000 ml ha⁻¹, respectively.

Phosphorus content in grain and stover

Effect of nitrogen levels : The increase in P content in grain and straw of wheat due to 100 per cent RDN was 15.31 per cent in grain and 11.11 per cent in straw over control, respectively.

Effect of nano urea spray : The improvement in P content of wheat by S₂ (%Nano-Urea Spray @ 2000 ml ha⁻¹) was 13.62 per cent in grain and 5.76 per cent in straw over control, respectively.

Potassium content in grain and stover (%)

Effect of nitrogen levels : The increase in K content in grain and straw of wheat due to 100 per cent RDN the tune of 11.95 and 12.22 per cent in grain and straw over control, respectively.

Effect of nano urea spray : The improvement in K content of wheat by S₂- Nano-Urea Spray @ 1000 ml ha⁻¹ was 10.27 and 5.523 per cent in grain and 11.02 and 7.47 per cent in straw over control, respectively.

Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nanofertilizer which leads to more penetration and uptake of the nutrient and thus results in high nutrient content and

their uptake (Liscano *et al.*, 2000). Significant improvement in the present study is in close agreement with the findings of Burhan and AL-Hassan (2019), Mehta and Bharat (2019 a) and AL-Gym and Al-Asady (2020).

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A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Agriculture, faculty members and non-teaching staff of Department of Agriculture, Vivekananda Global University, Jaipur for providing me the necessary help and suggestions during the course of the study.

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Effect of Varieties and Fertility Levels on Growth Parameter of Dual Purpose Barley

Lavinder Singh Mahawar*, P.K. Sharma, Manish Koli and Govind Mahawar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : mahawarlavindravgu@gmail.com

Abstract

Barley (*Hordeum vulgare* L.) is a valuable crop because it is grown for several purposes such as food and processed food products for human being and feed for cattle and poultry birds. Dual purpose variety RD 2552 attained significantly higher plant height over RD 2577 at 30, 60, 90 days and at harvest after green fodder cutting and harvest by 4.02, 7.25, 2.81 and 6.30 per cent, respectively. Application of 150 per cent RDN significantly increased dry matter over RDN, at 30, 60, 90 DAS and at harvest by 30 DAS, 43.03, 35.53, 20.30 per cent, at 60 DAS 34.99, 30.69, 15.93 per cent, at 90 DAS 17.20, 14.21, 7.88 per cent and at harvest 17.59, 12.68, 4.74 per cent 150 % RDN (90 kg N), 125 % RDN (75 kg N), 100 % RDN (60 kg N) over control, respectively. **Key words** : Barley, variety, plant height, dry matter.

Introduction

Barley (*Hordeum vulgare* L.) is a valuable crop because it is grown for several purposes such as food and processed food products for human being and feed for cattle and poultry birds. Each 100 g of barley grain comprise 10.6 g protein, 2.1 g fat, 64 g carbohydrate, 50 mg calcium, 6.0 mg iron, 31 mg vitamin B1, 0.10 mg vitamin B2 and 50 g folate (kaur *et al.*, 2013).

In Rajasthan, barley was cultivated on 269.7 thousands hectare area during 2020-21 with 939.2 thousand tonne of production at an average productivity status of 3482 kg ha⁻¹ (Anonymous, 2021). Nitrogen application at proper dose has the most important effect in terms of increasing crop production. Farmers use nitrogenous fertilizers indiscriminately without concerning actual soil requirements (Kumar *et al* 2017).

It is established fact that green fodder and grain yield potentials of the dual purpose barley genotypes are realized to the fullest extent when they are grown under optimum agro-climatic environment (Duhan *et al.*, 2009).

Materials and Methods

Experimental site : The experiment was laid out at Agronomy Farm, Vevakananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this zone is typically semi-arid characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 46°C, while, in winters, it may fall as low as 1.0 °C. The rainfall of this

tract varies from 400-500 mm. The mean maximum relative humidity fluctuated from 35 to 69 per cent and mean minimum relative humidity fluctuated from 0 to 46 per cent during the crop season. The mean maximum temperature during the crop growth period of mustard ranged between 20.1 °C to 35.0 °C, while minimum temperature ranged from -0.5 °C to 17 °C during the crop season. The total rainfall received during the crop season was 78.3 mm.

Experimental details

A Varieties	Symbol used
1. RD 2552	V ₀
2. RD 2715	V ₁
B. Nitrogen levels	
1. 75 % RDN (45 kg N)	F ₁
2. 100 % RDN (60 kg N)	F ₂
3. 125 % RDN (75 kg N)	F ₃
4. 150 % RDN (90 kg N)	F ₄

Growth Characters

Plant height : The plant height was recorded at time of green fodder cutting and at 30, 60 and 90 days after cutting of green fodder and at harvest.

Dry matter accumulation : The observation of dry matter accumulation was recorded at time of green fodder cutting and periodically at 30, 45, 60 days after cutting of green fodder and at harvest.

The experiment was conducted in a Randomized Block Design (RBD) with three replications for each treatment. the data were statistically analysed as described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of

Table-1 : Effect of varieties and fertility levels on plant height of dual purpose barley.

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Varieties				
RD-2552	30.10	35.85	42.37	66.68
RD-2517	28.89	33.25	41.18	62.48
SEm+	0.65	0.72	0.88	1.31
CD (P=0.05)	1.89	2.08	2.54	3.78
Nitrogen level				
75% RDN (45 kg N)	24.10	29.35	36.74	59.84
100% RDN (60 kg N)	28.34	32.90	40.50	61.63
125% RDN (75 kg N)	32.34	37.47	44.38	67.78
150% RDN (90 kg N)	33.20	38.48	45.48	69.06
SEm+	0.92	1.02	1.24	1.85
CD (P=0.05)	2.67	2.94	3.59	5.35
CV (%)	8.64	8.13	8.21	7.90

Table-2 : Effect of varieties and fertility levels on dry matter accumulation (g m^{-2}) of dual purpose barley.

Treatments	Dry matter accumulation (g m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest
Varieties				
RD-2552	16.81	26.71	37.40	56.74
RD-2517	16.11	24.21	33.10	51.46
SEm+	0.37	0.53	0.70	1.08
CD (P=0.05)	1.06	1.53	2.01	3.13
Nitrogen level				
75% RDN (45 kg N)	13.20	21.15	32.10	49.75
100% RDN (60 kg N)	15.88	24.52	34.63	52.11
125% RDN (75 kg N)	17.89	27.63	36.66	56.05
150% RDN (90 kg N)	18.88	28.54	37.62	58.49
SEm+	0.52	0.75	0.99	1.53
CD (P=0.05)	1.50	2.16	2.84	4.43
CV (%)	8.70	8.09	7.70	7.81

treatment means, wherever the 'f' test was found significant at 5 per cent level of probability.

Results and Discussion

Plant height

Varieties : It is apparent from data (Table-1). Dual purpose variety RD 2552 attained significantly higher plant height over RD 2577 at 30, 60, 90 days and at harvest after green fodder cutting and harvest by 4.02, 7.25, 2.81 and 6.30 per cent, respectively.

Nitrogen levels : It is apparent from data (Table-1) that application of 150 per cent RDN significantly increased plant height over RDN at 30, 60, 90 days and harvest, after green fodder cutting and at harvest. The magnitude of increase was at 30 days 37.76, 34.19, 17.59 per cent at 60 days, 31.07, 27.63, 12.10 per cent, at 90 days 23.82, 20.82, 10.23 per cent and at harvest 15.41, 13.27 and 2.99 per cent, 150 % RDN (90 kg N), 125 % RDN (75 kg

N), 100 % RDN (60 kg N) over control, respectively. Further increase in nitrogen level to 150% RDN though had effect but failed to record statistical significance at successive growth stage and at harvest.

Dry matter

Varieties : It is apparent from data (Table-2). After dual purpose varieties differed significantly with respect to dry matter accumulation recorded at successive growth stages and at harvest. The variety RD 2552 produced significantly higher dry matter 0.5 m^{-1} row length over RD 2552. The magnitude of increase was 4.16, 9.36, 11.50 and 9.31 per cent, respectively, at 30, 60, 90 DAS and at harvest.

Nitrogen levels : It is apparent from data (Table-2) . Application of 150 per cent RDN significantly increased dry matter over RDN, at 30, 60, 90 DAS and at harvest by 30 DAS, 43.03, 35.53, 20.30 per cent, at 60 DAS 34.99, 30.69, 15.93 per cent, at 90 DAS 17.20, 14.21, 7.88 per

cent and at harvest 17.59, 12.68, 4.74 per cent 150 % RDN (90 kg N), 125 % RDN (75 kg N), 100 % RDN (60 kg N) over control, respectively. Further increase in nitrogen level from 150 per cent RDN (90 kg N) to 125% RDN (75 kg N) improved dry matter significantly at 30, 60, 90 DAS and at harvest.

The results showed that between dual purposes, RD 2552 grew taller, produced higher tillers, dry matter. results are in close conformity with the findings of several previous researchers (Choudhary, 2018 and Nirmala *et al.*, 2017).

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A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Agriculture, faculty members and non-teaching staff of Department of Agriculture, Vivekananda Global University, Jaipur for providing me the necessary help and suggestions during the course of the study.

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Effect of Sulphur and Zinc on Nutrient Content of Indian Mustard (*Brassica juncea* L.)

Lavlesh Sharma*, P.K. Sharma and Sunil Kumar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : lavleshsharma92@gmail.com

Abstract

A field experiment was conducted at Department of Agronomy, Vivekananda Global University, Jaipur during *rabi* season 2022-2023, to study the "Effect of Sulphur and Zinc on Growth, Yield and Quality of Indian Mustard (*Brassica juncea* L.)". The experiment was laid out according to factorial randomized block design with three replications. The treatments consisting of three level of sulphur (Control, 20 kg/ha and 40 kg/ha) and three Zinc level (Zn 2.5 kg/ha, Zn 5.0 kg/ha and Zn 7.5 kg/ha) were applied to the mustard. Nitrogen, phosphorus and potassium content in seed and stover of mustard was significantly increased with the application of sulphur level 40 kg.

Key Words : Indian mustard, sulphur, zinc and nutrient content.

Introduction

Rapeseed and mustard belong to family Cruciferae, which is grown in northern India comprising traditionally grown indigenous species namely Indian mustard (*Brassica juncea*), brown sarson (*Brassica campestris* var. brown Sarson), Yellow sarson (*Brassica campestris* var. yellow Sarson), Toria (*Brassica campestris* var. toria) and Taramira (*Eruca sativa*) along with nontraditional species like Gobhi sarson (*Brassica napus*), White mustard (*Brassica alba*) and Ethiopian mustard (*Brassica carinata*). It is the most important group of *Rabi* oilseed crop and contributes a major share to the vegetable fat.

In India the area under mustard crop is 6.86 million ha producing about 9.12 million tons of seeds with an average productivity of 1331 kg ha⁻¹. Area under cultivation in Rajasthan is 3.08 million ha, having production of 4.20 million tones and productivity of 1366 kg ha⁻¹ (Anonymous, 2021).

Sulphur and zinc are most vital nutrients for growth and development oil seeds. Sulphur is considered to be the fourth important essential nutrient after nitrogen, phosphorus and potassium for the plant growth. Sulphur performs many physiological functions like synthesis of cysteine, methionine, chlorophyll and oil content of oil seed crops.

Materials and Methods

Experimental site : The experiment was carried out at the Research Farm, Vivekananda Global University, Jaipur (Rajasthan) India. Geographically Rajasthan Agricultural Research Institute is situated at 75° 47' East longitudes, at 26° 51' North latitude and at altitude of 393 m above mean sea level (AMSL) in Jaipur city of Rajasthan. According to

NARP, this region falls under Agro-climatic zone IIIa (Semi-arid eastern plain zone) of Rajasthan

Climate and weather conditions : The climate of this location is semi-arid characterized by aridity of the atmosphere and extremity of temperature during both summers (40.6° C) and winters (2.7° C). The average rainfall is 543.5 mm per annum, which is mostly received during July to September. The sporadic showers during winters are also common, which are probably observed during this period.

Experimental details : The present experiment consisting of different treatment combinations was laid out in Randomized Block Design.

Treatments	Symbol
Sulphur levels (Kg ha⁻¹)	
Control	S ₀
20 Kg Sulphur	S ₁
40 Kg Sulphur	S ₂
Zinc levels (kg ha⁻¹)	
2.5 Kg Zn	Zn ₁
5.0 Kg Zn	Zn ₂
7.5 Kg Zn	Zn ₃

Nutrient content (%) : The nitrogen, phosphorus and potassium contents in grain of wheat were estimated at maturity. The grain sample of crop was collected separately as per treatment at harvest. These samples were ground in the grinder after drying in oven at 70°C temperatures for 48 hours. Thus, the ground plant materials passed through 30-mesh sieve, and these materials used for determination of nitrogen, phosphorus and potassium content.

Table-1 : Effect of sulphur and zinc on N content in seed and straw of mustard.

Treatments	N content (%)	
	Seed	Straw
Sulphur level (kg ha⁻¹)		
S ₀ -Control	2.45	0.437
S ₁ -20 kg	2.93	0.484
S ₂ -40 kg	2.97	0.490
SEm±	0.04	0.009
CD (P=0.05)	0.13	0.026
Zinc level (kg ha⁻¹)		
Zn ₁ -2.5 kg/ha	2.39	0.413
Zn ₂ - 5.0 kg/ha	2.81	0.479
Zn ₃ -7.5 kg/ha	3.15	0.519
SEm±	0.04	0.009
CD (P=0.05)	0.13	0.026
CV (%)	4.83	5.65

Table-2 : Effect of sulphur and zinc on P content in seed and straw of mustard.

Treatments	P content (%)	
	Seed	Straw
Sulphur level (kg ha⁻¹)		
S ₀ -Control	0.406	0.219
S ₁ -20 kg	0.470	0.259
S ₂ -40 kg	0.479	0.266
SEm±	0.008	0.006
CD (P=0.05)	0.024	0.016
Zinc level (kg ha⁻¹)		
Zn ₁ -2.5 kg/ha	0.385	0.210
Zn ₂ - 5.0 kg/ha	0.454	0.251
Zn ₃ -7.5 kg/ha	0.515	0.283
SEm±	0.008	0.006
CD (P=0.05)	0.024	0.016
CV (%)	5.60	6.91

Table-3 : Effect of sulphur and zinc on K content in seed and straw of mustard.

Treatments	K content (%)	
	Seed	Straw
Sulphur level (kg ha⁻¹)		
S ₀ -Control	0.480	1.180
S ₁ -20 kg	0.564	1.339
S ₂ -40 kg	0.571	1.351
SEm±	0.010	0.026
CD (P=0.05)	0.02	0.075
Zinc level (kg ha⁻¹)		
Zn ₁ -2.5 kg/ha	0.459	1.110
Zn ₂ -5.0 kg/ha	0.555	1.320
Zn ₃ -7.5 kg/ha	0.601	1.440
SEm±	0.010	0.026
CD (P=0.05)	0.029	0.075
CV (%)	5.69	6.04

Results and Discussion

Nitrogen content in grain and stover (%)

Effect of Sulphur : Nitrogen content in seed and straw 20 kg/ha (S₁), registered significantly highest nitrogen content in seed (2.93%) and stover (0.484%) as compared to control (S₀) (2.45%) in seed and (0.437 %) in straw.

Effect of Zinc : The nitrogen content in seed and stover increased significantly up to application of zinc @ 7.5 kg/ha over zinc @ 5.0 kg /ha and zinc @ 2.5 kg. The magnitude of increase in nitrogen content in seed under zinc at 7.5 kg /ha was to the tune of 25.67 and 8.37 per cent over zinc @ 2.5 kg and zinc @ 5.0 kg/ha, respectively.

Phosphorus content in grain and stover (%)

Effect of Sulphur : The phosphorus content in seed and stover of mustard. 20 kg/ha (S₁) recorded significantly higher phosphorus content in seed and stover of mustard. Phosphorus content in seed and stover of mustard increased due to 20 kg/ha (S₁) to the tune of 15.76 per cent in seed and 18.26 per cent in straw over control (S₀), respectively.

Effect of Zinc : Application of zinc @ 7.5 kg /ha increased the phosphorus content in seed and stover by 33.77 and 13.44 per cent in seed and 34.76 and 12.75 per cent in stover over zinc @ 2.5 kg (Zn₁) and zinc @ at 5.0 kg/ha (Zn₁), respectively.

Potassium content in grain and stover (%)

Effect of Sulphur : Application of S at 20 kg/ha (S₁) recorded 17.50 per cent in seed and 13.47 per cent in stover increase over control (S₀).

Effect of Zinc : The magnitude of increase in potassium content in seed and stover of mustard due to zinc @ 7.5 kg /ha was 30.94 per cent in seed and 8.29 per cent in stover over zinc @ 2.5 kg and zinc, respectively.

The maximum values of N, P and K content in seed and stover was recorded with the application of sulphur 20 kg/ha (S₁). These results are in close conformity with the findings of Shukla *et al.* (2002), Tripathi *et al.* (2010), Virendra *et al* 2008 and Verma *et al* 2018.

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A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Agriculture, faculty members and non-teaching staff of Department of Agriculture, Vivekananda Global University, Jaipur for providing me

the necessary help and suggestions during the course of the study.

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Effect of Varieties and Fertility Levels on Nutrient Content of Wheat (*Triticum aestivum* L.)

Manish Koli*, P.K. Sharma, Lavinder Singh Mahawar and Govind Mahawar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding author Email : kolimanishvgu@gmail.com

Abstract

Wheat is an important staple food that feeds 20 per cent of the world's population. In India, it is a staple food for millions of people especially in northern and north-western parts of the country. Higher seed rate and closer row spacing in wheat is adopted under late sown conditions to compensate for the tiller count and shortened growing period of crops. wheat variety Raj. 4238 produced significantly highest nutrient content seed and straw with 22.5 cm + 125 kg/ha, spacing and seed rate, respectively.

Key words : Wheat, seed rate, variety, nutrient content.

Introduction

Wheat is an important staple food that feeds 20 per cent of the world's population. In India, it is a staple food for millions of people especially in northern and north-western parts of the country. Globally, India ranks second after China in the area and production of wheat and accounts for 12.5 per cent share of the total wheat production of the world. In India, wheat was cultivated on 31.61 million ha (mha) area with a production of 109.52 million tonne (mt) and productivity of 3464 kg/ha during 2020-21. Rajasthan ranked fourth in area (3.0 mha) and fifth in production (11.04 mt) during 2020-21 (Anonymous 2021).

Good agronomic practices are vital for crop establishment and higher yield. Optimum seed rate along with nutrient management is an essential pre-requisite for higher crop stand and thus the higher yield, and when coupled with optimum row spacing, it further improves crop establishment and yield.

Higher seed rate and closer row spacing in wheat is adopted under late sown conditions to compensate for the tiller count and shortened growing period of crops (Reddy and Ramu, 2016). In addition to this, higher seed rate to the tune of 20-30 per cent and narrow row spacing also result in higher yield due to higher crop stand and better weed control owed to lower crop weed competition. Higher crop stand also assures its higher access to soil nutrients and moisture due to the uniform distribution of roots.

Materials and Methods

Experimental site : The experiment was laid out at Agronomy Farm, Vevakananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of

427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this zone is typically semi-arid characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 46°C, while, in winters, it may fall as low as 1.0 °C. The rainfall of this tract varies from 400-500 mm. The mean maximum relative humidity fluctuated from 35 to 69 per cent and mean minimum relative humidity fluctuated from 0 to 46 per cent during the crop season. The mean maximum temperature during the crop growth period of mustard ranged between 20.1 °C to 35.0 °C, while minimum temperature ranged from -0.5 °C to 17 °C during the crop season. The total rainfall received during the crop season was 78.3 mm.

Experimental details

A. Main Plot	Varieties	Symbol used
1. Raj. 4238		V ₁
2. Raj. 4037		V ₂
B. Sub Plot	Row Spacing and Seed Rate	
1. 20 cm + 100 kg/ha		S ₁
2. 20 cm + 125 kg/ha		S ₂
3. 22.5 cm + 100 kg/ha		S ₃
4. 22.5 cm + 125 kg/ha		S ₄

Nutrient concentration (%) in grain and straw : The grain and straw samples collected at threshing from each plot were air dried and then ground to a fine powder for estimation of nitrogen and phosphorus concentration by standard methods.

Table-1 : Effect of varieties and fertility levels on nitrogen content of wheat.

Treatments	Nitrogen content (%)	
	Seed	Straw
Varieties		
V ₁ -Raj. 4238	1.690	0.301
V ₂ -Raj. 4037	1.720	0.314
SEm±	0.035	0.006
CD (P=0.05)	0.101	0.019
Row spacing		
S ₁ -20 cm + 100 kg/ha	1.705	0.294
S ₂ -20 cm + 125 kg/ha)	1.665	0.303
S ₃ -22.5 cm + 100 kg/ha	1.715	0.312
S ₄ -22.5 cm + 125 kg/ha	1.735	0.321
SEm±	0.049	0.009
CD (P=0.05)	0.142	0.027
CV (%)	7.960	8.227

Table-2 : Effect of varieties and fertility levels on phosphorus content of wheat.

Treatments	Phosphorus content (%)	
	Seed	Straw
Varieties		
RD-2552	0.421	0.202
RD-2517	0.009	0.214
SEm±	0.025	0.004
CD (P=0.05)		0.013
Nitrogen level	0.389	
75 % RDN (45 kg N)	0.409	0.199
100 % RDN (60 kg N)	0.420	0.208
125 % RDN (75 kg N)	0.424	0.208
150 % RDN (90 kg N)	0.012	0.217
SEm±	0.036	0.006
CD (P=0.05)	8.258	0.018
CV (%)	0.421	8.299

Table-3 : Effect of varieties and fertility levels on potassium content of wheat.

Treatments	Potassium content (%)	
	Seed	Straw
Varieties		
RD-2552	0.495	1.530
RD-2517	0.501	1.542
SEm±	0.010	0.031
CD (P=0.05)	0.029	0.090
Nitrogen level		
75 % RDN (45 kg N)	0.511	1.541
100 % RDN (60 kg N)	0.490	1.551
125 % RDN (75 kg N)	0.490	1.531
150 % RDN (90 kg N)	0.501	1.521
SEm±	0.014	0.044
CD (P=0.05)	0.041	0.127
CV (%)	7.858	7.870

The experiment was conducted in a Split Plot Design (SPD) with three replications for each treatment. the data were statistically analysed as described by Panse and Sukhatme (1985). The critical differences were calculated to assess the significance of treatment means, wherever the 'f' test was found significant at 5 per cent level of probability.

Results and Discussion

Nitrogen content in seed and straw

Varieties : A perusal of data (Table-1) reveals that there was a significant increase in nitrogen content in grain and stover performance wheat variety Raj. 4238 produced significantly highest seed of 1.72 per cent and straw (0.314 per cent) which was significantly higher by seed (1.78 per cent) and straw (4.32 per cent) over variety Raj. 4037.

Row spacing : It is evident from data (Table-1) that spacing involving combination of various spacing significantly increased nitrogen content in seed and straw. Thus when compared to nitrogen content in seed and straw of S₄ (22.5 cm + 125 kg/ha) which was at par with S₃-22.5 cm + 100 kg/ha) and S₂-20 cm + 125 kg/ha) realized under unfertilized condition, the crop fertilized with recommended dose of S₄ (22.5 cm + 125 kg/ha) and S₃-22.5 cm + 100 kg/ha), S₁-20 cm + 100 kg/ha with the tune of 4.19, 2.99 per cent and 2.40 per cent over S₂-20 cm + 125 kg/ha N) nitrogen content in straw by 9.38, 6.25 and 3.13, over (S₁-20 cm + 100 kg/ha, respectively.

Phosphorus content in seed and straw

Varieties : A perusal of data (Table-2) reveals that there was a significant increase in phosphorus content in seed and stover performance of wheat variety Raj. 4238 produced significantly highest seed of (0.421%) and straw (0.060%) which was significantly higher by seed (5.25 per cent) and straw (5.94 per cent) over variety Raj. 4037, respectively.

Row spacing : It is evident from data (Table-2) that spacing involving combination of various spacing significantly increased phosphorus content in seed and straw of S₄ (22.5 cm + 125 kg/ha), S₃-22.5 cm + 100 kg/ha) and S₂-20 cm + 125 kg/ha) with the tune of 8.97, 3.66 and 0.95 per cent and 9.52, 4.55 and 4.55 per cent, over (S₁-20 cm + 100 kg/ha), respectively.

Potassium content in seed and straw

Varieties : A perusal of data (Table-3) reveals that there was a significant increase in potassium content in seed and stover performance wheat variety Raj. 4238 produced significantly highest seed of (0.51%) and straw (1.542%) which was significantly higher by seed (1.21 per cent) and straw (0.78 per cent) over variety Raj. 4037, respectively.

Row spacing : It is evident from data (Table-3) that spacing involving combination of various spacing significantly increased potassium content in seed and straw of S₁-20 cm + 100 kg/ha and S₄ (22.5 cm + 125 kg/ha), with the tune of 4.08 and 2.04 per cent and 1.29 and 1.94 per cent over S₂-20 cm + 125 kg/ha N) and S₃-22.5 cm + 100 kg/ha), respectively.

Varieties had significant effect on nutrient content of grain and straw. Maximum nutrient content was observed under variety Raj. 4238. 22.5 cm + 125 kg/ha row spacing registered significant increase in nutrient content in grain and straw. More or less similar findings were reported by Kaur *et al.* 2015; Gill *et al.*, 2009 and Singh *et al.* 2010. Thus present results are strongly substantiated

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A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Agriculture, faculty members and

non-teaching staff of Department of Agriculture, Vivekananda Global University, Jaipur for providing me the necessary help and suggestions during the course of the study.

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Effect of FYM and Nano Urea Spray on Nutrient Uptake of Wheat (*Triticum aestivum* L.)

Omveer Gurjar*, P.K. Sharma and Sahil Budania

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : omveer3691@gmail.com

Abstract

A field experimentation was conducted at carried out during *rabi* season of the year 2022-23 at research farm, Vivekananda Global University, Jaipur. The objectives were to study the effect of FYM and nano urea spray on productivity and quality of wheat. The experiment consisted of 12 treatment combinations comprising four levels of FYM (control, FYM @ 5 t/ha, FYM @ 10 t/ha and FYM @ 15 t/ha) with three levels of nano urea (control, one spray of nano urea @ 4 ml/l at tillering and two spray of nano urea @ 4 ml/l at tillering and pod formation). The experiment was laid out in Factorial Randomized Block Design and replicated thrice. FYM @ 15 t/ha recorded significant improvement NPK uptake in grain and straw. Foliar application of nano urea upto N₂ (two spray of nano urea @ 4 ml/l at tillering and pod formation) significantly increased NPK uptake in grain and straw.

Key Word : Wheat, FYM, nano urea and nutrient uptake.

Introduction

Wheat [*Triticum aestivum* (L.)] is the most important widely cultivated staple food crop of world due to its adaptability under diversified climatic conditions. Wheat play a major role towards meeting 40 % of world global food demand of world population and act as a boon for mankind to provide half of the dietary protein as well as more than half of the calories (Meena *et al.*, 2017).

India contributes highest wheat cultivated area (31.45 million hectares) in the world while acquired second position with respect to production (107.59 million tonnes) after china with the average productivity of 3.42 tonnes ha⁻¹ (Anonymous, 2020a).

In Rajasthan, the crop covers an area of 3.49 million hectares and production of 13.88 million tonnes with an average productivity of 3.97 tonnes ha⁻¹ (Anonymous, 2020b).

Nano-fertilizers are a new concept of nutrient management in crop and it is in its belonging stage there is a great thrust area in agriculture for sustainable crop improvement with major importance of nano-nitrogen. Nano fertilizers are important because they are environmentally friendly and critical to promote sustainable agricultural development.

In order to evaluate response of different nutrients management practices along with water management practices should be need to study as a way of addressing the nutrient deficiencies with suitable irrigation level which subsequently increase the nutrient use efficiency as well as water use efficiency and give sustainable yield of wheat.

Materials and Methods

Experimental site : The experiment was laid out at Research Farm, Vevakananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs/day.

Experimental details : The experiment comprised 4 levels of FYM and 3 levels of nano urea spray, thereby making twelve treatment combinations that were laid out in Factorial Randomized Block Design (FRBD) and replicated three times.

S.No.	Treatments	Symbols
A. FYM levels		
1.	Control	F ₀
2.	FYM @ 5 t/ha	F ₅
3.	FYM @ 10 t/ha	F ₁₀
4.	FYM @ 15 t/ha	F ₁₅
B. Spray of nano urea		
1.	Control	N ₀
2.	One spray of Nano urea @ 4 ml/l at tillering stage	N ₁
3.	Two spray of Nano urea @ 4 ml/l at tillering and pod formation stage	N ₂

Nutrient uptake (kg/ha) : The total uptake of nitrogen and phosphorus in grain and straw was calculated by using following formula :

$$\text{Total uptake of N/P/K} = \frac{\left(\frac{\text{Per cent N/P/K concentration in grain}}{100} \times \text{Grain yield (kg/ha)} \right) + \left(\frac{\text{Per cent N/P/K concentration in straw}}{100} \times \text{Straw yield (kg/ha)} \right)}{100}$$

Results and Discussion

Nitrogen uptake

FYM levels : The increase in N uptake in grain and straw of wheat due to FYM @ 15 t/ha was 49.34 per cent in grain and 35.16 per cent in straw over control, respectively. They also increase in N uptake in grain and straw of wheat due to FYM @ 5 t/ha and FYM @ 10 t/ha was 19.03, 23.53 per cent in grain and 18.54, 12.99 per cent in straw over control, respectively

Spray of nano urea : The improvement in N uptake of wheat by N₂ (two spray of nano urea @ 4 ml/l at tillering)

was 36.36 and 11.79 per cent in grain and 25.43 and 11.30 per cent in straw over control, respectively.

Phosphorus uptake

FYM levels : The increase in P uptake in grain and straw of wheat due to FYM @ 15 t/ha was 62.81 per cent in grain and 39.61 per cent in straw over control, respectively.

Spray of nano urea : The improvement in P uptake of wheat by N₂ (two spray of nano urea @ 4 ml/l at tillering and pod formation stage) was 48.74 and 14.73 per cent and 29.62 and 12.52 per cent in grain and straw over control, respectively.

Potassium uptake

FYM levels : The increase in K uptake in grain and straw of wheat due to FYM @ 15 t/ha was 58.09 per cent in grain and 40.96 per cent in grain and straw over control, respectively.

Hydrogel

Spray of nano urea : The improvement in K uptake of wheat by N₂ (two spray of nano urea @ 4 ml/l at tillering and pod formation stage) was 44.28, 14.15 per cent and 31.67, 14.01 per cent in grain and straw over control, respectively.

Treatment with FYM @ 15 t/ha fetched significantly higher nitrogen, phosphorus and potassium uptake in grain and straw over rest of the treatments. Similar results were reported by Yadav (2001), Kumawat (2003), Singh and Singh (2022), Singh *et al.* (2013) and Ram *et al.* (2014).

Table-1 : Effect of FYM and Nano Urea on nitrogen uptake of wheat.

Treatments	N uptake (kg/ha)	
	Grain	Straw
FYM levels		
F ₀ -Control	54.18	24.32
F ₅ -FYM @ 5.0 t/ha	64.49	27.73
F ₁₀ -FYM @ 10 t/ha	66.93	29.09
F ₁₅ -FYM @ 15 t/ha	80.91	32.87
SE _m ±	1.94	0.79
CD (P=0.05)	5.60	2.28
Spray of Nano urea		
N ₀ -Cocontrol	55.78	25.29
N ₀ -One spray of Nano urea @ 4 ml/l at tillering stage	68.04	28.50
N ₀ -Twospray of Nano urea @ 4 ml/l at tillering and pod formation stage	76.06	31.72
SE _m ±	1.68	0.68
CD (P=0.05)	4.85	1.97
CV (%)	8.73	8.31

Table-2 : Effect of fertilizer and hydrogel on phosphorus uptake of wheat.

Treatments	P uptake (kg/ha)	
	Grain	Straw
FYM levels		
F ₀ -Control	10.73	6.11
F ₅ -FYM @ 5.0 t/ha	13.60	7.16
F ₁₀ -FYM @ 10 t/ha	14.19	7.54
F ₁₅ -FYM @ 15 t/ha	17.47	8.53
SEm±	0.39	0.20
CD (P=0.05)	1.12	0.56
Spray of Nano urea		
N ₀ -Coontrol	11.10	6.38
N ₀ -One spray of Nano urea @ 4 ml/l at tillering stage	14.39	7.35
N ₀ -Twospray of Nano urea @ 4 ml/l at tillering and pod formation stage	16.51	8.27
SEm±	0.34	0.17
CD (P=0.05)	0.97	0.49
CV (%)	8.30	7.98

Table-3 : Effect of FYM and Nano Urea on nitrogen uptake of wheat.

Treatments	K uptake (kg/ha)	
	Grain	Straw
FYM levels		
F ₀ -Control	14.58	78.88
F ₅ -FYM @ 5.0 t/ha	17.99	92.69
F ₁₀ -FYM @ 10 t/ha	18.70	97.74
F ₁₅ -FYM @ 15 t/ha	23.05	111.19
SEm±	0.57	2.84
CD (P=0.05)	1.65	8.19
Spray of Nano urea		
N ₀ -Coontrol	15.04	81.96
N ₀ -One spray of Nano urea @ 4 ml/l at tillering stage	19.01	95.50
N ₀ -Twospray of Nano urea @ 4 ml/l at tillering and pod formation stage	21.70	107.92
SEm±	0.50	2.46
CD (P=0.05)	1.43	7.09
CV (%)	9.25	8.95

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Effect of liquid organic formulation on growth parameters of wheat (*Triticum aestivum* L.)

Piyush Jain*, P.K. Sharma and Manish Koli

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : jpiyush428@gmail.com

Abstract

A field experimentation was conducted at Agronomy farm, Vivekananda Global University, Jaipur district of Rajasthan during *rabi* season of 2022-23. The experiment consisted of 9 liquid organic formulations spray treatments viz., T1-control (no spray), T2-water spray, T3-jeepamrit spray (10%), T4-panchgavya (10%), T5-vermiwash spray (10%), T6-jeepamrit (10%) + panchgavya spray (10%), T7-jeepamrit spray (10%) + vermiwash spray (10%), T8 - panchgavya (10%) + vermiwash spray (10%), T9-Jeevamrit spray (10%)+ Panchgavya spray (10%) + vermiwash spray (10%) that were laid out in a Randomized Block Design and replicated thrice. Wheat variety Raj- 4238 was sown on 15th November, 2022 in the rows spaced 20 cm apart. Foliar spray of Jeevamrit spray (10%) + Panchgavya spray (10%) + vermiwash spray (10%) was the most superior treatment in improving all the growth attributes viz., plant height, dry matter accumulation/m row length,

Introduction

Wheat [*Triticum aestivum* (L.)] is the most important widely cultivated staple food crop of world due to its adaptability under diversified climatic conditions. Wheat play a major role towards meeting 40 % of world global food demand of world population and act as a boon for mankind to provide half of the dietary protein as well as more than half of the calories (Meena *et al.*, 2017). At present senerario, wheat covered 31.61 M ha area and nearly 109.52 Mt productions with 3.46 tonnes productivity (Anonymous, 2021a).

Organic farming aims for human welfare without harming the environment and it follows the principles of ecology, health, fairness and care for all including soil. The modern concept of organic farming involves the science, innovation and tradition.

The role of organic manures and other nutrient management practices such as use of fermented organic formulation viz., panchgavya, jeevamrit, vermiwash, beejamrit, sasyamrit *etc.*, are becoming popular among farmers nowadays. The plant can absorb nutrients about 20 times faster through the leaves than applied through the soil; therefore, liquids are helpful to overcome temporary nutrient shortages.

As wheat is a very important food crop and hence organic production of this crop using such fermented organic formulation and other input may be a good effort towards sustainable crop production and maintaining quality of produce. These formulations are generally used as foliar spray or soil application with irrigation water.

Materials and Methods

Experimental site : The experiment was laid out at

Agronomy Farm, Vevakananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this zone is typically semi-arid characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 46°C, while, in winters, it may fall as low as 1.0 °C. The rainfall of this tract varies form 400-500 mm. The mean maximum relative humidity fluctuated from 35 to 69 per cent and mean minimum relative humidity fluctuated from 0 to 46 per cent during the crop season. The mean maximum temperature during the crop growth period of mustard ranged between 20.1 °C to 35.0 °C, while minimum temperature ranged from -0.5 °C to 17 °C during the crop season. The total rainfall received during the crop season was 78.3 mm.

Experimental details : The experiment consisting of 9 treatment and was carried out in Randomized Block Design (RBD).

S.No.	Treatments	Symbols
1.	Control (No Spray)	T ₁
2.	Water Spray	T ₂
3.	Jeevamrit (10%) Spray	T ₃
4.	Panchgavya (10%) Spray	T ₄
5.	Vermiwash (10%) Spray	T ₅
6.	Jeevamrit (10%) + Panchgavya (10%) Spray	T ₆
7.	Jeevamrit (10%) + Vermiwash (10%) Spray	T ₇
8.	Panchgavya (10%) + Vermiwash (10%) Spray	T ₈
9.	Jeevamrit (10%) + Panchgavya (10%)+Vermiwash (10%)Spray	T ₉

Table-1 : Effect of liquid organic formulations on plant height at different stages.

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T ₁ - Control	19.10	35.15	67.24	80.36
T ₂ - Water spray	19.15	35.32	68.65	80.96
T ₃ - Jeevaamrit (10%) spray	20.01	40.05	75.62	92.42
T ₄ - Panchgavya (10%) spray	20.12	40.29	76.14	93.11
T ₅ - Vermiwash (10%) spray	20.35	40.33	76.95	93.65
T ₆ - Jeevamrit (10%) + Panchgavya (10%) spray	20.69	43.12	79.00	94.00
T ₇ - Jeevamrit (10%) + vermiwash (10%) spray	20.75	43.69	79.62	94.25
T ₈ - Panchgavya (10%) + vermiwash (10%) spray	20.88	43.89	80.19	94.39
T ₉ - Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray	21.05	44.45	82.14	98.97
SEm+	0.85	1.56	2.25	3.79
CD (P=0.05)	NS	4.69	6.75	11.37
CV (%)	7.91	6.65	5.12	7.19

Table-2 : Effect of liquid organic formulations on dry matter accumulation at different stages of wheat.

Treatments	Dry matter accumulation (g/ m row length)			
	30 DAS	60 DAS	90 DAS	At harvest
T ₁ - Control	15.62	48.28	135.62	162.25
T ₂ - Water spray	15.77	49.10	136.98	165.22
T ₃ - Jeevaamrit (10%) spray	16.12	55.14	176.62	195.62
T ₄ - Panchgavya (10%) spray	16.19	55.92	180.62	202.45
T ₅ - Vermiwash (10%) spray	16.35	56.64	182.63	210.63
T ₆ - Jeevamrit (10%) + Panchgavya (10%) spray	16.49	57.00	183.14	211.58
T ₇ - Jeevamrit (10%) + vermiwash (10%) spray	16.55	57.92	191.63	220.63
T ₈ - Panchgavya (10%) + vermiwash (10%) spray	16.82	60.24	197.24	232.47
T ₉ - Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray	17.10	62.99	210.44	245.87
SEm+	0.91	1.92	7.23	8.33
CD (P=0.05)	NS	5.76	21.67	24.98
CV (%)	8.85	5.96	7.06	7.03

Pant height : The periodical plant height at 30, 60, 90 DAS and at harvest was measured from the ground level to the top of the main shoot of the selected five plants from each net plot. Average values for each plot at each stage were computed and recorded.

Dry matter accumulation : The periodical change in dry matter accumulation at 30, 60, 90 DAS and at harvest was recorded by collecting whole plant samples from randomly selected observational rows of each plot in 0.5 m running length of row. These samples were dried in sunlight for 2-3 days and finally dried in an oven at 70°C till a constant weight was obtained. Thereafter, the samples were weighed for estimating total dry matter accumulation and their average was taken as dry matter accumulation and expressed in gram.

Results and Discussion

Plant height : Foliar application of T₉ (Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray) recorded

the maximum plant height at 30, 60, 90 DAS and at harvest. T₉ treatment recorded significantly higher plant height as compared to control (T₁) and water spray (T₂) at 60, 90 DAS and at harvest.

Dry matter accumulation : Foliar application of liquid organic manures significantly enhanced the dry matter accumulation of wheat over control and water spray. Foliar application of organic formulation recorded did not differ at 30 DAS. Further, the foliar application of T₉ (Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray) recorded the maximum dry matter at 60, 90 DAS and at harvest. Foliar application of T₉ (Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray) recorded an increase of 30.47, 28.29 per cent, 55.17, 53.67 per cent and 51.54 and 48.54 per cent at 30, 60, 90 DAS and at harvest respectively, over control and water spray.

Foliar application of different liquid formulations either alone or in combination significantly improved the various growth parameters of wheat viz. plant height, dry

matter accumulation, (table 4.2 to 4.3). Among various liquid formulations, application of foliar sprays of T9 - Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray recorded significantly taller plants during all stages of plant growth which was found to be at par with the rest of the treatments. Foliar sprays of Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray attained the highest crop dry matter accumulation among all the treatments at all the stages. However it was found accompanied by T8 - Panchgavya (10%) + vermiwash (10%) spray, T7 - Jeevamrit (10%) + vermiwash (10%) spray, T6 – Jeevamrit (10%) + Panchgavya (10%) spray, T5 - Vermiwash (10%) spray, T4 - Panchgavya (10%) spray and T3 – Jeevaamrit (10%) spray. The observed improvement in growth attributes under the influence of various liquid formulations might be due to the role played by these manures in providing nutrients to the crops reported earlier by Munji *et al.* (2010) and Kumawat *et al.* (2009b) in sesame and groundnut.

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Effect of Sulphur and Zinc Fertilization on yield of Cumin (*Cuminum cyminum* L.)

Ranveer Badiyasar*, P.K. Sharma and Anil Bharnanga

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : badiyasar66@gmail.com

Abstract

The field experiment entitled "Response of Cumin (*Cuminum cyminum* L.) to Sulphur and Zinc Fertilization" was conducted at village Badgaon, Merta, Nagaur under the supervision of Department of Agriculture, Vivekananda Global University, Jaipur during *rabi* season of 2022-23. The experiment consisting of nine treatments was laid out in factorial randomised block design with three replications on loamy sand soil. The experiment result showed that the significantly higher seed yield (715 kg ha⁻¹) and straw yield (1425 kg ha⁻¹) with higher net returns (₹366,386 ha⁻¹) of cumin was obtained with application of 20 kg ha⁻¹ Sulphur.

Key Words : Seed yield, straw yield, sulphur and cumin.

Introduction

Cumin (*Cuminum cyminum* L.) popularly known as 'jeera' or 'zeera' in India is an important spice used in Indian kitchen regularly for flavoring various food preparation. Cumin seed contains 2-5 per cent volatile oil which consists of 25-35 per cent aldehydes, pinene and alpheterpineol. The seed also contain flavonoids (including apigenin). The typical pleasant aroma is extensively used in flavouring vegetables and pickles. Cumin oil is used in perfumery for flavouring liquors and cordials. Cumin is a drought-tolerant, tropical or subtropical crop and requires moderately cool and dry climates for its growth, with a temperature between 25o C to 30o C. It grows best on well drained sandy loam soil with a pH range from 6.8 to 8.3. Rajasthan and Gujarat are known as "Seed Spices Bowl" and contributes more than 80 per cent of total seed spices production in India.

Sulphur is one of the plant nutrients which is deficient in the aridisols of Western Rajasthan. Sulphur is one of the essential plants nutrients which is best known for its important and specific role in the synthesis of amino acids like methionine (20%) and cysteine (27%) and synthesis of proteins, chlorophyll and oil. Moreover, it is also associated with the synthesis of vitamins (biotine, thiamine), co-enzyme-A metabolism of carbohydrates, proteins and fats. It's nutrition to crops is vital both from quality and quantity point of view. It lowers the HCN content of certain crops and produces heavier grains of oil seeds. Its application increases drought and cold tolerance in plant by process of disulphide linkage. Now a days, continuous use of high analysis sulphur devoid fertilizers like Urea, DAP, MOP etc. coupled with intensive cropping using high yielding varieties and reduction in use

of organic manure and sulphur containing fungicides and insecticides resulted in sulphur deficiency in soils.

Materials and Methods

Experimental site : The experiment was carried out at village Badgaon, Merta, Nagaur which is situated at a distance of about 25 km from Merta road railway station. Geographically, it is located between 26° 29' N to 39° 5' North latitude and 73° 56' E to latitude 29° 3' East longitude at an altitude of 322 meter above mean sea level. This region falls under agro-climatic zone IIa (Transtional Plan of Inland Drainage) of Rajasthan.

Climate and weather conditions : The climate of Nagaur is typically arid with hot dry summers. The average annual rainfall is about 367 mm (CV 52%) and bulk of it (85 to 90%) is received from June to September (kharif season) by the southwest monsoon. The normal time of onset of monsoon is the last week of June to first week of July, but weather aberrations are quite common with respect to late arrival and early withdrawal of monsoon that resulted dry spells and high temperature during kharif season. The other distinct climatic features of this region are low relative humidity (15 to 30%) with high wind velocity (30 to 40 km hour⁻¹), solar incidence (520 cal cm⁻²), potential evapotranspiration (1843 mm year⁻¹) and wide range of maximum (24.6oC in January to 41.6o C in May) and minimum (9.6 in January to 27.7o C in June) temperatures.

Experimental details : The experiment consisting of 9 treatment combinations was laid out in Factorial Randomized Block Design.

S. No.	Treatments	Symbols
A. Nitrogen levels (kg ha⁻¹)		
1.	0	S ₀
2.	10	S ₁
3.	20	S ₂
B. Zinc levels (kg ha⁻¹)		
1.	0	Zn ₀
2.	2.5	Zn ₁
3.	5.0	Zn ₃

Seed yield : After winnowing, cleaned seeds were weighed per plot to record seed yield plot⁻¹ and then converted into kg ha⁻¹.

Straw yield : Straw yield was calculated by subtracting of seed yield from the biological yield plot⁻¹ and then converted into kg ha⁻¹.

Biological yield : Weight of total biomass (whole plant) was taken from each net plot after complete drying for

Table-1 : Effect of Sulphur and Zinc on seed, straw yields and harvest index of cumin.

Treatments	Seed Yield (kg/ha)	Straw Yield (kg/ha)	Harvest Index
Sulphur (kg ha⁻¹)			
0	630	1205	0.37
10	700	1360	0.43
20	715	1425	0.44
SEm ±	23.545	62.366	0.029
CD (P=0.05)	70.153	185.785	0.086
Zinc lvels (kg ha⁻¹)			
0	630	1205	0.37
2.5	650	1250	0.39
5	675	1305	0.41
SEm ±	13.943	36.919	0.017
CD (P=0.05)	41.510	109.657	0.051

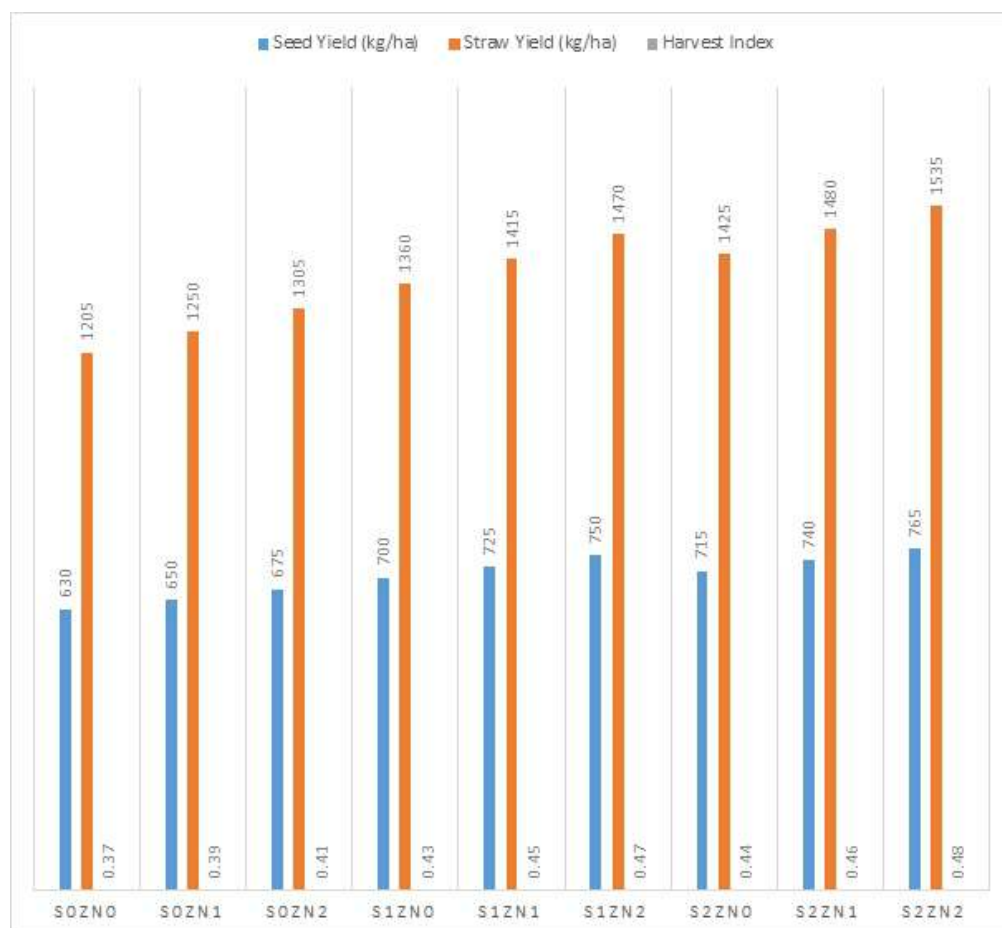


Fig.-1 : Effect of Sulphur and Zinc on seed, straw, biological yields and harvest index of cumin.

estimating biological yield plot⁻¹ and then converted into kg ha⁻¹.

Harvest index : The ratio of economic yield (seed yield) to the biological yield was worked out and expressed in percentage. The harvest index (HI) was calculated as per formula advocated by Donald and Hamblin (1976).

Results and Discussion

Seed yield, Straw yield and Harvest Index

Effect of Sulphur : At 10 kg/ha of sulphur, the seed yield increased by 11.11% compared to the control (0 kg/ha, and at 20 kg/ha, it further rose by 13.49% compared to the control. Similarly, the straw yield increased by 12.45% at 10 kg/ha of sulphur and by 18.59% at 20 kg/ha, both compared to the control. Additionally, the harvest index increased by 16.22% at 10 kg/ha of sulphur and by 18.92% at 20 kg/ha, both compared to the control.

Effect of Zinc : At 2.50 kg/ha of zinc, the seed yield increased by 3.17% compared to the control (0 kg ha⁻¹), and at 5 kg/ha, it rose by 7.14% compared to the control. Likewise, the straw yield increased by 8.30% at 2.50 kg/ha of zinc and by 8.30% at 5 kg/ha, both compared to the control. The harvest index also showed no significant change.

Higher seed yield (715 kg ha⁻¹) was obtained with application of sulphur @ 20 kg ha⁻¹ when compared to without application of sulphur (630 kg ha⁻¹). These results are in conformity with the work of Rajaraman and

Paramguru 2011 in soybean and Veerana, 2000 in safflower.

Acknowledgments

A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Agriculture, faculty members and non-teaching staff of Department of Agriculture, Vivekananda Global University, Jaipur for providing me the necessary help and suggestions during the course of the study.

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Effect of Seaweed Extracts on Yield and its Attributing Characters of Indian Mustard [*Brassica juncea* (L.)]

Bharti^{1*}, P.K. Sharma¹ and Ruchi Bishnoi²

¹Department of Agriculture, Vivekananda Global University, Jaipur (Rajasthan).

²Department of Genetics and Plant Breeding, College of Agriculture, Kota, AU, Kota, Rajasthan

*Corresponding Author E-mail : bhartikauhsik19246@gmail.com

Abstract

The investigation entitled "Effect of Seaweed extracts on yield and its attributing characters of Indian Mustard [*Brassica juncea* (L.)]" was initiated during Rabi, 2021-22 at Research Farm, Vivekananda Global University, Jaipur to understand the effect of seaweed extract at different combinations on yield and its attributing characters of mustard variety Pioneer 45S46. The experiment was laid in Randomized block design with 8 treatments and 3 replications with different combination in application of seaweed extracts. All other practices were adopted as per standard procedure and as per treatment. The treatments consisted of T1 (Without Seed Treatment with Seaweed Extract + Water spray); T2 (Without Seed Treatment with Seaweed Extract + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre- flowering stage)); T3 (Without Seed Treatment with Seaweed Extract + Foliar application of Seaweed Extract @ 4 ml/ lit. (at post siliqua formation stage)); T4 (Without Seed Treatment with Seaweed Extract + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre-flowering and post siliqua formation stage)); T5 (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Water spray + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre-flowering and post siliqua formation stage)); T6 (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre-flowering stage)); T7 (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at post siliqua formation stage)); T8 (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre- flowering and post siliqua formation stage)). The experimental finding revealed that the treatment T7 (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at post siliqua formation stage) was found superior in the terms of yields and yield attributes, as compared to other treatment combinations in mustard. Therefore, Indian Mustard can be grown by treating then seeds followed by spraying of seaweed extract as one among source of organic nutrient for not only better yield of crop but also generating and doubling farming net income.

Key words : Indian mustard, seaweed extract, yield and its attributes.

Introduction

The Oilseeds sector has been one of the most dynamic components of world in the past three decades. The performance of oilseeds on the domestic front during the last two decades has been commendable braving the vagaries of weather conditions, the global price aberrations, and the ever-increasing domestic demand. Indian mustard (*Brassica juncea* L.) is second important oilseed crop in India after Groundnut contributing to about 25 per cent of countries total oilseed production. Indian mustard commonly known as *Rai* is the most important member of the cruciferous oilseeds, occupying nearly 70 per cent of the total area under rapeseed mustard. Major states producing Rapeseed-Mustard are Rajasthan, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat, and West Bengal. the area under mustard crop was 6.86 million ha producing about 9.12 million tonnes of seeds with an average productivity of 1331 kg ha⁻¹. Area under cultivation in Rajasthan was 3.08 million ha, having production of 4.20 million tonnes and productivity of 1366 kg ha⁻¹ (Anonymous, 2021). But the average productivity

of the country remained plateaued around 900 kg/ha which is far below the world average of 1408 kg/ha (FAOSTAT, 2020).

Seaweed or macro-algae, refers to thousands of species of macroscopic, multicellular, marine algae. The term includes some types of Rhodophyta (red), Phaeophyta (brown) and Chlorophyta (green) macro-algae. Seaweed species such as kelps provide essential nursery habitat for fisheries and other marine species and thus protect food sources; other species, such as planktonic algae, play a vital role in capturing carbon, producing at least 50% of Earth's oxygen (National Ocean Service, 2021). Marine algal seaweed species are often regarded as an underutilized bio-resource, many have been used as a source of food, industrial raw materials and in therapeutic and botanical applications for centuries. Moreover, seaweed and seaweed-derived products have been widely used as amendments in crop production systems due to the presence of several plant growth-stimulating compounds. However, the bio stimulatory potential of many of these

products has not been fully exploited due to the lack of scientific data on growth factors present in seaweeds and their mode of action in affecting plant growth. Seaweed has been utilized directly as a soil conditioner and as fertilizer in various coastal areas in all over the world and seaweed extracts have also been widely marketed as additives to plant fertilizers which have benefits have been widely reported. Utilization of seaweed as fertilizer seem a cheapest alternative solution to environmental problems because it is non-harmful for soil and plant microbes also. The uses of seaweed-based bio-products gaining importance in crop production systems owing to their unique bioactive components and stimulative effects on plant growth. They have phyto-stimulatory tendency that increased plant growth and yield parameters in crop plants. This possesses phyto-elicitor activity as their components inducing defence responses in plants that contribute to mechanism of resistance to various pests, diseases and a biotic-stresses including drought, salinity, and cold priming the plant defences against future attacks. Seaweed extracts contain a plethora of substances which are mostly organic, but trace levels of inorganic nutrient elements are also available. Whole seaweed extracts have been consistently proven to be very efficient useful, which places of interest the role of multiple components and their complex combined effects on plant growth processes. Since seaweed extracts are mainly organic, they are preferably suited for organic farming and environmentally safe crop production. The productivity of Mustard in terms of quantity and quality as well as the plant's reaction to stress conditions (biotic and abiotic) may be increased using seaweed extracts in conjunction with fertilizers, which may also raise the market price and profitability.

Keeping this point in view and to learn more about the impact of various treatment combinations of seaweed extracts on yield characteristics of the Mustard crop, the present investigation was carried out.

Materials and Methods

The present investigation was done to understand the effect of seaweed extract at different doses combination on yield and its attributing characters in Indian mustard variety *i.e.* Pioneer 45S46. The experiment was conducted at Research Farm, Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan during the *Rabi* 2022-23 in Randomized Block Design (RBD) comprising 3 replications and 8 treatment combinations, as depicted in table-1.

The experimental field was prepared by ploughing with a tractor drawn disc plough followed by two cross harrowing and planking. The field was thoroughly levelled by a leveller before it was laid out. The land was well

prepared first by ploughing deep, followed by two cross harrowing. Care was taken to see that weeds and stubbles were well removed from the field and the soil contains adequate moisture. Seed rate of 4 kg seed is required for raising required seedlings for one ha land. Accordingly, seed was taken for sowing on raised beds. About 30 cm distance is kept between rows to carry out operations of watering, weeding, etc. The surface of beds was kept smooth and well levelled. Seeds are sown at a depth of 2-3 cm and covered with a fine layer of soil followed by light watering. Excess seedlings are gently removed by hand or tool to avoid root damage to improve sunlight exposure, nutrient absorption, and higher yields. Seed sowing for the experiment trial was done on 18th October, 2022, manually in the furrows opened by hand drawn plough and harvested on 5th March, 2023.

The data recorded during experimental investigation were subjected to statistical analysis of "Analysis of variance" technique (Fisher and Yates, 1967) for drawing conclusion. The significance and non-significance of the treatments were judged with the help of 'F' (Variance ratio) test the significant differences between the means were tested with the critical differences at 5% probability level.

Results and Discussion

The mean performance of all the treatments and mean sum of squares for all the 3 replications and 8 treatments are depicted in table-2 and 3. The analysis of variance showed that there is significant difference present between and among the treatments.

Among the different treatments, the maximum number of siliquae per plant and the maximum number of seeds per siliquae was seen in T7 *i.e.* 195.2 (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit (at post siliquae formation stage) whereas minimum number of siliquae was recorded in T1 *i.e.*, 111.19 (without Seed Treatment with Seaweed Extract + Water spray). The maximum number of seeds per siliquae was seen in in T7 *i.e.* 17.83 (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at post siliquae formation stage) over rest of the treatments, whereas minimum number of seeds per siliquae was recorded in T1, which is 12.12 (Without Seed Treatment with Seaweed Extract + Water spray).

The application of seaweed extracts on mustard plants promotes the development of a higher number of siliquae per plant and an increased number of seeds per siliquae. Seaweed extracts contain growth-promoting hormones like gibberellic acid and auxins, which stimulate flower initiation and enhance floral development. This

Table-1 : The detailed treatments used in the present investigation for yield and its attributing characters in Indian mustard.

S. No.	Treatment Symbols	Treatment combination
1.	T ₁	Without Seed Treatment with Seaweed Extract + Water spray
2.	T ₂	Without Seed Treatment with Seaweed Extract + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre-flowering stage)
3.	T ₃	Without Seed Treatment with Seaweed Extract + Foliar application of Seaweed Extract @ 4 ml/ lit. (at post siliquae formation stage)
4.	T ₄	Without Seed Treatment with Seaweed Extract + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre-flowering and post siliquae formation stage)
5.	T ₅	Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Water spray + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre- flowering and post siliquae formation stage)
6.	T ₆	Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre-flowering stage)
7.	T ₇	Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at post siliquae formation stage)
8.	T ₈	Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit. (at pre-flowering and post siliquae formation stage)

Table-2 : The mean performance of all the treatments under study for yield and its attributing characters.

	Number of siliquae per plant	Number of seeds per siliquae	Test weight (g)	Seed yield	Straw yield	Biological yield	Harvest index (%)
T ₁	111.19	12.12	4.34	10.86	35.99	47.62	22.79
T ₂	147	13.71	4.88	11.35	45.66	57.81	19.63
T ₃	157.41	14.55	4.63	13.62	41.87	56.2	24.23
T ₄	170.19	13.12	5.1	16.66	41.09	59.14	28.17
T ₅	178.26	12.25	5.17	15.85	51.19	67.84	23.36
T ₆	168.51	16.87	5.35	15.36	38.11	54.22	28.32
T ₇	195.2	17.83	5.5	17.75	53.64	72.16	24.6
T ₈	176.14	15.47	4.9	16.11	48.43	65.33	24.65
SEm	5.87	1.09	0.54	3.34	3.59	4.22	0.14
CD (p=0.05)	11.33	5.48	NS	4.83	5.08	7.68	0.41

Table-3 : The mean sum of squares (ANOVA) for the characters under study.

Characters	Replication	Treatment
Number of siliquae per plant	16.39	1926.88*
Number of seeds per siliquae	5.69	13.25*
Test weight	2.78	0.43*
Seed yield	7.15	18.85*
Straw yield	11.63	118.65*
Biological yield	7.69	190.42*
Harvest index (%)	13.05	24.04*

*indicates significant difference at 5% level.

leads to the production of more siliquae in each mustard plant. Furthermore, seaweed extracts improve nutrient uptake and assimilation, particularly phosphorus, which is essential for seed formation. The availability of adequate nutrients through seaweed extract application promotes successful pollination and fertilization, resulting in a higher number of seeds per siliquae. Ultimately, these combined effects contribute to increased seed yield and productivity in mustard crops treated with seaweed extracts. Similar findings were reported by Kavitha *et al.*, (2008) in maize; Babu and Rangaswamy (2012) in paddy; Shah *et al.*, (2012) in wheat; Rathore *et al.*, (2014) in

soyabean; Selvakumari *et al.*, (2017) in tomato and Yusuf *et al.*, (2021) in Mustard.

The maximum test weight, grain yield per hectare, maximum straw yield per hectare and maximum biological yield per hectare were recorded in treatment T7 *i.e.* 5.5 g, 17.75 g, 53.64 g, 72.16 g (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit (at post siliquae formation stage), respectively. The minimum test weight, grain yield per hectare, maximum straw yield per hectare and maximum biological yield per hectare were recorded in treatment T1. Yield is the resultant coordinated interplay of growth

and yield attributing characters. Seed yield increased with increase in the doses of seaweed extract. Increase in yield with seaweed extracts application might be due to increase in dry matter production. Seaweed extract application pushed up the removal of nutrients and water from soil by the crop which might have enhanced the photosynthesis and translocation of assimilates from source (leaves and stem) to sink (silique and seed) vis-a-vis seed yield. Moreover, seaweed extracts stimulate physiological processes such as photosynthesis, leading to enhanced grain yield per hectare. The improved nutrient availability and physiological functioning also translate into increased straw yield and biological yield per hectare. The additional biomass production contributes to higher crop productivity and overall yield in mustard crops treated with seaweed extracts, making it a valuable addition to cultivation practices. Results were in accordance with the findings of Kavitha *et al.*, (2008) in maize; Babu and Rangaswamy (2012) in paddy; Shah *et al.*, (2012) in wheat; Rathore *et al.*, (2014) in soyabean; Selvakumari *et al.*, (2017) in tomato and Yusuf *et al.*, (2021) in Mustard.

The maximum harvest Index were recorded in treatment T6 i.e., 28.32 % (Seed Treatment with Seaweed Extract @ 3 ml/kg seeds + Foliar application of Seaweed Extract @ 4 ml/ lit (at pre- flowering stage) whereas minimum was recorded in T2 (19.63 %). Seaweed extract application improves the harvest index in mustard by promoting efficient partitioning of assimilates towards reproductive structures, such as seeds. The bioactive compounds present in seaweed extracts stimulate hormonal balance and enhance plant growth, leading to increased seed development and maturation. These results in a higher proportion of total biomass allocated towards the desired yield component, improving the harvest index of mustard crops. Results were in accordance with the findings of Kavitha *et al.*, (2008) in maize; Babu and Rangaswamy (2012) in paddy; Shah *et al.*, (2012) in wheat; Rathore *et al.*, (2014) in soyabean; Selvakumari *et al.*, (2017) in tomato and Yusuf *et al.*, (2021) in Mustard.

Conclusions

On the basis of one year experimental results, it may be concluded that seed treatment with Seaweed Extract @ 3 ml/kg seeds + foliar application of Seaweed Extract @ 4

ml/ l at post siliquae formation stage was found superior in the terms of yields and yield attributes, as compared to other treatment combinations in mustard. Therefore, Indian Mustard can be grown by treating then seeds followed by spraying of seaweed extract as one among source of organic nutrient for not only better yield of crop but also generating and doubling farming net income.

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Effect of Fertilizers and Hydrogel on Nutrient Uptake of Wheat (*Triticum aestivum* L.)

Sahil Budania*, P.K. Sharma and Omveer Gurjar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : budaniasahil19@gmail.com

Abstract

A field experimentation was conducted at carried out during *rabi* season of the year 2022-23 at research farm, Vill. Heatmsar, Jhunjhunu. The objectives were to study the effect of fertilizers and hydrogel on productivity and quality of wheat. The experiment consisted of 12 treatment combinations comprising three levels of fertilizer (50% RDF (60Kg N + 20Kg P₂O₅ + 20Kg K₂O), 75% RDF (90Kg N + 30Kg P₂O₅ + 30Kg K₂O) and 100% RDF (120Kg N + 40Kg P₂O₅ + 40Kg K₂O) with four levels of hydrogel (control, hydrogel @ 2.5 kg/ha, hydrogel @ 5.0 kg/ha, and hydrogel @ 7.5 kg/ha.). The experiment was laid out in Factorial Randomized Block Design and replicated thrice. 100% RDF (120Kg N + 40Kg P₂O₅ + 40Kg K₂O) recorded significant improvement in NPK content, uptake in grain and straw over the rest of the treatments.

Key words : Wheat, fertilizers, hydrogel and nutrient uptake.

Introduction

Wheat [*Triticum aestivum* (L.)] is one of the most important staple food crops of the world as well as India. It is cultivated under diverse growing conditions of soil and climate. In India, it is the second most important food crop after rice. It is an excellent health-building food containing approximately, 78% carbohydrates, 12% protein, 2% fat and minerals each and considerable amount of vitamins (Kumar *et al.*, 2011).

India contributes highest wheat cultivated area (31.61 million hectares) in the world while acquired second position with respect to production (109.52 million tonnes) after china with the average productivity of 3.46 tonnes ha⁻¹ (Anonymous, 2020-21).

Hydrogel is one of the products, which is believed to increase infiltration rate in field besides increasing water holding capacity of the soil. Further studies revealed that hydrogel not only reduces amount of irrigation water but also frequency of irrigation from 55 to 80% of total water requirements to the crop and, therefore, increases crop yield (El-Hady *et al.*, 2006).

Materials and Methods

Experimental site : The experiment was laid out at Research Farm, Vill. Heatmsar, Dist. Jhunjhunu during *rabi* seasons of 2022-23. Jaipur is situated at 28° 12" North latitude and 75° 39" East longitudes at an altitude of 341 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-III A (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of

temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs/day.

Experimental details : The experiment comprised 3 levels of fertilizers and 4 levels of hydrogel, thereby making twelve treatment combinations that were laid out in Factorial Randomized Block Design (FRBD) and replicated three times.

S. No.	Treatments	Symbols
A.	Fertilizer levels	
1.	50% RDF (60Kg N + 20Kg P ₂ O ₅ + 20Kg K ₂ O)	F ₀
2.	75% RDF (90Kg N + 30Kg P ₂ O ₅ + 30Kg K ₂ O)	F ₁
3.	100% RDF (120Kg N + 40Kg P ₂ O ₅ + 40Kg K ₂ O)	F ₂
B.	Hydrogel	
1.	Control	H ₀
2.	Hydrogel @ 2.5 Kg/ha	H ₁
3.	Hydrogel @ 5.0 Kg/ha	H ₂
4.	Hydrogel @ 7.5 Kg/ha	H ₃

Nutrient uptake (kg/ha) : The total uptake of nitrogen and phosphorus in grain and straw was calculated by using following formula :

Total uptake of N/P/K = (kg/ha)	Per cent N/P/K concentration in grain	Grain yield (kg/ha)	Per cent N/P/K concentration in straw	Straw yield (kg/ha)
100				

Results and Discussion

Nitrogen uptake

Fertilizer levels : The fertilizer levels i.e., F₃-100% RDF (120Kg N + 40Kg P₂O₅ + 40Kg K₂O) increased significantly higher N uptake in grain and straw of wheat.

Hydrogel : Foliar application of hydrogel i.e., H₃ (hydrogel @ 7.5 kg/ha) resulted significantly highest N uptake in grain and straw as compared to control and H₁.

Phosphorus uptake

Fertilizer levels : The increase in P uptake in grain and

straw of wheat due to F₃-100% RDF (120Kg N + 40Kg P₂O₅ + 40Kg K₂O) was 48.474 and 14.73 per cent in grain and 29.62 and 12.52 per cent in straw over F₁ and F₂, respectively.

Hydrogel : The improvement in P uptake of wheat by H₃ (hydrogel @ 7.5 kg/ha) was 53.90 and 21.43 per cent and 34.30 and 14.0 per cent in grain and straw over control and H₁, respectively.

Potassium uptake

Fertilizer levels : The increase in K uptake in grain and straw of wheat due to 100% RDF (120Kg N + 40Kg P₂O₅ + 40Kg K₂O) -100% RDF (120Kg N + 40Kg P₂O₅ + 40Kg K₂O).

Hydrogel : The improvement in K uptake of wheat by H₃ (hydrogel @ 7.5 kg/ha) was 47.61 and 19.63 per cent in

Table-1 : Effect of fertilizer and hydrogel on nitrogen uptake of wheat.

Treatments	N uptake (kg/ha)	
	Grain	Straw
Fertilizer levels		
F ₁ -50% RDF (60Kg N + 20Kg P ₂ O ₅ + 20Kg K ₂ O)	55.78	25.29
F ₂ -75% RDF(90Kg N + 30Kg P ₂ O ₅ + 30Kg K ₂ O)	68.04	28.50
F ₃ -100% RDF (120Kg N + 40Kg P ₂ O ₅ + 40Kg K ₂ O)	76.06	31.72
SEm±	1.68	0.68
CD (P=0.05)	4.85	1.97
Hydrogel		
H ₀ -Control	54.18	24.32
H ₁ -Hydrogel @ 2.5 Kg/ha	64.49	27.73
H ₂ -Hydrogel @ 5.0 Kg/ha	70.9	30.31
H ₃ -Hydrogel @ 7.5 Kg/ha	76.43	31.49
SEm±	1.94	0.79
CD (P=0.05)	5.60	2.28
CV (%)	8.73	8.31

Table-2 : Effect of fertilizer and hydrogel on phosphorus uptake of wheat.

Treatments	P uptake (kg/ha)	
	Grain	Straw
Fertilizer levels		
F ₁ -50% RDF (60Kg N + 20Kg P ₂ O ₅ + 20Kg K ₂ O)	11.10	6.38
F ₂ -75% RDF(90Kg N + 30Kg P ₂ O ₅ + 30Kg K ₂ O)	14.39	7.35
F ₃ -100% RDF (120Kg N + 40Kg P ₂ O ₅ + 40Kg K ₂ O)	16.51	8.27
SEm±	0.34	0.17
CD (P=0.05)	0.97	0.49
Hydrogel		
H ₀ -Control	10.73	6.11
H ₁ -Hydrogel @ 2.5 Kg/ha	13.60	7.16
H ₂ -Hydrogel @ 5.0 Kg/ha	14.19	7.54
H ₃ -Hydrogel @ 7.5 Kg/ha	17.47	8.53
SEm±	0.39	0.20
CD (P=0.05)	1.12	0.56
CV (%)	8.30	7.98

Table-3 : Effect of fertilizer and hydrogel on potassium uptake of wheat.

Treatments	K uptake (kg/ha)	
	Grain	Straw
Fertilizer levels		
F ₁ -50% RDF (60Kg N + 20Kg P ₂ O ₅ + 20Kg K ₂ O)	15.04	81.96
F ₂ -75% RDF (90Kg N + 30Kg P ₂ O ₅ + 30Kg K ₂ O)	19.01	95.50
F ₃ -100% RDF (120Kg N + 40Kg P ₂ O ₅ + 40Kg K ₂ O)	21.70	107.92
SEm±	0.50	2.46
CD (P=0.05)	1.43	7.09
Hydrogel		
H ₀ -Control	14.58	78.88
H ₁ -Hydrogel @ 2.5 Kg/ha	17.99	92.69
H ₂ -Hydrogel @ 5.0 Kg/ha	20.01	101.27
H ₃ -Hydrogel @ 7.5 Kg/ha	0.477	1.68
SEm±	0.007	0.020
CD (P=0.05)	0.020	0.059
CV (%)	4.55	3.81

grain and 35.48 and 15.29 per cent in straw over control and H₁, respectively.

Treatment F₃ where fertilizer was practised with F₃-100% RDF (120Kg N + 40Kg P₂O₅ + 40Kg K₂O) fetched significantly higher nitrogen, phosphorus and potassium uptake in grain and straw over rest of the treatments. These results are in close conformity with those of Singh *et al.* (2017a), Tyagi *et al.* 2012, Jat *et al.* (2013a) and Naik *et al.* (2020).

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Effect of Fertility Levels on Nutrient Content of Pearl Millet (*Pennisetum glaucum* L.)

Sunil Kumar*, P.K. Sharma and Lavlesh Sharma

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : srk.jogawat0@gmail.com

Abstract

A field experiment entitled "Effect of Fertility Levels, Vermicompost and Bio-Fertilizers on Growth, Yield and Quality of Pearl millet (*Pennisetum glaucum* L.)" was initiated during *Kharief* season of 2022-23 at Agriculture Research Farm, Vivekananda Global University, Jaipur. The experiment was laid out in randomized block design with three replications comprising of nine treatments viz. (T₁) 100 % RDF, (T₂) 75 % RDF + 2.5 t/ha Vermicompost, (T₃) 75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter at 600 g/ha, (T₄) 75 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha, (T₅) 75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each, (T₆) 50 % RDF + 2.5 t/ha vermicompost, (T₇) 50 % RDF + 2.5 t/ha vermicompost + seed treatment with azotobacter at 600 g/ha, (T₈) 50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha and (T₉) 50 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each. Pioneer 86M82 variety of pearl millet was used as test crop. The maximum nutrient content and uptake was recorded with 75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each.

Key Words : Pearl millet, azotobacter, nutrient content and vermicompost.

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend. Stuntz] or *Bajra* is sixth most important cereal of the world and stands fourth in order of importance as food grain in India. It is a staple food grain crop in the arid and semiarid regions of India and Africa and new grain crop in USA. India occupied 7.52 million ha area with the total production of 10.28 million tonnes and average productivity of 1368 kg/ha during 2019-20. While Rajasthan has the highest area under bajra and accompanied with highest production in the country. The Rajasthan occupied 4.29 million ha area with the total production of 4.69 million tonnes and average productivity of 1093 kg/ha during 2019-20 (Anonymous, 2021).

Efficient fertilizer management plays an important role in increasing the crop yield through efficient utilization of limited water supply. The soils of these areas are deficient in various nutrient elements in general and nitrogen and phosphorus in particular. It is, therefore, imperative to have better understanding of growth, yield and quality of this crop in relation to nitrogen and phosphorus nutrition and promoting its adoption by farmers of these regions. Though nitrogen and phosphorus management of pearl millet cultivars has been studied by various researchers.

Materials and Methods

Experimental site : The experiment was conducted during *kharif* season of 2022-23 at Agricultural Research Farm, Vivekananda Global University, Jaipur. In

Rajasthan, this region all under agro- climatic zone III A (Semi-arid Eastern Plain Zone).

Climate and weather conditions : The climate of this zone is typically semi-arid characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while, in winters it may fall as low as 1.0 °C. The rainfall of this zone varies from 450-550 mm, most of which is contributed by south-west monsoon during the months of July and August. The mean maximum temperature during the growth period of pearl millet ranged between 30.2°C to 40.9°C, while minimum temperature ranged from 14.3°C to 25.4°C during the crop season. The mean maximum relative humidity fluctuated from 55 to 85 per cent and mean minimum relative humidity fluctuated from 15 to 59 per cent during the crop season, while the average sunshine hours ranged between 1.8-9.3 hrs/day. The average annual rainfall ranges between 350 - 450 mm.

Experimental details : The present experiment consisting of 9 treatments was carried out in randomized block design.

S.No.	Treatments	Symbols
1	100 % RDF	T1
2	75 % RDF + 2.5 t/ha Vermicompost	T2
3	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter at 600 g/ha	T3
4	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	T4
5	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	T5

6	50 % RDF + 2.5 t/ha vermicompost	T6
7	50 % RDF + 2.5 t/ha vermicompost + seed treatment with azotobacter at 600 g/ha	T7
8	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	T8
9	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	T9

Nutrient content (%) : The nitrogen, phosphorus and potassium contents in grain of wheat were estimated at maturity. The grain sample of crop was collected separately as per treatment at harvest. These samples were ground in the grinder after drying in oven at 70°C temperatures for 48 hours. Thus, the ground plant materials passed through 30-mesh sieve, and these materials used for determination of nitrogen, phosphorus and potassium content.

Results and Discussion

Nitrogen content in grain and stover (%) : Nitrogen content in grain of pearl millet among the treatments varied from 1.58 per cent to 1.83 per cent. The treatment T₉ had significantly more nitrogen content in grain as compared to rest of the treatments. Nitrogen content in stover of pearl millet among the treatments varied from 0.39 per cent to 0.62 per cent. The treatment T₈ had significantly more nitrogen content (0.62 %) in stover as compared to rest of the treatments.

Phosphorus content in grain and stover (%) : The phosphorus content in grain was not significantly influenced by different treatments, however, on mean basis it varied from 0.19 to 0.35 percent. Similar to phosphorus content in stover was also not significantly influenced by different treatments.

Table-1 : Effect of fertility levels, vermicompost and bio-fertilizers on nitrogen content of pearl millet.

Sr. No.	Treatments	Nitrogen content (%)	
		Grain	Stover
T1	100 % RDF	1.587	0.397
T2	75 % RDF + 2.5 t/ha Vermicompost	1.757	0.517
T3	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter at 600 g/ha	1.830	0.590
T4	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	1.813	0.553
T5	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	1.813	0.543
T6	50 % RDF + 2.5 t/ha vermicompost	1.700	0.560
T7	50 % RDF + 2.5 t/ha vermicompost + seed treatment with azotobacter at 600 g/ha	1.713	0.493
T8	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	1.840	0.620
T9	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	1.833	0.593
	SEm ±	0.048	0.048
	CD (P=0.05)	0.144	NS

Table-2 : Effect of fertility levels, vermicompost and bio-fertilizers on phosphorus content of pearl millet.

Sr. No.	Treatments	Phosphorus content (%)	
		Grain	Stover
T1	100 % RDF	0.193	0.118
T2	75 % RDF + 2.5 t/ha Vermicompost	0.248	0.125
T3	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter at 600 g/ha	0.302	0.115
T4	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	0.258	0.122
T5	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	0.250	0.118
T6	50 % RDF + 2.5 t/ha vermicompost	0.289	0.123
T7	50 % RDF + 2.5 t/ha vermicompost + seed treatment with azotobacter at 600 g/ha	0.267	0.105
T8	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	0.354	0.110
T9	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	0.302	0.122
	SEm ±	0.048	0.003
	CD (P=0.05)	NS	0.009

Table-3 : Effect of fertility levels, vermicompost and bio-fertilizers on potassium content of pearl millet.

Sr. No.	Treatments	Potassium content (%)	
		Grain	Stover
T1	100 % RDF	0.467	1.777
T2	75 % RDF + 2.5 t/ha Vermicompost	0.537	1.887
T3	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter at 600 g/ha	0.600	1.970
T4	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	0.553	1.933
T5	75 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	0.553	1.943
T6	50 % RDF + 2.5 t/ha vermicompost	0.550	1.890
T7	50 % RDF + 2.5 t/ha vermicompost + seed treatment with azotobacter at 600 g/ha	0.543	1.883
T8	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha	0.640	1.990
T9	50 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each	0.603	1.963
	SEm $\pm$	0.048	0.048
	CD (P=0.05)	NS	NS

Potassium content in grain and stover (%) : 50 % RDF + 2.5 t/ha Vermicompost + seed treatment with azotobacter + PSB at 600 g/ha each (T₉) recorded highest potassium content in grain (0.60 %) and 50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha in stover (1.99 %) of pearl millet which was significantly superior over rest of the treatments.

Nitrogen content varied from 1.58 to 1.84 per cent in grain and 0.39 to 0.62 per cent in stover among different treatments. The treatments receiving 50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha (T₈) exhibited higher nitrogen content both in grain and stover over the 100 % RDF (T₁). Similar were the findings of Choudhary and Gautam (2007) in pearl millet. Phosphorus content in both grain and stover was not significantly affected by different treatments, however, on mean basis, the treatments receiving 50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha (T₈) were having higher phosphorus content over their corresponding treatments. Pearl millet is a heavy feeder of potash nutrient and in our study the range of potassium content was 0.46 to 0.64 per cent in the grain and these values were 1.77 to 1.99 per cent in stover among different treatments. 50 % RDF + 2.5 t/ha Vermicompost + seed treatment with PSB at 600 g/ha (T₈) recorded highest potassium content in grain and stover with 0.64 per cent and 1.99 per cent, respectively. Similar findings were obtained by Patil *et al.* (2014) and Jadhav *et al.* (2011).

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Relationship Between the Independent Variables Onion Growers with their Utilization Behaviour Regarding Integrated Pest Management Practices in Jodhpur District of Rajasthan

Kamlesh Gurjar^{1*}, Banwari Lal¹, Ravindra Singh Choudhary¹, Pramod² and Narendra Kumar Choudhary³

Department of Extension Education, Agriculture University, Jodhpur, Rajasthan

²*Department of Extension Education, SKNAU, Jobner, Rajasthan*

³*Department of Extension Education, RCA, MPUAT, Udaipur, Rajasthan*

*Corresponding Author Email : kamleshgurjar0962@gmail.com

Abstract

Onion is most important vegetable and spice crops grown throughout India. The present study was conducted in Jodhpur district of Rajasthan. The Jodhpur district had sixteen Panchayat Samities, out of 16 Panchayat Samities, two Panchayat Samities namely Tinwari and Osian were selected purposively because both have highest area and production of Onion cultivation in Jodhpur district. Out of 103 villages, total ten villages (six from Tinwari and four from Osian) were selected through proportionate random sampling along with highest area and production. Thus, the total 120 respondents were selected for the study. The findings revealed that correlation between the independent & dependent variables showed that the occupation, education, family income, land holding, social participation, extension contacts, mass media exposure, were positively and significantly correlated at 0.05 per cent level of probability. However, the variables like age, caste and type of family had shown non-significant relationship with the utilization of IPM practices by the respondents.

Key words : *Onion, variables, relationship, vegetable, IPM.*

Introduction

Science is advancing at a rapid pace right now, and new knowledge and information are continually being created. The fastest possible delivery of this knowledge and information to the intended users is essential. In order to achieve this goal, they need to be able to connect and communicate effectively. The quick transition of better farming techniques from the lab to the field (from research stations to the Vegetable Growers) would aid thousands of Indian Vegetable Growers in overcoming ignorance, poverty, and achieving a level of social and economic wellbeing. The current state of vegetable technology, which has developed as a result of national research and contributed to a noticeable increase in vegetable production, demonstrates how swiftly the research phenomenon surrounding onions is evolving. Even though knowledge is rapidly developing, many study findings are challenging to put into practise. The top practitioners are those who grow vegetables. So that they may use it successfully, the vegetable growers must be informed of this information. Different communication channels and sources lead to different reactions from farmers. The top practitioners are those who grower onion. So that they may use it successfully, the onion growers must be informed of this information. Different communication channels and sources lead to different reactions from respondents age, education, type of family. IPM is a set of

strategies that includes biological control, habitat alteration, altered agronomic procedures, and the use of resistant varieties for long-lasting pest and insect management. In order to address pest and disease problems in onion crops in India in a sustainable and ecologically friendly way, Integrated Pest Management (IPM) employs a combination of several agricultural techniques and practises. IPM seeks to maximise pest management effectiveness while minimising the usage of chemical pesticides. The best chance of maintaining long-term crop protection is through the integration of several different insect control approaches. Only when evaluation using monitoring and scouting indicates they are required to avert economic damage may pesticides be used to eradicate or prevent the target organism.

Research Methodology

The present study was conducted in Jodhpur district of Rajasthan. The Jodhpur district had sixteen Panchayat Samities, out of 16 Panchayat Samities, two Panchayat Samities namely Tinwari and Osian were selected purposively because both have highest area and production of Onion cultivation in Jodhpur district. Out of 103 villages, total ten villages (six from Tinwari and four from Osian) were selected through proportionate random sampling along with highest area and production. Thus, the total 120 respondents were selected for the study. To measure the relationship between socio-personal

characteristics like age, caste, occupation, education, type of family, family income, land holding, social participation, extension contact and mass media exposure etc. of Onion growers.

The Karl Pearson's correlation coefficient was applied to draw the inferences for the relationship.

Correlation Coefficient (r) : The correlation coefficient ("r" value) was used to measure the relationship between dependent and independent variables. The correlation coefficient between two groups was calculated by using the following formula.

$$r = \frac{\frac{\sum XY}{n} - \frac{\sum X}{n} \frac{\sum Y}{n}}{\sqrt{\left[\frac{\sum X^2}{n} - \left(\frac{\sum X}{n} \right)^2 \right] \left[\frac{\sum Y^2}{n} - \left(\frac{\sum Y}{n} \right)^2 \right]}}$$

Where r = Correlation Coefficient

X = Independent variable

Y = Dependent variable

n = Total number of respondents

Results and Discussion

The relationship between extent of utilization behaviour of onion growers about integrated pest management practices and their selected independent variables viz., like age, caste, occupation, education, type of family, family income, land holding, social participation, extension contact and mass media exposure were measured by computing correlation coefficient (r).

Table-1 : Relationship between selected independent variables with utilization behaviour of onion growers.

S. No.	Selected independent variables	Correlation coefficients ('r' value)
1.	Age	0.123NS
2.	Caste	0.135NS
3.	Occupation	0.240**
4.	Education	0.213*
5.	Type of Family	0.026NS
6.	Family Income	0.195*
7.	Land Holding	0.225*
8.	Social Participation	0.259*
9.	Extension Contacts	0.209*
10.	Mass Media Exposure	0.249**

**= significant at 1% level, *= significant at 5% level, NS = non-significant

It could be seen from the design of the table-1 that characteristics of Onion growers namely, occupation, education, family income, land holding, social participation, extension contact and mass media

exposure were positively significant and significantly related with their information utilization of integrated pest management. Age, caste, and family type of respondents' characteristics had no statistically significant relationship to how much onion growers used IPM techniques. Pratap et al. (2019) obtained similar results as well. Occupation was positively and significantly associated with information usage behaviour, possibly because a farmer who works multiple jobs has a strong financial situation and can afford to buy new farm equipment, material possessions, etc. It was discovered that education of onion producers positively and strongly correlated with their usage habit. It might be conceivable because a progressive and innovative onion grower might consider education to be a crucial and important aspect. As a result, onion producers with an appropriate level of education can use more information. Social interaction is undoubtedly a way to generate fresh concepts and raise agricultural involvement. In such a situation with an increase in social participation the degree of utilization behaviour might be increased. The words and concepts were operationalized after a review of the pertinent literature. Responses from the respondents were gathered using an interview schedule that included a measurement tool for the dependent and independent variables of onion growers. The respondent's socio-personal characteristics made up the first section of the schedule. i.e. age, caste, occupation, education, type of family, family income, land holding, social participation, extension contact and mass media exposure of the respondents.

The second section of the timetable was created to evaluate how onion growers use their land. The third section of the programme was designed to pinpoint the challenges experienced by farmers while using integrated pest management techniques. The data were gathered using the personal interview approach, classified, tabulated, and inferences were made after the data through the proper statistical analysis, which produced the primary conclusions listed below. The results are consistent with those published by Pratap et al. (2019).

Conclusions

It was evident from the study that the correlation coefficient of independent variable shows that, occupation, education, family income, land holding, social participation, extension contacts, mass media exposure were positively and significantly related at 0.05 per cent level of probability with utilization of integrated pest management practices by the onion growers. The variable like age, caste and type of family has not at all shown any relationship with utilization of integrated pest management practices by the respondents.

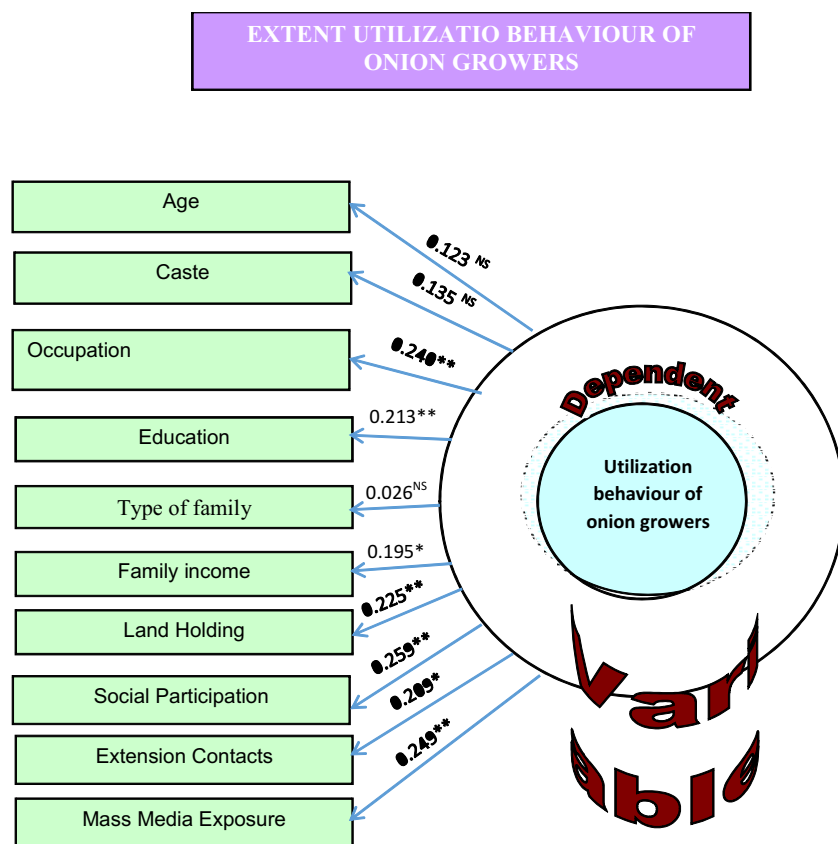


Fig.-1 : Relationship between selected independent variables with utilization behaviour of onion growers.

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Effect of Fertility Levels and Genotypes on Growth Parameters and Yield of Sweet Sorghum (*Sorghum bicolor* L.) Under Rainfed Environment

Sachin Kumar Gurjar¹, Jagdish Choudhary^{1*}, Roshan Choudhary², Ram Hari Meena³ and N.L. Meena⁴

¹Department of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan

²Directorate of Research, SKNAU, Jobner, Rajasthan

³Department of Soil Science and Agriculture Chemistry, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan

⁴Department of Plant Pathology, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan

*Corresponding Author Email : jaggiudr@gmail.com

Abstract

A field experiment was conducted at Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan during Kharif season of 2022 on multi cut forage sorghum hybrid under different fertility levels. The experiment consists of four fertility levels (control, 50% RDF, 100% RDF, 150% RDF) in main plot and three genotypes (SPV 2789, SPV 2794, CSH 22SS) in subplot of split plot design within three replications. The results revealed that maximum growth and yield of sweet sorghum was recorded by the application of 150% RDF. Among genotypes, SPV 2789 recorded significantly higher plant height, dry matter accumulation, grain and straw. But, minimum days to 50% flowering was observed with CSH 22SS.

Key words : sweet sorghum, genotypes, RDF.

Introduction

The sorghum (*Sorghum bicolor* L.) is the very important crop especially arid regions most expanding crop across the globe. This is cultivated since ancient era and is historically cultivated for variety of food for human, grain for poultry and animal feed, commercial uses as alcoholic beverage and biofuels. Sweet sorghum is diversified form of sorghum and its stalk is sweeter in taste because of higher sugar content. Sweet sorghum thrives better under drier and warmer conditions than many other crops and is grown primarily for silage, syrup and forage production. Sweet sorghum syrup is known as "sorghum molasses" and used as pan cakes, corn meal mush, grits and other hot cereals.

Globally, sorghum production was 62.66 million tones in 2022 under area of 40.97 million hectares. More than 90 % area in the world of sorghum production is found in Africa, America and Asia. India ranks fifth in total sorghum production with 4.23 million tones grown under area of 3.90 million hectares.

Inadequate or lack of suitable nutrient-responsive genotypes is the main reason for low production in the southern part of Rajasthan. It takes time for elite genotypes with higher- yielding potential and resistance to specific abiotic and biotic stressors to develop. In terms of their growth and development patterns, crop length and the efficient use of readily available resources like nutrients and minerals.

It is a further accepted fact since long that amongst

the plant nutrients, nitrogen plays a significant role in the development and augmentation of crops. Nitrogen is absorbed by plants in comparatively bulky amounts but most of the Indian soils are found nitrogen deficit. Nitrogen is a constituent of protoplasm and major molecules like chlorophyll and associated with the activity of every living cell, coupled with higher volatilization rate and leaching losses. Phosphorous is major component in many physiological and biochemical processes of plants. It plays dynamic role in energy production, storage and transfer. It also helps in regulation of photosynthesis, respiration, root growth and tolerance against root disease, stem diseases, plant reproduction and seed formation. It is also a component of vitamin B complex. Phosphorous availability to plants early in the growing season is of particular importance (Grant *et al.*, 2001).

A variety of high yielding sorghum genotypes have been developed in recent years. Although genotypes are critical for boosting crop yield, there is virtually little data on how these novel genotypes react to different levels of fertility. So, it is reasonable to assess the relative performance of different sorghum genotypes with different fertility levels under the agro-climatic situation of southern Rajasthan.

Materials and Methods

The field experiment was carried out during Kharif 2022 at Maharana Pratap University of Agriculture and Technology, Udaipur, India. The soil of the experimental field was clay-loam in texture, slightly alkaline in nature (pH 7.5), high in organic carbon (0.35%), low in available

nitrogen ($276.21 \text{ kg ha}^{-1}$), medium in available phosphorus (22.47 kg ha^{-1}) and high in available potassium (316 kg ha^{-1}). In split plot design, main plots contain four fertility levels (control, 50% RDF, 100% RDF, 150% RDF) and three genotypes (SPV 2789, SPV 2794, CSH 22SS) in sub plots and replicated thrice. Plot size was $3.0 \text{ m} \times 4.2 \text{ m}$. Nitrogen was supplied through urea and DAP, phosphorus through DAP and potassium through K_2O . Full dose of nitrogen, phosphorous and potassium was applied according to the treatment at the time of sowing as basal dose. For evaluation of the experiment five plant samples were taken from each plot.

Results and discussion

Plant population : The fertility levels and genotypes failed to register any significant variation in plant population in 0.5 m row length at 15 DAS.

Plant height : The application of 150 % RDF recorded maximum plant height at 25, 50, 75 DAS and at harvest (83.1, 107.14, 172.9 and 236.5 cm, respectively), which was statistically at par with 100% RDF at 25 and 50 DAS but at 75 DAS and at harvest it was statistically at with 50 and 100% RDF as represented in Table 1. Among the genotypes, SPV 2789 recorded maximum plant height at 25, 50, 75 DAS and at harvest (82.70, 104.40, 173.80 and 230.60 cm, respectively).

Dry matter accumulation : In different fertility levels with the application of 150% RDF there was maximum dry matter accumulation was recorded as shown in Table 1. However, it was statistically at par with 100% RDF at 25, 50 and 75 DAS but at harvest it was statistically at par with 50% and 100% RDF but significantly superior over rest of the fertility levels. Among the genotypes, SPV 2789 was found maximum dry matter accumulation.

Days to 50% flowering : A perusal of data in Table-1 shows that fertility level make significant variation in days to 50% flowering. The application of 150% RDF took minimum days to 50% flowering which was at par with 100% RDF and significantly lesser than 50% RDF and control. Among the genotypes CSH 22SS at earliest flower initiation at 75.2 days than rest of genotypes.

Days to 50% maturity: Fertility level of genotypes both are failed to produce significant effect on days to 50% maturity (Table-1).

The absolute effect of increasing fertility levels on growth attributes of the crop analyzed in this investigation was mainly because of increasing of plant available nutrient status in rhizosphere of the plant. In general, overall increased development and growth of sorghum plants because of higher rate of fertility levels could be approved to the inherent role of N, P and K containing

fertilizers in bringing about certain advantageous modifications in soil environment as well as in plant surroundings. Especially N performs an important regulative functional role in plant metabolic activity through biosynthesis of phytohormones and their transport to sites of action, which generally act as stimulant for certain steps of growth and development (Beringer, 1980). phosphorus is related with increasing root growth and fruit set and seed progress. The extensively root system facilitate in exploiting the higher nutrients and water from soils (Tandon and Narayan, 1990). K fertilizer increase vegetative vigour more than reproductive growth which is improved by phosphate application (Raheja, 1996 and Brady and Weil, 2002). The variation in these growth parameters of the genotypes might be related to inherent differences and high vigour in these genotypes. Similar observations regarding differences in height, dry matter and days to 50 % flowering of various sweet sorghum genotypes at very different stages of growth were recorded by Mishra *et al.* (2015) and Meena *et al.* (2020) for plant height and dry matter accumulation Bhoya *et al.* (2014) and Panwar (2013) for days to 50 % flowering.

Grain yield : The maximum grain yield was observed in 150% RDF and it was statistically at par with 100% RDF. Among the genotypes, SPV 2789 was found significantly superior over rest of the genotypes.

Significant increase in grain production of crop up to 150% RDF could be ascribed to profound effect of N, P and K fertility levels on vegetative and reproductive growth stages of the crop due to increment in nutrient content and uptake as well as production of photosynthates and their translocation to grain. These findings on grain yield are agreed with Thakare *et al.* (2020), Bhutada *et al.* (2019). The variation in these parameters might be due to differential capability of genotypes in utilizing the available resources. Yadav *et al.* (2019) findings found similarity with our results.

Straw yield : The maximum grain yield was observed in 150% RDF and it was statistically at par with 50% and 100% RDF. Among the genotypes, SPV 2789 was recorded significantly superior over rest of the genotypes.

Straw yield also enhanced significantly with increase of fertilizer level up to 150% RDF. The positive effect of fertility levels show on Straw yield by nutrients were involved in increasing protoplasmic constituents, root, shoot growth and accelerating the process of cell division, enlargement and elongation which in turn showed higher straw yield. Similar results are also reported by Oberoi and Kaur (2020), Yadav *et al.* (2019). The variation in these parameters might be due to differential capability of genotypes in utilizing the available resources. These

Table-1 : Effect of fertility level and genotypes on growth of sweet sorghum.

Treatment detail	Plant population	Plant height				Dry matter accumulation				Days to 50% flowering	Days to 50% maturity
		25 DAS	50 DAS	75 DAS	At harvest	25 DAS	50 DAS	75 DAS	At harvest		
Fertility levels											
Control	5.0	73.7	90.24	147.9	200.0	2.84	16.08	53.41	92.3	81.6	93.0
50% RDF	5.4	75.8	94.53	164.0	218.3	3.60	16.76	60.82	106.2	78.6	91.7
100% RDF	5.4	82.7	100.71	172.4	221.4	3.87	18.22	67.62	114.1	77.9	91.8
150% RDF	5.5	83.1	107.14	172.9	236.5	4.13	19.01	70.64	117.8	73.1	89.7
SEm±	0.26	2.00	2.98	4.08	5.76	0.10	0.59	2.00	3.47	1.43	0.64
CD (P=0.05)	NS	6.92	10.31	14.13	19.94	0.35	2.04	6.90	12.01	4.93	NS
Genotypes											
SPV 2789	5.4	82.7	104.40	173.8	230.6	4.28	18.80	68.92	114.8	79.3	91.5
SPV 2794	5.1	77.1	92.49	162.3	211.4	3.01	16.64	58.70	100.6	78.8	91.3
CSH 22SS	5.5	76.7	97.58	156.9	215.1	3.54	17.11	61.76	107.4	75.2	91.8
0SEm±	0.14	1.57	2.43	3.38	3.88	0.07	0.28	1.44	2.12	1.14	0.44
CD (P=0.05)	NS	4.70	7.30	10.13	11.64	0.20	0.83	4.32	6.36	3.43	NS

Table-2 : Effect of fertility level and genotypes on yield of sweet sorghum.

Treatment details	Grain yield (kg ha ⁻¹)	Straw Yield (kg ha ⁻¹)
Fertility levels		
Control	1887	7879
50% RDF	2146	8789
100% RDF	2464	9433
150% RDF	2496	9505
SEm±	65	276
CD (P=0.05)	225	956
Genotypes		
SPV 2789	2405	9391
SPV 2794	2157	8658
CSH 22SS	2183	8656
SEm±	52	212
CD (P=0.05)	156	635

findings on grain and straw yield are agreed with Mishra et al. (2017).

Conclusions

This study concluded that higher recommended dose of fertilizer gave maximum growth and yield at each cut and among hybrids SPV 2789 gave best results on growth parameters and yield.

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Effect of Supplementation of Tulsi (*Ocimum sanctum*) and Ginger (*Zingiber officinale*) Powder as Feed Additives on Carcass Characteristics of Japanese Quail (*Coturnix japonica*)

Dashrath Singh Chundawat^{1*}, Lokesh Gupta¹, Bhavya Pal¹, Pawan Acharya¹, Surendra Singh¹ and Anita Kumari Meena¹

¹Department of Animal Production, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan

*Corresponding Author Email : dschundawat2018@gmail.com

Abstract

The present study was conducted to evaluate effect of supplementation of tulsi (*Ocimum sanctum*) and ginger (*Zingiber officinale*) powder as feed additives on carcass characteristics of Japanese quail (*Coturnix japonica*). Two hundred ten, Japanese quail chicks (day-old) were used in a completely randomized design in 7 treatments with 3 replicates, each consisting of 10 chicks. Seven different experimental diets were prepared for feeding of Japanese quail under different dietary groups. The dietary treatment consists of basal diet T1 (Control) feeding without additives, T2 (T1 + Tulsi powder @ 0.5%), T3 (T1 + Ginger powder @ 0.5%), T4 (T1 + Tulsi powder @ 0.25% + Ginger powder @ 0.25 %), T5 (T1 + Tulsi powder @ 1 %), T6 (T1+ Ginger powder @ 1 %) and T7 (T1 + Tulsi powder @ 0.5% + Ginger powder @ 0.5%). The effect of supplementation was studied on live weight, dressed weight, eviscerated weight, giblet weight (g/bird), dressing percentage and eviscerated percentage (% of live weight) of birds were measured at the end of experiment. The weight of individual organ (heart, gizzard and liver) as per cent of live weight was also studied. From the results, it may be concluded that supplementation of 0.5% tulsi + 0.5% ginger powder in diet is beneficial in improving carcass characteristics of Japanese quail.

Key words : Japanese quail, tulsi, ginger, carcass, dressed weight, giblet weight.

Introduction

Poultry in agriculture sector is one of the fastest growing sectors in India with an average growth rate of 6 per cent in egg production and 12 per cent for broiler production per annum. Eggs and poultry meat has emerged next to milk as a contributor to the output from livestock sector in recent years. The percentage contribution of eggs and poultry meat was 4.47 percent in 1951-52, which reached to a little over 9 per cent in 2015-16. India is the third largest producer of eggs with total production of 129.60 billion eggs and eighth largest meat producers with 9.29 million tonnes meat in 2021-22 (Annual Report, 2022-23, Department of Animal Production and Dairying, Ministry of Fisheries, Animal Husbandry and Dairying, Govt. of India). As per 20th livestock census, the total poultry population in Rajasthan has registered a phenomenal increase of about 80% over last livestock census and the current poultry population of Rajasthan which is about 14.62 million, however, it is only 1.72% of poultry population of India. Rajasthan holds 17th rank in poultry population (Economic survey 2020-21).

Feed is a major component, affecting net profit from the poultry industry, as more than 75% of the total cost in terms of cash is spent on poultry raising. A feed additive is a substances or mixture of substances other than the basal diet used in small quantities in order to improve the

quality of feed stuff and performance of birds. Present time, various types of chemical substances are used as feed supplements to increase production parameter of poultry. These type chemical substances may produce many adverse effects like stress, toxicity and immune suppression if fed inappropriate quantity. In recent the restriction of the use of these harmful chemical substances and shifted towards the natural and herbal substances of produce to optimize productivity of birds.

Tulsi (*Ocimum sanctum*), is described as sacred and medicinal plant in Ayurveda. It is one of the holiest and most cherished herbs in India. Medicinal herbs (Tulsi), as a new class of additives to animal and poultry feeds, have beneficial properties such as anti-oxidant, anti-microbial and anti-fungal as well as immunomodulatory and anticoccidial qualities, which lead to their increased use. Ginger belongs to the family Zingiberaceae; which are aromatic herbs with fleshy, tuberous or non-tuberous rhizomes and, often have tuber bearing roots (Ke *et al.*, 2000). Ginger has also been known to have antioxidant activity due to presence of gingerol-related compounds (Kikuzaki and Nakatani, 1993). Ginger as a natural feed additive may be of immense benefit and value in poultry nutrition especially for broilers due to their antibacterial, anti-inflammatory antiseptic, antiparasitic and immune-modulatory properties (Onu, 2010). Therefore, in

the present study the tulsi (*Ocimum sanctum*) and ginger (*Zingiber officinale*) powder will be used as feed additive.

Materials and Methods

Experimental birds : The 210 chicks of Japanese quail were procured from hatchery unit of Poultry Farm, Department of Animal Production, Rajasthan College of Agriculture, Udaipur. Day old, Japanese quail chicks were randomly divided into 7 treatment groups with 3 replications (10 chicks in each replication) for 8 weeks. All the birds were reared under cage system for eight weeks with identical standard management practices. Birds were provided free access to feed and water during the entire experimental period.

Experimental diets : Feed ingredients like Maize, Soya-DOC, Broken Rice and DCP were used with feed additives such as Tulsi (*Ocimum sanctum*) and Ginger (*Zingiber officinale*) powder for preparation of feed. The dietary treatment consists of basal diet T1 (Control) feeding without additives, T2 (T1 + Tulsi powder @ 0.5%), T3 (T1 + Ginger powder @ 0.5%), T4 (T1 + Tulsi powder @ 0.25% + Ginger powder @ 0.25 %), T5 (T1 + Tulsi powder @ 1 %), T6 (T1+ Ginger powder @ 1 %) and T7 (T1 + Tulsi powder @ 0.5% + Ginger powder @ 0.5%). The ME content of grower rations was 2907, 2892, 2892, 2892, 2878, 2878 and 2878 (kcal/kg) in in T1, T2, T3, T4, T5, T5, T6 and T7, respectively.

Carcass Parameters : At the end of experiment, three birds were randomly selected from each treatment groups (one from each replication) for studying carcass parameter. All the 21 birds selected for carcass characteristics were offered ad libitum water and kept off feed for 12 hours before slaughter. Live weights of quail birds were recorded before slaughtering. birds were bled five minutes following slaughtering and each bird was dipped in hot water bath. Feathers were removed manually. After removal of head, feathers and shank dressed weight was determined. Evisceration was done after scalding and defeathering and internal organ such as heart, liver and gizzard. weight of internal organs was also weighed.

Statistical Analysis : Data collected during the present investigation were subjected to statistical analysis by adopting appropriate methods of analysis of variance as described by Snedecor and Cochran (1994). Probabilities values of less than 0.05 ($P < 0.05$) were considered significant.

Results and Discussion

The data on carcass parameters under various treatment groups are presented in Table-1. The carcass characteristics such as live weight, dressed weight,

dressing percentage, eviscerated weight, eviscerated percentage and organ weight were studied during the end of experiment. The weight of different organ namely heart, gizzard and liver were expressed as percentage of live weight. The data revealed that the difference in carcass parameters was significant among different treatment groups except heart, gizzard and liver weight.

The live weight (Table-1) of the Japanese quail birds was 256.13 ± 1.61 , 267.13 ± 0.79 , 265.85 ± 0.63 , 285.23 ± 0.86 , 264.37 ± 0.71 , 266.17 ± 0.81 and 305.67 ± 0.67 g in T1, T3, T4, T5, T6 and T7 groups, respectively. The live weight was significantly highest in T7 and significantly lowest in T1 as compare to rest of groups. The difference among T2, T3, T5 and T6 was found statistically non-significant for live weight of Japanese quail.

The dressed weight (Table-1) was 195.01 ± 2.77 , 199.18 ± 2.21 , 198.04 ± 1.65 , 222.11 ± 1.61 , 200.39 ± 2.47 , 200.17 ± 1.82 and 238.18 ± 1.93 g in T1, T3, T4, T5, T6 and T7 groups, respectively. The dressed weight was significantly highest in T7 as compare to rest of groups. Dressed weight of all treatments except T4 and T7 was found statistically non-significant.

The dressing percentage (Table-1) was 76.13 ± 0.62 , 74.56 ± 0.61 , 74.49 ± 0.45 , 77.87 ± 0.33 , 75.80 ± 0.79 , 75.2 ± 0.46 and 77.92 ± 0.46 g in T1, T3, T4, T5, T6 and T7 groups, respectively. The dressing percentage was significantly higher in T7 and lowest in T1. The difference among all treatments except T4 and T7 was noted found statistically non-significant.

The eviscerated weight (Table-1) of the Japanese quail birds was 161.74 ± 2.32 , 170.57 ± 0.31 , 169.78 ± 0.04 , 190.38 ± 0.74 , 171.24 ± 1.84 , 169.88 ± 0.10 and 203.57 ± 2.39 g in T1, T3, T4, T5, T6 and T7 groups, respectively. The eviscerated weight was significantly highest in T7. The difference for eviscerated weight among T2, T3, T5 and T6 was statistically non-significant.

The eviscerated percentage (Table 1) was 63.14 ± 0.53 , 63.85 ± 0.22 , 63.87 ± 0.14 , 66.75 ± 0.07 , 64.78 ± 0.87 , 63.82 ± 0.22 and 66.60 ± 0.64 g in T1, T3, T4, T5, T6 and T7 groups, respectively. The eviscerated percentage was significantly higher in T7. The difference among T2-T3-T5-T6 and T1-T2-T3-T6 was found statistically non-significant for eviscerated percentage.

The giblet weight (Table-1) was 15.52 ± 0.13 , 16.24 ± 0.09 , 16.10 ± 0.08 , 17.94 ± 0.10 , 16.23 ± 0.08 , 16.33 ± 0.09 and 19.53 ± 0.09 g in T1, T3, T4, T5, T6 and T7 groups, respectively. The giblet weight was significantly highest in T7 as compare to rest of groups. There was non-significant difference among T2, T3, T5 and T6.

The weight of individual organ (Table-1) as per cent

Table-1 : Effect of supplementation of tulsi and ginger powder on carcass parameters.

	T1	T2	T3	T4	T5	T6	T7	SEm±	CD at 5%
Live Weight (g/bird)	256.13 ^d ±1.61	267.13 ^c ±0.79	265.85 ^c ±0.63	285.23 ^b ±0.86	264.37 ^c ±0.71	266.17 ^c ±0.81	305.67 ^a ±0.67	0.92	2.83
Dressed Weight (g/bird)	195.01 ^c ±2.77	199.18 ^c ±2.21	198.04 ^c ±1.65	222.11 ^b ±1.61	200.39 ^c ±2.47	200.17 ^c ±1.82	238.18 ^a ±1.93	2.10	6.44
Dressing Percentage	76.13 ^b ±0.62	74.56 ^b ±0.61	74.49 ^b ±0.45	77.87 ^a ±0.33	75.80 ^b ±0.79	75.2 ^b ±0.46	77.92 ^a ±0.46	0.55	1.68
Eviscerated Weight (g/bird)	161.74 ^d ±2.32	170.57 ^c ±0.31	169.78 ^c ±0.04	190.38 ^b ±0.74	171.24 ^c ±1.84	169.88 ^c ±0.10	203.57 ^a ±2.39	1.47	4.51
Eviscerated Percentage	63.14 ^c ±0.53	63.85 ^{bc} ±0.22	63.87 ^{bc} ±0.14	66.75 ^a ±0.07	64.78 ^b ±0.87	63.82 ^{bc} ±0.22	66.60 ^a ±0.64	0.47	1.45
Giblet Weight (g/bird)	15.52 ^d ±0.13	16.24 ^c ±0.09	16.10 ^c ±0.08	17.94 ^b ±0.10	16.23 ^c ±0.08	16.33 ^c ±0.09	19.53 ^a ±0.09	0.10	0.30
Organ weight as percentage of live weight									
Heart	0.95±0.01	0.93±0.01	0.92±0.01	1.02±0.01	0.95±0.01	0.94±0.01	1.04±0.01	0.01	NS
Liver	2.60±0.01	2.62±0.01	2.59±0.01	2.67±0.01	2.65±0.01	2.64±0.01	2.70±0.01	0.01	NS
Gizzard	2.51±0.01	2.53±0.01	2.55±0.01	2.60±0.01	2.54±0.01	2.55±0.01	2.65±0.01	0.01	NS

Figures bearing different superscript in a row differ significantly ($P < 0.05$) from each other

of live weight was also studied. The heart weight (% of live weight) was 0.95 ± 0.01 , 0.93 ± 0.01 , 0.92 ± 0.01 , 1.02 ± 0.01 , 0.95 ± 0.01 , 0.94 ± 0.01 and 1.04 ± 0.01 in T1, T3, T4, T5, T6 and T7 groups, respectively which are found statistically non-significant. The liver weights (% of live weight) was 2.60 ± 0.01 , 2.62 ± 0.001 , 2.59 ± 0.01 , 2.67 ± 0.01 , 2.65 ± 0.01 , 2.64 ± 0.01 and 2.70 ± 0.01 in T1, T3, T4, T5, T6 and T7 groups, respectively. The perusal of data revealed that the difference in the liver weight was non-significant. Similar trend was also found with respect to gizzard weigh (% of live weight), the values were 2.51 ± 0.01 , 2.53 ± 0.001 , 2.55 ± 0.01 , 2.60 ± 0.01 , 2.54 ± 0.01 , 2.55 ± 0.01 and 2.65 ± 0.01 in T1, T3, T4, T5, T6 and T7 groups, respectively.

The interpretation of data revealed that the live weight, dressed weight, eviscerated weight and giblet weight (g/bird) was highest in T7 group and lowest in control group (T1). The dressing percentage and eviscerated percentage (% of live weight) was highest in T7 group as compared to rest of groups. The heart, liver and gizzard percentage (% of live weight) was found statistically non-significant in all treatment groups but numerically highest weight was observed in T7 group as compared to other groups. It can be visualized from the data obtained in the present study that the carcass parameters increased when the tulsi and ginger were included in alone and its combination in the diet of Japanese quails.

Similarly, the results of present study are in close agreement with the findings of Eltazi (2014) who reported that using a mixture of garlic and ginger as feed additives enhanced the carcass quality of broilers. However, Arif *et al.* (2022) concluded that the carcass weight was significantly improved by Aloe vera and clove powder as a supplementation in diets of Japanese quail. Okoleh *et al.* (2014) also reported that the use of garlic and ginger in diet had a significant effect on dressing percentage of broilers. Mahumud (2014) reported the live body weight and dressing percentage was improved with

supplementation of fennel seed meal in diet Japanese quail. Elmakki *et al.* (2013) carried out study on the effect of ground ginger root (*Zingiber officinale*) addition in the diet of broiler chicks and reported that carcass weight was higher for birds fed ginger in diet, in comparison to control.

Naeem *et al.* (2021) reported no significant effect of tulsi supplementation on heart in all groups but heart weight was numerically increased with supplementation of tulsi in Japanese quail. Deepthi *et al.* (2020) also reported that supplementation of ajwain powder in diet of Japanese quail had no significant effect on per cent weight of heart, gizzard, liver and giblets in quail. However, Mahumud (2014) observed that the liver, heart and gizzard percentage of Japanese quail was non-significantly increased on supplementation of fennel seed in Japanese quail diet. The results are in close agreement with the findings reported in the present study on supplementation of tulsi and ginger in Japanese quails.

Conclusions

From the results, it may be concluded that supplementation of 0.5% tulsi + 0.5% ginger powder in diet is beneficial in improving carcass characteristics of Japanese quail. Thus, supplementation of 0.5% tulsi along with 0.5% ginger powder in the diets is recommended for improved growth and carcass traits of Japanese quails.

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To measure the Impact of Water Diggis on Beneficiary Farmers in Bikaner District of Rajasthan

Rakesh Chouhan¹, S.R. Singh¹, Suresh Chandra Sharma¹ and Rajesh Kumar Serawat²

¹Choudhary Charan Singh National Institute of Agricultural Marketing

²Department of Extension Education, College of Agriculture, Jodhpur

Abstract

In the arid region of Rajasthan, India, it is very often a challenge to store up rain/surface water for year-round use by human and livestock. The inhabitants of this desert area have developed several water storages structures, which they used to construct based on their indigenous knowledge of local terrain conditions. Recently, farmers living in the lower command areas of Indira Gandhi Canal have constructed micro-farm water storage structures, called diggi, in their cropland. They store allocated canal water in diggi to timely utilize it as per irrigation requirements, and thus, done away with problems of deficit and untimely canal water supply. This impact assessment study carried out by CCS NIAM, Jaipur. This study was carried out in Khajuwala and Lunkaransar tehsils of Bikaner district in Rajasthan.

Key words : Diggi, micro-farm water storage structures, indigenous system, irrigated agriculture, canal command area.

Introduction

"Diggi", a "surface water bank" is an intermediate water storage tank between the watercourse and the farm. It is a farmer's response to water scarcity and unreliable canal water supply in the IGNP. The canal irrigated area in the IGNP command has gradually increased over the last 20 years. Accordingly, the frequency of canal water releases to the farms in the command area has decreased. Initially, the number of turns into the field was 4 turns a month, and 4-5 hours per each turn. Today, with increasing command area, the number of turns has decreased to two times a month and 2-3 hours per each turn. The reduction of duration of water supply had many negative implications, which includes decreased irrigated area; crop failures; and in some cases where the supply was not adequate or available to meet crop requirement at the critical stages of growth. India has about 31.7 million ha (m ha) land under hot arid zone and a major proportion of such land (62% or 19.6 m ha) lies in the Great Indian Desert region situated in Rajasthan. The arid region of Rajasthan, which is bounded by aridity index values between -59.5 in the east (in Sikar district) and -88.9 in the west (in Jaisalmer district) comprises twelve districts (Ram, 2014). There is a wide spatial variability in the rainfall distribution that influences the availability of water resources. The annual rainfall is the lowest (100-150 mm) in the west and the highest (500-600 mm) in the east that helps about 75% of desert dwellers to continue agriculture at least once in a year.

Research Methodology

As per 2011 census, Khajuwala and Lunkaransar block

has a geographical area of 5453.24 and 6328.02 km² respectively. The blocks are located within the desert area of the Bikaner district where 58% of the area is covered by sand dunes and 33% area by sandy plains (Moharana *et al.*, 2013). The western, southwest, northern and northeast parts of the district are largely covered with 12 to 20 m high sand dunes. The district receives a scanty annual rainfall that varies from 300 mm (in the east) to 180 mm (in the west). The surface water resources of the district are rather meager, due to erratic and low rainfall, large infiltration rate of the upper sediments and practically having no river system. Under such situation, the segment of IGNP (Indira Gandhi Nahar Pariyojana) passing through the district is the lifeline for people including Khajuwala and Lunkaransar tehsils, livestock and agriculture.

This study was carried out in Bikaner district in Rajasthan, India. There are total nine tehsils in Bikaner district of Rajasthan, out of which, two tehsils namely Khajuwala and Lunkaransar tehsils were selected. Five villages from each selected tehsil were selected on the basis of maximum number of diggi beneficiaries. 50 beneficiaries were selected from ten selected villages by these were having maximum number of diggi were selected for research study (5 farmers from each selected village were selected). Data and information were collected by investigator through personal interview technique with the help of interview schedule. Thereafter, data were tabulated and various statistical measures viz. per cent, mean, mean per cent scores, standard deviation, ranking and correlation were used to arrive at specific inference.

Table-1 : Socio-economic characteristics of the respondents.

S. No.	Variables	Frequency	Percentage (%)	
1.	Age	Young Age <35	15	30
		Middle Age (36-58)	26	52
		Old Age >59	9	18
2.	Education level	Illiterate	24	48
		Primary school	15	30
		Middle school	7	14
		High school	2	4
		College	2	4
3.	Land Holding	Small (<0.5 ha)	13	26
		Medium (0.6- 1 ha)	28	56
		Large (>1 ha)	9	18
4.	Annual income (Rs.)	<18,000/-	5	10
		19,000-30,000/-	28	56
		>31,000	17	34
5.	Type of Farmer	Small Farmer	10	20
		Medium Farmer	29	58
		Large Farmer	11	22
6.	Area under crop	1-5 Ha	9	18
		6-10 Ha	31	62
		> 10 Ha	10	20
7.	Irrigation source	Diggi	50	100
8.	Market Type	Mandi	35	70
		Retailer	9	18
		Wholesaler	6	12
9.	Distance of field to market (km)	1-5 Km	8	16
		6-10 Km	27	54
		>11 Km	15	30
10.	Cost of Diggi (Lacks Rs.)	1-5 lacks	11	22
		6-8 lacks	29	58
		>9 lacks	10	20

Table-2 : Distribution of the respondents according to change in cropping pattern.

Categories		Change in Cropping Pattern							
		Before				After			
		Number		percent		Number		percent	
Low	5.231003	14	28	Low	7.137396057	7	14		
Medium	5.231003 8.128997	31	62	Medium	7.137396057 8.942603943	29	58		
High	8.128997	5	10	High	8.942603943	14	28		
		50	28			50	14		
Mean	6.68 SD	1.448996838		Mean	8.04 SD	0.902604			

Results and Discussion

In absence of proper bench mark observations, the study attempted comparison between beneficiaries before and after use of diggi respectively. For the reason that all the situational, administrative, climatic and other such forces should be common to both. It was assumed that the higher change would be observed in use of diggis. Therefore, in order to isolate impact of diggi the comparison between after and before use of diggi was made.

Change in cropping pattern : It was revealed from Table-2 that cropping pattern (area) of all crops viz. wheat,

barley, oats, mustard, bajra, linseed, cluster bean, and sesame etc. increased from 10 per cent to 28 per cent in high category of cropping pattern. Likewise in low category, per cent of the beneficiaries decreased from 28 per cent to 14 per cent after the diggis. Most of the beneficiaries came under medium category. It was found that after the diggi per cent of the beneficiaries were 58 in comparison to 62 per cent before diggi. Mean of change in cropping pattern of beneficiaries was 8.04 (after farm pond) and 6.68 (before farm pond). The standard deviation was 1.44 (before diggi) and 0.90 (after diggi). It was assumed that the scores in different categories were

Table-3 : Distribution of the respondents according to change in crop productivity.

S. No.	Crops	Productivity q/ha		Percentage Increase
		Before Diggi	After Diggi	
A. Rabi				
1.	Wheat	41.02593	45.97485	10.7644
2.	Barley	48.9322	52.93056	7.553958
3.	Oates	13.04651	15.87337	17.80879
4.	Mustard	14.96711	17.9671	16.69716
5.	Linseed	4.035885	5.244397	23.04386
	Total Rabi	122.0076	137.9903	11.58243
B. Karif				
1.	Pearl millet	13.02549	15.02546	13.31056
2.	Moth bean	5.964912	8.013186	25.56129
3.	Cluster Bean	70.68	78.54	10.00764
4.	Sesame	6.030875	7.587	20.51041
	Total Kharif	95.70128	109.1656	12.33389

Table-4 : Distribution of the respondents according to change in cropping intensity.

S. No.	Crops	Area Before Diggi	Percentage	Area After Diggi	Percentage
A. Rabi					
1.	Wheat	77.12	28.88714	83.5	28.14
2.	Barley	44.25	16.5749	46.8	15.77
3.	Oates	43	16.10668	49.75	16.77
4.	Mustard	60.8	22.77409	65.35	22.02
5.	Linseed	41.8	15.65719	51.31	17.29
	Total Rabi	266.97		296.71	
B. Karif					
1.	Pearl millet	84.35	40.47505	86.4	38.81
2.	Moth bean	42.75	20.51344	47.4	21.29
3.	Cluster Bean	41.3	19.81766	45.3	20.35
4.	Sesame	40	19.19386	43.55	19.56
	Total Kharif	208.4		222.65	
	Gross Cropped Area	475.37		519.36	
	Net cultivated Area	337.7166809		337.7166809	
	Cropping Intensity	140.76		153.7857113	
	Percentage Change in Cropping Intensity			8.47	

taken as rounded figure. Calculated 'Z' value showed that difference in change in cropping pattern of before and after of diggi beneficiaries is positive and significant.

Before construction of diggi respondents followed traditional cropping pattern *i.e.* they cultivated only one or two crops. After construction of diggi cropping pattern changed to growing more than one or two crops particularly in *Rabi* crops.

This result indicated that after construction of diggi the cropping pattern changed due to availability of water for irrigation and putting additional land for cultivation of more crops. The findings were supported by Ahire (2000), Mankar (2014) and Desmukh *et al.* (2017).

Change in crop productivity : It is revealed from Table-3 that all the crops showed change in average productivity in positive direction *i.e.* increase in productivity. Majority of *Kharif* and *Rabi* crops showed increase in average

productivity. In *Kharif* crops bajra, moth been, sesame and cluster bean were increased in average productivity *i.e.* 11.72 %, 7.17%, 16.64 % and 17.52 % over base year, respectively.

With regards to *Rabi* crops, there were change in average productivity in wheat, barley, mustard, gram and pea with per cent change 13.31%, 25.56 %, 10.00 % and 20.51 16.71%, respectively. The findings are in line with Ahire (2000), Nipanikar (2006), Kulkarni (2009), Thakur (2014) and Chavai and Sinde (2017).

From the above findings it could be concluded that there was definite impact of diggis on productivity of different *Kharif*, and *Rabi* crops mostly due to availability of protective irrigation facility from diggi and also drip irrigation facility. All the crops showed change in average productivity in positive direction *i.e.* increase in productivity. Majority of *Kharif*, and *Rabi* crops showed increase in average productivity.

Change in cropping intensity : It is concluded from the Table-4 that after construction of diggi the area in hectares in most of the crops has been increased. A critical observation of change in cropping intensity Table - 4 revealed that the gross cropped area increased from 475.37 ha. to 519.36 ha. after construction of diggi over before construction of diggi. Before construction of diggi the cropping intensity was 140.76 per cent whereas after construction of diggi it was 153.78 per cent. After construction of diggi the per cent change in cropping intensity was observed as 8.47 per cent. As far as *Kharif* crops concerned there were no much change in area.

Conclusions

The findings of the study indicated that cropping pattern (area) of all crops *viz.* wheat, barley, oat, mustard, bajra, and sesame etc. increased from 10 per cent to 28 per cent in high category of cropping pattern and also And in low category decreased from 28 per cent to 14 per cent after the diggis. In *Kharif* crops bajra, cluster been and sesame, there were maximum increase in average productivity 13.31 %, 25.56 %, and 20.57% over base year respectively. With regards to *Rabi* crops there were change in average productivity in wheat, barley, oats, mustard and linseed with per cent change 10.76 %, 7.5 %, 17.80 %, 16.69%, and 23.04% respectively. The study clearly showed that before construction of diggis the cropping intensity was 140.76 the per cent whereas after construction of diggis it was 153.78 per cent. After construction of diggis change in cropping intensity was observed as 8.47 per cent.

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Growth and Quality of Indian Mustard [*Brassica juncea* (L.)] As Influenced by Hydrogel and Irrigation Levels

Manendra Nunia*, P.K. Sharma and Nitesh Rar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan-303012, India

*Corresponding Author Email : manendranunia@gmail.com

Abstract

India is one of the top producing countries in the world for oilseeds. The oilseed crop is the second-largest agricultural output after cereals. A field experiment was conducted at carried out during *rabi* season of the year 2022-23 at Agricultural Farm in Kolida village near Sikar district of Rajasthan under the guidance of Department of Agriculture, Vivekananda Global University, to study the effect of hydrogel and irrigation levels on growth and quality of mustard. The experiment consisted of 9 treatment combinations comprising three levels of hydrogel (control, hydrogel at 2.5 kg/ha and hydrogel at 5.0 kg/ha) with three levels of irrigation (no irrigation, one irrigation and two irrigation). The experiment was laid out in Factorial Randomized Block Design and replicated thrice. Results showed that the significantly highest plant height at harvest, dry matter accumulation, number of branches per plant, protein content, oil content and oil yield of mustard was significantly increased with the application H₂ (hydrogel at 5.0 kg/ha). Further showed that the significantly highest plant height, dry matter accumulation, number of branches per plant, protein content, oil content and oil yield of mustard was significantly increased with the application of two irrigation (I₂).

Key words : Hydrogel, plant height, protein and oil.

Introduction

Brassica juncea (L.) Czern & Coss., the second-largest edible oilseed crop in India, providing the majority of the people in all the northern states with the necessary fat [1]. A total of 68.57 lakh hectares are used to manufacture the mustard oil cake, which has a 40% protein content. Additionally, it contains 1.8% phosphorus, 5.1% nitrogen, and 1.2 percent potassium [2]. The absence of winter rainfall means that mustard reacts better to irrigation. Due to its higher susceptibility to water changes and its relative presence throughout important growth periods, this crop's yield suffered [3]. The Indian mustard's production was improved by irrigation at crucial phases, possibly as a result of the plant's increased nutritional availability and more effective metabolic processes [4]. Furthermore, it is generally agreed that timing irrigation during crucial crop growth phases would maximise the use of limited irrigation water [5].

The bulk of Indian soils are deficient in nitrogen and organic matter. These soils feature a loose structure, compaction, crusting, and setting properties. These problems result in the soil retaining less water and increasing its susceptibility to erosion. The role of organic materials in maintaining and enhancing soil fertility is well established, and it must be preserved in order to maintain a sustainable level of production. The ecologically friendly and effective method of recycling food and agricultural waste is vermicomposting. The application of vermicompost not only adds plant nutrients (macro and

micro) and growth regulators to one but also increases soil water retention, microbial population, humic substances of the soil, mineralization and release of nutrients. Besides these, vermicompost also improves soil aeration, reduction of soil erosion, reduces evaporation losses of water, accelerates the process of humification, stimulates the microbial activity, destruction of pathogens, detoxification of pollutant in soil etc [6]. Since FYM is the source of all necessary nutrients, it enhances the humus and organic matter components of the soil. Additionally, FYM is crucial for the habitation of good bacteria, which makes nutrients available to the crops. The majority of crops take up nitrogen in the form of nitrate, which is only changed by soil microorganisms. Even in soils damaged by salt or soils with high pH, FYM containing humic acid helps to hold plant nutrients in an exchangeable or accessible state. To preserve the fertility and productivity of the soil, FYM has long been employed in agriculture [7].

The most precious resource, water, has a significant influence on applied input efficiency and individual factor production, especially in semi-arid environments. Because of greater non-beneficial evapotranspiration, *rabi* crops are watered by surface irrigation systems, which have an irrigation efficiency as low as 30–40% [8]. Over 40% of the mustard grown in underdeveloped countries is produced using irrigation systems. Deficit watering has been proven to have an impact on mustard output and water use efficiency (WUE). Moreover, the

Table-1 : Effect of hydrogel and irrigation levels on plant height at different stages of mustard.

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Hydrogel				
H ₀ -Control	28.66	60.11	92.14	139.46
H ₁ -Hydrogel @ 2.5 kg/ha	35.69	70.95	110.19	166.17
H ₂ -Hydrogel @ 5.0 kg/ha	40.45	78.19	121.25	180.32
SEm±	0.85	2.01	3.47	4.62
CD (P=0.05)	2.45	5.79	10.03	13.35
Irrigations				
I ₀ -No irrigation	28.73	60.21	92.04	140.53
I ₁ -One irrigation	35.77	70.70	109.66	165.77
I ₂ -Two irrigation	40.31	78.34	121.88	179.65
SEm±	0.85	2.01	3.47	4.62
CD (P=0.05)	2.45	5.79	10.03	13.35
CV (%)	7.28	8.63	9.66	8.56

Table-2 : Effect of hydrogel and irrigation levels on dry matter accumulation at different stages of mustard.

Treatments	Dry matter accumulation (g m ⁻¹ row length)			
	30 DAS	60 DAS	90 DAS	At harvest
Hydrogel				
H ₀ -Control	28.64	62.46	132.44	162.84
H ₁ -Hydrogel @ 2.5 kg/ha	37.96	81.00	161.82	190.64
H ₂ -Hydrogel @ 5.0 kg/ha	42.45	92.98	178.36	206.49
SEm±	1.03	1.87	4.90	5.28
CD (P=0.05)	2.97	5.41	14.15	15.25
Irrigations				
I ₀ -No irrigation	28.43	62.61	132.41	159.93
I ₁ -One irrigation	38.02	80.98	161.88	190.28
I ₂ -Two irrigation	42.60	92.85	178.33	209.76
SEm±	1.03	1.87	4.90	5.28
CD (P=0.05)	2.97	5.41	14.15	15.25
CV (%)	8.49	7.13	9.33	8.49

scheduling of irrigation is a key to water Management. Irrigation missing at some critical growth stage sometime drastically reduces grain yield due to lower test weight. Efficient water management, being one of the good agronomic management practices, it not only leads to improve crop productivity but also minimize susceptibility from disease and insect pest under favorable environment for flourishing these biotic stresses [9]. Keeping these facts in view, the present investigation was planned with an objective the effect of hydrogel and irrigation levels on growth and quality of mustard.

Materials and Methods

The experiment was laid out at Agricultural Farm in Kolida village near Sikar district of Rajasthan under the guidance of Department of Agriculture, Vivekananda Global University, Jaipur during *rabi* seasons of the years 2022-23. It is situated at 27° 61" North latitude and 75° 13" East longitudes at an altitude of 427 meters above mean

sea level. In Rajasthan, this region falls under Agro-climatic zone-IIA (Transitional Plains of Inland Drainage). The region has typically semi-arid climate characterized by dryness of atmosphere. The annual total rainfall of the zone varies between 350 and 450 mm, most of which is received from July to September. The temperature may go as high as 48 °C during summer and it may fall below freezing point during winter. During summers, the temperature may go as high as 46°C, while, in winters, it may fall as low as 1.0 °C. The rainfall of this tract varies from 800-900 mm, most of which is contributed by south-west monsoon during the months of July and August. The soil of the experimental field was silt loam in texture, alkaline in reaction (pH 7.95), poor in organic carbon (0.32 %), low in available nitrogen (181.60 kg/ha), medium in phosphorus (18.75 kg/ha) and potassium (291.19 kg/ha). The experiment consisted of 9 treatment combinations comprising three levels of hydrogel (control, hydrogel at 2.5 kg/ha and hydrogel at 5.0 kg/ha) with three

Table-3 : Effect of hydrogel and irrigation levels on branches per plant of mustard.

Treatments	Branches per plant
Hydrogel	
H ₀ -Control	4.29
H ₁ -Hydrogel @ 2.5 kg/ha	5.30
H ₂ -Hydrogel @ 5.0 kg/ha	5.77
SEm±	0.12
CD (P=0.05)	0.35
Irrigations	
I ₀ -No irrigation	4.35
I ₁ -One irrigation	5.30
I ₂ -Two irrigation	5.71
SEm±	0.12
CD (P=0.05)	0.35
CV (%)	7.00

Table-4 : Effect of hydrogel and irrigation levels on protein content and protein yield of mustard.

Treatment	Protein content (%)	Protein yield (kg/ha)
Hydrogel		
H ₀ -Control	14.69	164.55
H ₁ -Hydrogel @ 2.5 kg/ha	17.38	271.88
H ₂ -Hydrogel @ 5.0 kg/ha	19.44	333.28
SEm±	0.36	8.94
CD (P=0.05)	1.03	25.82
Irrigations		
I ₀ -No irrigation	14.74	163.32
I ₁ -One irrigation	17.33	271.76
I ₂ -Two irrigation	19.43	334.63
SEm±	0.36	8.94
CD (P=0.05)	1.03	25.82
CV (%)	6.24	10.45

Table-5 : Effect of hydrogel and irrigation levels on oil content and oil yield of mustard.

Treatment	Oil content (%)	Oil yield (kg/ha)
Hydrogel		
H ₀ -Control	29.350	327.201
H ₁ -Hydrogel @ 2.5 kg/ha	33.050	514.622
H ₂ -Hydrogel @ 5.0 kg/ha	35.190	600.418
SEm±	0.981	18.632
CD (P=0.05)	2.833	53.807
Irrigations		
I ₀ -No irrigation	29.167	321.123
I ₁ -One irrigation	32.570	507.484
I ₂ -Two irrigation	35.853	613.634
SEm±	0.981	18.632
CD (P=0.05)	2.833	53.807
CV (%)	9.05	11.63

levels of irrigation (no irrigation, one irrigation and two irrigation). The experiment was laid out in Factorial Randomized Block Design and replicated thrice. Mustard variety RH-0406 was used as a test crop.

Five plants were selected randomly from each plot and tagged permanently. Height of these five plants was measured at 30 DAS, 60 DAS, 90 DAS and at harvest from the base of the plant to the top of the main shoot by metre scale and their mean was expressed as plant height (cm). Dry matter accumulation was recorded at 30 DAS, 60 DAS, 90 DAS and at harvest and these plants from one-metre row length were uprooted randomly from sample rows of each. Primary and secondary branches were counted on five randomly selected and tagged plants in each plot at harvest. Protein content in seed was calculated by multiplying nitrogen content in seed with the factor 6.25 [10]. Oil content in mustard seed was determined by Soxhlet apparatus using petroleum ether (60-80°C) as an extractant [10]. Oil yield was worked out on the basis of oil percentage in seed using following formula.

$$\text{Oil yield (kg /ha)} = \frac{\text{Oil content in seed (\%)} \times \text{Seed yield (kg / ha)}}{100}$$

The experimental data recorded were subjected to statistical analysis using analysis of variance technique [11]. The critical difference (CD) was worked out to assess the significance of treatments means wherever the 'F' test was found significant at 5% level of probability.

Results and Discussion

Growth of Mustard : The data indicated (Table-1) that the maximum plant height of mustard at 30, 60, 90 DAS and at harvest was recorded with the application of hydrogel at 5.0 kg /ha which was significantly higher than hydrogel at 2.5 kg /ha and control. The increase in plant height of mustard due to application of hydrogel at 5.0 kg /ha was 40.31 and 12.69 per cent at 30 DAS, 30.11 and 10.81 per cent at 60 DAS, 32.42 and 11.14 per cent at 90 DAS and 27.84 and 8.37 per cent at harvest, respectively over control. The increase in plant height of mustard due to two irrigations (I₂) was 41.14, 13.34 per cent at 30 DAS, 30.08, 10.20 per cent at 60 DAS, 31.59, 10.04 per cent at 90 DAS and 29.30, 8.52 per cent at harvest, respectively over control (no irrigations).

The data (Table-2) showed that dry matter accumulation of mustard was affected significantly by different levels of hydrogel at all the growth stages. Increasing levels of hydrogel significantly enhanced the dry matter accumulation up to 5.0 kg /ha over preceding levels. Application of hydrogel at 5 kg /ha increased the dry matter by 49.84 and 12.05 per cent at 30 DAS, 48.30 and 14.66 per cent at 60 DAS, 34.68 and 10.16 per cent

at 90 DAS and 31.16 and 10.24 per cent at harvest over hydrogel at 2.5 kg /ha and control, respectively. Two irrigations was found significantly higher dry matter accumulation of mustard as compared to control at 30, 60, 90 DAS and at harvest of mustard. Dry matter accumulation of mustard increased due to two irrigations (I_2) to the tune of 48.22, 48.86, 34.67 and 26.82 per cent over control (I_0) and 11.83, 14.79, 10.22 and 8.31 per cent over one irrigation (I_1), respectively at 30, 60, 90 DAS and at harvest of mustard.

A perusal of data (Table-3) revealed that hydrogel significantly enhanced the branches per plant of Indian mustard over control. Hydrogel @ 5.0 kg/ha recorded an increase of 31.26 and 7.74 per cent over control and H_1 -hydrogel @ 2.5 kg/ha, respectively. An investigation of data (Table 3) showed that branches per plant of Indian mustard increased progressively with the advancement of crop stage. Irrigation levels had significant influence on the branches per plant. The significantly maximum branches per plant were recorded under the treatment I_2 (two irrigations). The significantly lowest branches per plant were noted in I_0 (control). The increase in branches per plant due to the above treatment i.e. I_2 was 34.50 and 8.87 per cent over control and one irrigation, respectively.

Augmentation in crop growth parameters with the application of hydrogel might be due to its property of retaining and releasing water to maintain proper soil moisture for longer period in the rhizosphere. Adequate moisture content in soil facilitates better root growth, proper translocation and uptake of nutrients in the soil by the plants, which support better plant growth. Hydrogel also increase availability of macro nutrients as well as micronutrient to the roots of crop which helps in turns to increase in photosynthetic activity of plants that later enhanced the vegetative growth [12,13]. The optimum moisture supplies under more frequent irrigation treatments promoted the division and expansion of cell components and thereby stem elongation, which virtually increased the plant growth in terms of plant height. Hence, significantly tallest plants were recorded under I_2 treatment. Shortest plant height observed under treatment I_0 (control) might be due to reduction in cell enlargement under moisture stress condition created in respective plots which affected plant growth in terms of plant height. [14,15].

Quality of Mustard : Data presented in Table-4 showed that successive increase in levels of hydrogel up to 5.0 kg /ha significantly increased the protein content in grain and protein yield of mustard over hydrogel at 2.5 kg /ha and control. The per cent increase in protein content in grain of mustard due to application of hydrogel at 5.0 kg /ha was in the order of 31.82 and 12.12 per cent over control and

hydrogel at 2.5 kg /ha, respectively. Two irrigations recorded significantly maximum protein content in grain (19.43) as compared to control (14.74) and one irrigations (17.33). Two irrigations recorded 32.33 and 11.85 per cent higher protein content in grain over one irrigation and control, respectively.

The experimental findings presented in Table 5 indicated that successive increase in hydrogel level, significantly increased oil content of mustard over control. Application of hydrogel at 5.0 kg /ha recorded significantly maximum oil content in seed of mustard over preceding levels of hydrogel. The magnitude of increase in oil content due to hydrogel at 5.0 kg /ha was 22.92 and 10.08 per cent over control and hydrogel at 2.5 kg /ha, respectively. Varying level of irrigations significantly increased the oil content of mustard. Significantly maximum oil content of mustard was obtained by two irrigations which was found superior over one irrigation and control. Two irrigations level increased the oil content of mustard by 19.90 and 6.48 per cent over control (no irrigation) and one irrigation, respectively.

Under high nutrient supply, a large proportion of photosynthates diverted to protein formation leaving a potential deficiency of carbohydrates to be degraded to 'acetyl co-enzyme A' for the synthesis of fatty acids [16]. Further, a significant increase in oil content and oil yield might be to the fact that synthesis of fatty acids in plants occurs through conversion of acetyl Co-A to malonyl Co-A in presence of ATP and phosphate [17]. Secondly, the higher oil content could be attributed to formation of more lecithin [18]. Significant increase in protein content also observed because of increased nitrogen content in seed which might be the result of increased availability of nitrogen to plants and ultimately increased the protein content in seed. The oil yield is the cumulative function of oil content in seed and seed yield and significant improvement in seed yield also resulted improvement in oil yield of mustard [19,20].

Conclusions

It can be inferred from the present investigation that significantly highest plant height at harvest, dry matter accumulation, number of branches per plant, protein content, oil content and oil yield of mustard was significantly increased with the application of hydrogel at 5.0 kg/ha over lower levels of hydrogel. Further showed that the significantly highest plant height, dry matter accumulation, number of branches per plant, protein content, oil content and oil yield of mustard was significantly increased with the two irrigations as compared to one irrigation and control.

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Effect of Irrigation Levels and Nitrogen Scheduling on Nutrient Uptake of Wheat (*Triticum aestivum* L.)

Atma Ram Saini*, P.K. Sharma and Ratan Lal

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : choudharyanuj9529@gmail.com

Abstract

A field experimentation was conducted at carried out during *rabi* season of the year 2022-23 at research farm, Banthali, Tonk. The objectives were to study the Effect of irrigation levels and nitrogen scheduling on productivity and quality of wheat. The experiment consisted of 9 treatment combinations comprising three irrigation levels (3 irrigations, 4 irrigations and 5 irrigations) with three levels of nitrogen scheduling ($\frac{1}{2}$ at basal + $\frac{1}{2}$ at CRI (21-25 DAS), $\frac{1}{2}$ at basal + $\frac{1}{4}$ at CRI (21- 25 DAS) + $\frac{1}{4}$ at Joining stage (65-70 DAS) and $\frac{1}{3}$ at basal + $\frac{1}{3}$ at CRI (21-25 DAS) + $\frac{1}{3}$ at Joining stage (65-70 DAS). The experiment was laid out in split plot design and replicated thrice. The result revealed that irrigation levels significantly influenced NPK uptake in grain and straw. Nitrogen scheduling upto N_3 - $\frac{1}{3}$ at basal + $\frac{1}{3}$ at CRI (21-25 DAS) + $\frac{1}{3}$ at Joining stage (65-70 DAS) Nitrogen scheduling upto N_3 - $\frac{1}{3}$ at basal + $\frac{1}{3}$ at CRI (21-25 DAS) + $\frac{1}{3}$ at Joining stage (65-70 DAS) significantly increased NPK uptake.

Key Words : Wheat, jointing stage, cri, nutrient uptake and NPK.

Introduction

Wheat [*Triticum aestivum* (L.) emend. Fiori & Paol.] is important cereal crop after rice grown under diverse agro climatic conditions in India. Wheat was grown on an area of 29.6 million ha with production of 99.7 million tonnes and productivity of 3371 kg/ha (GOI, 2021). In Rajasthan, the crop occupies an area of 3.1 million hectares and production of 11.3 million tonnes with an average productivity of 3698 kg/ha (GOR, 2021).

Among the major elements, nitrogen is most important because most of the Indian soils are deficient in this element. Nitrogen governs considerable degree to the utilization of phosphorus and potassium. The presence of optimum amount of readily available nitrogen in the soil fertility status leading to the successful crop production.

As irrigation water is scarce and costly input, its economic and scientific utilization and optimal allocation among the different crops grown becomes quite imperative. Wheat is highly sensitive to water stress during the crown root initiation and flowering but excess irrigation may lead to heavy vegetative growth and shortening of reproductive period and ultimately decrease the yield. Thus, timing the length of irrigation interval with the stages of crop growth might bring about a reduction in the number of irrigations and results in an economic crop yield.

Materials and Methods

Experimental site : The experiment was laid out at Research Farm, Banthali, Tonk during *rabi* seasons of

2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs/day.

Experimental details : The experiment comprised 3 levels of irrigation and 3 levels of nitrogen scheduling, thereby making twelve treatment combinations that were laid out in split plot design and replicated three times.

S. No.	Treatments	Symbols
A.	Main plot	
	Irrigation level	
1.	3 Irrigation	I_1
2.	4 Irrigation	I_2
3.	5 Irrigation	I_3
	Sub plot	

B. Nitrogen scheduling

1. $\frac{1}{2}$ at basal + $\frac{1}{2}$ at CRI (21-25 DAS) N_1
2. $\frac{1}{2}$ at basal + $\frac{1}{4}$ at CRI (21-25 DAS) + $\frac{1}{4}$ at Joining stage (65-70 DAS) N_2
3. $\frac{1}{3}$ at basal + $\frac{1}{3}$ at CRI (21-25 DAS) + $\frac{1}{3}$ at Joining stage (65-70 DAS) N_3

Nutrient uptake (kg/ha) : The total uptake of nitrogen and phosphorus in grain and straw was calculated by using following formula.

Total uptake of N/P/K = (kg/ha)	Per cent N/P/K concentration in x grain	Grain yield (kg/ha)	Per cent N/P/K + concentration in x straw	Straw yield (kg/ha)
			100	

Results and Discussion**Nitrogen uptake**

Irrigation levels : The irrigation levels I_3 i.e., 5 irrigations increased significantly higher N uptake in grain and straw of wheat. The increase in N uptake in grain and straw of wheat due to 5 irrigations was 24.23 and 12.75 per cent and 19.35 and 10.02 per cent in grain and straw over I_1 and I_2 , respectively.

Nitrogen scheduling : Nitrogen scheduling i.e., N_3 -1/3 at basal + 1/3 at CRI (21-25 DAS) + 1/3 at Joining stage (65-70 DAS) resulted significantly highest N uptake in grain and straw. The improvement in N uptake of wheat by N_3

Table-1 : Effect of irrigation levels and nitrogen scheduling on N uptake in grain and straw of wheat.

Treatments	N uptake (kg/ha)	
	Grain	Straw
Irrigation levels		
I_1 -3 irrigations	60.88	26.67
I_2 -4 irrigations	67.08	28.93
I_3 -5 irrigations	75.63	31.83
SEm+	2.00	0.64
CD (P=0.05)	7.86	2.51
CV (%)	8.85	6.59
Nitrogen scheduling		
N_1 - $\frac{1}{2}$ at basal + $\frac{1}{2}$ at CRI (21-25 DAS)	60.72	26.66
N_2 - $\frac{1}{2}$ at basal + $\frac{1}{4}$ at CRI (21-25 DAS) + $\frac{1}{4}$ at Joining stage (65-70 DAS)	66.95	29.11
N_3 -1/3 at basal + 1/3 at CRI (21-25 DAS) + 1/3 at Joining stage (65-70 DAS)	75.92	31.66
SEm+	1.40	0.56
CD (P=0.05)	4.30	1.72
CV (%)	6.17	5.76

Table-2 : Effect of irrigation levels and nitrogen scheduling on P uptake in grain and straw of wheat.

Treatments	P uptake (kg/ha)	
	Grain	Straw
Irrigation levels		
I_1 -3 irrigations	12.08	6.77
I_2 -4 irrigations	14.15	7.44
I_3 -5 irrigations	16.53	8.13
SEm+	0.42	0.16
CD (P=0.05)	1.64	0.63
CV (%)	8.82	6.48
Nitrogen scheduling		
N_1 - $\frac{1}{2}$ at basal + $\frac{1}{2}$ at CRI (21-25 DAS)	12.11	6.82
N_2 - $\frac{1}{2}$ at basal + $\frac{1}{4}$ at CRI (21-25 DAS) + $\frac{1}{4}$ at Joining stage (65-70 DAS)	14.03	7.47
N_3 -1/3 at basal + 1/3 at CRI (21-25 DAS) + 1/3 at Joining stage (65-70 DAS)	16.63	8.04
SEm+	0.34	0.10
CD (P=0.05)	1.05	0.29
CV (%)	7.16	3.84

Table-3 : Effect of irrigation levels and nitrogen scheduling on K uptake in grain and straw of wheat.

Treatments	K uptake (kg/ha)	
	Grain	Straw
Irrigation levels		
I ₁ -3 irrigations	16.44	86.84
I ₂ -4 irrigations	19.09	93.08
I ₃ -5 irrigations	21.72	108.33
SEm+	0.64	2.77
CD (P=0.05)	2.50	10.88
CV (%)	9.99	8.65
Nitrogen scheduling		
N ₁ -½ at basal + ½ at CRI (21-25 DAS)	16.46	86.58
N ₂ -½ at basal + ¼ at CRI (21-25 DAS) + ¼ at Joining stage (65-70 DAS)	19.06	93.60
N ₃ -1/3 at basal + 1/3 at CRI (21-25 DAS) + 1/3 at Joining stage (65-70 DAS)	21.73	108.08
SEm+	0.42	2.65
CD (P=0.05)	1.30	8.17
CV (%)	6.64	8.28

was 25.03 and 13.40 per cent and 18.75 and 8.76 per cent in grain and straw over N₁ and N₂, respectively.

Phosphorus uptake

Irrigation levels : The irrigation levels I₃ i.e., 5 irrigations increased significantly higher P uptake in grain and straw of wheat. The increase in P uptake in grain and straw of wheat due to 5 irrigations was 36.84 and 16.82 per cent in grain and 20.09 and 9.27 per cent in grain and straw over I₁ and I₂, respectively.

Nitrogen scheduling : Nitrogen scheduling i.e., N₃-1/3 at basal + 1/3 at CRI (21-25 DAS) + 1/3 at Joining stage (65-70 DAS) resulted significantly highest P uptake in grain and straw.

Potassium uptake

Irrigation levels : The irrigation levels I₃ i.e., 5 irrigations increased significantly higher K uptake in grain and straw of wheat. The increase in K uptake in grain and straw of wheat due to 5 irrigations was 32.12 and 13.78 per cent in grain and 24.75 and 16.38 per cent in grain and straw over I₁ and I₂, respectively.

Nitrogen scheduling : The improvement in K uptake of wheat by N₃ was 32.02 and 14.01 per cent and 24.83 and 15.47 per cent in grain and straw over N₁ and N₂, respectively.

Results showed that treatment I₃ where irrigation was practised with 5 irrigations fetched significantly higher nitrogen, phosphorus and potassium uptake in grain and straw over rest of the treatments. Availability of adequate amount of nitrogen increases the cation exchange capacity of roots thereby enabling them to absorb more nutrients from the soil. Meena (2011) reported that uptake of nutrients by grain and straw increased due to higher

availability of nutrients resulting higher yield of grain and straw. Similar result was observed by Singh and Singh (2012) and Kumar *et al.* (2015).

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Effect of Foliar Application of Cow Urine and Vermiwash on Yield attributes of Chickpea (*Cicer arietinum*)

Avanish Sharma*, P.K. Sharma and Rameshwer Suthar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : avanishsharma9636@gmail.com

Abstract

A field experiment was conducted at Kotawal ka bas, dausa Rajasthan during *rabi* season 2022-23, to study the "Response of Chickpea (*Cicer arietinum*) to Foliar Application of Cow Urine and Vermiwash under Rain fed Conditions". The experiment was laid out according to randomized block design with three replications. The treatments consisting of ten levels of foliar spray (control, water spray, cow urine @ 5%, cow urine @ 10%, vermiwash @ 5%, vermiwash @ 10%, cow urine @ 5% + vermiwash @ 5%, cow urine @ 5% + vermiwash @ 10%, cow urine @ 10% + vermiwash @ 5% and cow urine @ 10% + vermiwash @ 10%) were applied to the chickpea. The highest plant height, dry matter accumulation, number of branches per plant, number of pods per plant, number of seeds per pod of chickpea was significantly increased with the application of cow urine @ 10% + vermiwash @ 10% (T₁₀).

Key Words : Chickpea, cow urine, vermiwash and yield attributes.

Introduction

The chickpea (*Cicer arietinum* L.) as a healthy vegetarian food has an important role in human food and domestic animal feed in India. It is a cheap source of high quality protein in the diets of millions of people in developing countries, who cannot afford animal protein for balanced nutrition. In addition to proteins, it is a good source of carbohydrates, minerals and trace elements. Also, chickpea plays a key role in organic cropping systems.

During 2020-21, the area under chickpea in India was 9.44 million hectares, with a production of 10.13 million tonnes and an average productivity of 1073 kg per hectare.

Vermiwash is also very good plant tonic which can be used for foliar spray. As it contains plant nutrients, vitamins, plant growth promoting substances. Vermiwash play an important role in growth of plants and its development contribute to initiation of rooting, root growth, plant development, promotion of growth rate and improvement in crop production increasing the organic matter of soil and increase in nutrient content of soil which made readily available for plants, resulting in good crop yield.

Materials and Methods

Experimental site : The experiment was laid out at Kotwal ka bas, MDR 48 Rajasthan during *rabi* seasons of 2022-23. Jaipur is situated at 27° 07' North latitude and 76° 68' East longitudes at an altitude of 427 meters above mean sea level.

Climate and weather conditions : The region has

typically semi-arid climate characterized by dryness of atmosphere. The annual total rainfall of the zone varies between 350 and 450 mm, most of which is received from July to September. The temperature may go as high as 48 °C during summer and it may fall below freezing point during winter.

Weather acts as input, influencing the growth, yield and quality of crops as well as biotic phase of soil during season. Hence, it is important to present climatic variable in this context. The mean weekly data for temperature, relative humidity and rainfall recorded of the crop seasons.

Experimental details : The experiment comprised of 10 treatment combinations of cow urine and vermiwash that were laid out in randomized block design and replicated three times.

S.No.	Treatments	Symbols
1.	Control	T ₁
2.	Water spray	T ₂
3.	Cow urine spray @ 5 %	T ₃
4.	Cow urine spray @ 10 %	T ₄
5..	Vermiwash spray @ 5 %	T ₅
6.	Vermiwash spray @ 10 %	T ₆
7.	Cow urine spray @ 5% + Vermiwash spray @ 5 %	T ₇
8.	Cow urine spray @ 5% + Vermiwash spray @ 10 %	T ₈
9.	Cow urine spray @ 10% + Vermiwash spray @ 5 %	T ₉
10.	Cow urine spray @ 10% + Vermiwash spray @ 10 %	T ₁₀

Table-1 : Effect of foliar application of cow urine and vermiwash on number of pods per plant, number of seeds per pod and test weight of chickpea.

Treatments	Number of pods per plant	Number of seeds per pod	Test weight (g)
Control	42.51	1.25	17.62
Water spray	42.70	1.27	17.75
Cow urine spray @ 5 %	47.62	1.33	19.00
Cow urine spray @ 10 %	47.92	1.34	19.10
Vermiwash spray @ 5 %	48.00	1.35	19.19
Vermiwash spray @ 10 %	48.75	1.35	19.33
Cow urine spray @ 5% + Vermiwash spray @ 5 %	49.00	1.36	19.36
Cow urine spray @ 5% + Vermiwash spray @ 10 %	49.82	1.37	19.45
Cow urine spray @ 10% + Vermiwash spray @ 5 %	55.61	1.42	21.12
Cow urine spray @ 10% + Vermiwash spray @ 10 %	55.98	1.43	21.29
SEm+	1.67	0.02	0.41
CD (P=0.05)	4.97	0.05	1.21
CV (%)	7.94	6.32	7.66

Table-2 : Effect of foliar application of cow urine and vermiwash on test weight of chickpea.

Treatments	Test weight (g)
Control	17.62
Water spray	17.75
Cow urine spray @ 5 %	19.00
Cow urine spray @ 10 %	19.10
Vermiwash spray @ 5 %	19.19
Vermiwash spray @ 10 %	19.33
Cow urine spray @ 5% + Vermiwash spray @ 5 %	19.36
Cow urine spray @ 5% + Vermiwash spray @ 10 %	19.45
Cow urine spray @ 10% + Vermiwash spray @ 5 %	21.12
Cow urine spray @ 10% + Vermiwash spray @ 10 %	21.29
SEm+	0.41
CD (P=0.05)	1.21
CV (%)	7.66

Number of pods per plant : All the pods from five sampled plants were counted separately after harvest and the average number of pods plant⁻¹ was worked out.

Number of seeds /pod : After harvest the number of seeds per pod from five sampled plants were counted separately and the average number of seeds per pod was worked out.

Seed index : A small seed sample was taken from the produce of each of the net plot harvested and 1000-seeds were counted and their weight was recorded as test weight (g).

Results and Discussion

Number of seeds /pod : The magnitude of increase in number of seeds /pod of chickpea due to cow urine @ 10% + vermiwash @ 10 % was 12.60 and 14.40 per cent, respectively over water spray (T₂) and control (T₁).

Test weight (g) : Test weight was recorded Significantly maximum with cow urine @ 10% + vermiwash @ 10 % as compared to control and water spray which was at par with

cow urine @ 10% + vermiwash @ 5% (T₉). Cow urine @ 10% + vermiwash @ 10 % were recorded 20.83 and 19.94 per cent increase over control and water spray in respect of test weight of chickpea.

The yield attributes of chickpea were significantly influenced with the foliar application of cow urine and vermiwash. Application of cow urine @ 10% + vermiwash @ 10% (T₁₀) gave highest number of pods per plant, number of seeds per pod, test weight, seed yield and straw yield of chickpea. The results are in close association with Ingle S.R. (2007), The results are in close association with Jadhav *et al.* (2014) and Thakare *et al.*, (2006).

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the necessary help and suggestions during the course of the study.

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Influence of Fertility Levels and Plant Growth Regulators on Growth parameters of Wheat (*Triticum aestivum* L.)

Charar Singh Meena*, P.K. Sharma and Harish Saini

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : chatarmahwa46@gmail.com

Abstract

A field experimentation was carried out at research farm, Bagadpur, Moradabad, Uttar Pradesh under the guidance of Department of Agriculture, Vivekananda Global University, Jaipur during *rabi* seasons of 2022-23. The objectives were to study the effect of fertility levels and plant growth regulators on growth and productivity of wheat. The experiment consisted of 12 treatment combinations comprising three fertility levels (F_1 -100% RDF (150 kg N + 60 P_2O_5 + 40 K_2O), F_2 -150% RDF (200 kg N + 90 kg P_2O_5 + 60 kg K_2O) and F_3 -150% RDF + FYM @ 5 t/ha) with four levels of plant growth regulators (T_0 -Control, T_1 -Chlormequat chloride at 0.01% spray, T_2 -Tebuconazole at 0.2% spray and T_3 -Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray). The experiment was laid out in factorial randomized block design and replicated thrice. The result showed that fertility levels significantly influenced highest plant height (cm), dry matter accumulation per m row length with the application of F_3 -150% RDF + FYM @ 5 t/ha.

Key Words : Wheat, fertility levels, growth regulators, and growth parameters.

Introduction

Wheat [*Triticum aestivum* (L.)] is one of the most important staple food crops of the world as well as India. It is an excellent health-building food containing approximately, 78% carbohydrates, 12% protein, 2% fat and minerals each and considerable amount of vitamins (Kumar *et al.*, 2011). About 80 to 85% of wheat grains are ground into flour (atta) and consumed in the form of chapaties. Soft wheat is used for making chapaties, bread, cake, biscuits, pastry and other bakery products.

India has the largest area under wheat (31.61 million hectares), but ranks second in production (109.52 million tonnes) after China with the average productivity of 3464 kg/ha (GOI, 2020-21). In Rajasthan, this crop occupies an area of 3.0 million hectares and production of 11.04 million tonnes with an average productivity of 3676 kg/ha (GOR, 2020-21). Growth regulators are chemical substances that have the potential to alter structural or vital processes inside the plant by modifying hormone balance to increase yield, improve quality. Since information on the choice of a dose of nitrogen fertilizer as well as plant growth regulators (PGR's) for wheat varieties with high potential is scanty, an attempt has been taken to find out the standardization of various doses of N for enhancing the productivity of wheat while reducing lodging. Application of growth inhibitors, like ethephon (2-chloro ethyl phosphonic acid) or CCC (Chlormequat Chloride), was reported to be useful in decreasing plant height and subsequently reducing lodging.

Materials and Methods

Experimental site : The experiment was laid out at Agricultural farm, Bagadpur, Moradabad, Uttar Pradesh during *rabi* seasons of the years 2022-23. It is situated at 29°51' N longitude and 77°53' E altitude at an elevation of 274 m above the mean sea level.

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 27.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 88.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 46 to 70 per cent, while the average sunshine hours ranged between 4.1 to 9.2 hrs/day.

Experimental details : The experiment comprised 3 levels of fertility levels and 4 levels of PGRs, thereby making twelve treatment combinations that were laid out in factorial randomized block design and replicated three times.

S.No.	Treatments	Symbols
A. Fertility levels		
1.	100% RDF (150 kg N + 60 P ₂ O ₅ + 40 K ₂ O)	F ₁
2.	150% RDF (200 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O)	F ₂
3.	150% RDF + FYM @ 5 t/ha	F ₃
B. PGRs		
1.	Control	T ₀
2.	Chlormequat chloride at 0.01% spray	T ₁
3.	Tebuconazole at 0.2% spray	T ₂
4.	Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray	T ₃

Pant height : The periodical plant height at 30, 60, 90 DAS and at harvest was measured from the ground level to the top of the main shoot of the selected five plants from each plot. Average values for each plot at harvest were computed and recorded.

Total number of tillers/m row length : The total number of tillers were counted at harvest in three randomly selected one metre row lengths. The dried infant tillers were not counted at later stages. These were averaged to estimate total number of tillers/m row length at respective stage.

Table-1 : Effect of fertility levels and plant growth regulators on plant height of wheat.

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
Fertility levels				
F ₁ -100% RDF (150 kg N + 60 P ₂ O ₅ + 40 K ₂ O)	20.36	48.92	70.32	75.62
F ₂ -150% RDF (200 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O)	20.76	55.92	79.96	84.95
F ₃ -150% RDF + FYM @ 5 t/ha	21.10	62.45	87.49	90.65
SEm+	0.47	1.31	1.71	1.91
CD (P=0.05)	NS	3.78	4.95	5.51
PGRs				
T ₀ -Control	20.24	49.57	66.11	70.30
T ₁ -Chlormequat chloride at 0.01% spray	20.80	54.30	76.33	81.08
T ₂ -Tebuconazole at 0.2% spray	20.92	58.86	84.83	90.53
T ₃ -Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray	20.99	60.32	89.77	93.05
SEm+	0.54	1.51	1.98	2.20
CD (P=0.05)	NS	4.36	5.71	6.36
CV (%)	7.77	8.12	7.49	7.89

Table-2 : Effect of fertility levels and plant growth regulators on total tillers per plant of wheat.

Treatments	Total tillers per m row length at harvest
Fertility levels	
F ₁ -100% RDF (150 kg N + 60 P ₂ O ₅ + 40 K ₂ O)	104.80
F ₂ -150% RDF (200 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O)	114.62
F ₃ -150% RDF + FYM @ 5 t/ha	121.24
SEm+	2.22
CD (P=0.05)	6.40
PGRs	
T ₀ -Control	99.92
T ₁ -Chlormequat chloride at 0.01% spray	110.23
T ₂ -Tebuconazole at 0.2% spray	119.42
T ₃ -Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray	124.64
SEm+	2.56
CD (P=0.05)	7.39
CV (%)	6.76

Table-3 : Effect of fertility levels and plant growth regulators on dry matter accumulation at different stages of wheat.

Treatments	Dry matter accumulation/m row length (g)			
	30 DAS	60 DAS	90 DAS	At harvest
Fertility levels				
F ₁ -100% RDF (150 kg N + 60 P ₂ O ₅ + 40 K ₂ O)	18.25	132.25	175.62	210.54
F ₂ -150% RDF (200 kg N + 90 kg P ₂ O ₅ + 60 kg K ₂ O)	18.65	141.01	184.62	229.32
F ₃ -150% RDF + FYM @ 5 t/ha	18.71	149.25	194.99	248.11
SEm+	0.58	2.84	3.31	4.85
CD (P=0.05)	NS	8.20	9.56	14.00
PGRs				
T ₀ -Control	18.04	130.86	173.63	207.67
T ₁ -Chlormequat chloride at 0.01% spray	18.49	140.52	184.69	228.99
T ₂ -Tebuconazole at 0.2% spray	18.74	144.11	188.2	237.01
T ₃ -Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray	18.89	147.86	193.75	243.6
SEm+	0.67	3.28	3.82	5.60
CD (P=0.05)	NS	9.46	11.04	16.17
CV (%)	10.79	6.98	6.19	7.32

Dry matter accumulation : The periodical change in dry matter accumulation at 30, 60, 90 DAS and at harvest was recorded by collecting whole plant samples from randomly selected observational rows of each plot in 0.5 m running length of row. These samples were dried in sunlight for 2-3 days and finally dried in an oven at 70°C till a constant weight was obtained. Thereafter, the samples were weighed for estimating total dry matter accumulation and expressed in g per m row length.

Results and Discussion

Plant height

Fertility levels : Application of F₃ i.e., 150% RDF + FYM @ 5 t/ha recorded the maximum plant height at 60, 90 DAS and at harvest of wheat.

PGRs : The data indicated that plant height of wheat at 60, 90 DAS and at harvest as affected significantly by spray of PGR treatment T₃ (Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray) The increase in plant height of wheat due to Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray (T₃) at 35 DAS was 21.69, 11.04 per cent at 60 DAS, 35.79, 17.61 per cent at 90 DAS and 32.36, 14.76 per cent at harvest, respectively.

Total number of tillers

Fertility levels : Application of F₃-150% RDF + FYM @ 5 t/ha recorded an increase of 15.69 and 5.78 per cent over F₁ and F₂, respectively.

PGRs : The increase in total number of tillers due to chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray (T₃) was 24.74 and 13.07 per cent, respectively over T₀-Control and T₁-Chlormequat chloride at 0.01% spray, respectively.

Dry matter accumulation

Fertility levels : Application of F₃ i.e., 150% RDF + FYM @ 5 t/ha recorded the maximum dry matter at 60, 90 DAS and at harvest of wheat. This treatment recorded significantly maximum dry matter as compared to F₁-100% RDF (150 kg N + 60 P₂O₅ + 40 K₂O) and F₂-150% RDF (200 kg N + 90 kg P₂O₅ + 60 kg K₂O) at 60, 90 DAS and at harvest.

PGRs : The increase in dry matter of wheat due to Chlormequat chloride at 0.01% + Tebuconazole at 0.2% spray (T₃) was 12.99, 5.22 per cent at 60 DAS, 11.59, 4.91 per cent at 90 DAS and 17.30, 6.38 per cent at harvest, respectively over control and chlormequat chloride at 0.01% spray.

The application of higher dose of fertilizer might have increased interception, absorption and utilization of radiant energy which in turn increased thereby overall growth, photosynthesis and finally fresh and dry weight. The beneficial effect of optimum and balanced fertilization primary nutrients (NPK) on dry matter accumulation stages and number of tillers were also observed by several researchers in wheat crop. Similar finding was also reported by (Laghari *et al.* 2010, Singh *et al.* 2017 and Patel *et al.* 2017).

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Effect of Phosphorus and Zinc Level on Growth Parameters of Chickpea (*Cicer arietinum*)

Kushvendra Singh Jadaun*, P.K. Sharma and Sunil Kumar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : tjadaun91@gmail.com

Abstract

A field experiment was conducted at Research Farm, Vivekananda Global University, Jaipur during *Rabi* season of 2022-23, to study the "Response of Chickpea (*Cicer arietinum*) to Phosphorus and Zinc Level". The experiment was laid out according to randomized block design with three replications. The treatments consisting of seven treatment combinations viz., control (T_1), 20 kg ha⁻¹ phosphorus (T_2), 40 kg ha⁻¹ phosphorus (T_3), 80 kg ha⁻¹ phosphorus (T_4), 2.5 kg ha⁻¹ zinc (T_5), 5.0 kg ha⁻¹ zinc (T_6) and 7.5 kg ha⁻¹ zinc (T_7) were applied to the chickpea var. RSG-888. The growth attributes of chickpea was increased due to different Phosphorus and zinc level treatments. The maximum plant height, number of branches plant⁻¹ of chickpea was obtained with combined application of 80 kg ha⁻¹ phosphorus.

Key Words : Chickpea, phosphorus, zinc and growth attributes.

Introduction

Chickpea (*Cicer arietinum* L.) is an important grain legume in Asia. Being a rich and cheap source of protein, it can help people to improve the nutritional quality of their diet. Chickpea is relatively of minor importance on the world market but it is extremely important for local trade in numerous tropical and subtropical regions. It is grown and consumed in large quantities from South East Asia to India and in the Middle East and Mediterranean countries. Chickpea is the third most important pulse crop in the world after French bean (*Phaseolus vulgaris* L.) and field peas (*Pisum sativum* L.).

Amongst the required essential nutrients, phosphorus (P) and zinc (Zn), being crucial element for optimum growth and yield of all crop (Ryan et al., 2012) throughout the world, are most important for our farmers consideration because of the sensitivity of these two nutrients to the existing soil conditions and their mutual interaction. Phosphorus availability in optimum quantities is needed for early growth stages, development of the reproductive parts, root growth, reduced disease incidence and early maturity.

Materials and Methods

Experimental site : The experiment was conducted during *Rabi* 2022-23 at Research Farm, Vivekananda Global University, Jaipur. Geographically, the study area is located at 075°88'99" E longitude and 26°81'17" N latitude and this region falls under agro-climatic zone III A of Rajasthan (Semi-arid Eastern Plain Zone).

Climate and weather conditions : The climate of this zone is typically semi-arid characterized by extremes of

temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while, in winters, it may fall as low as 1.0 °C. The rainfall of this tract varies from 450-500 mm, most of which is contributed by south-west monsoon during the months of July and August. The mean maximum relative humidity fluctuated from 38 to 88 per cent and mean minimum relative humidity fluctuated from 13 to 34 per cent during the crop season. The mean maximum temperature during the crop growth period of chickpea ranged between 19.8 °C to 36.8 °C, while minimum temperature ranged from 5.8 °C to 21.5 °C during the crop season. The total rainfall received during the crop season was 16.6 mm.

Experimental details : The presented experiment consisting of 8 treatment combinations was carried out in Randomized Block Design (RBD).

S. No.	Treatments	Symbols
1.	Control	T_1
2.	20 kg phosphorus ha ⁻¹	T_2
3.	40 kg phosphorus ha ⁻¹	T_3
4.	80 kg phosphorus ha ⁻¹	T_4
5.	2.5 kg zinc ha ⁻¹	T_5
6.	5.0 kg zinc ha ⁻¹	T_6
7.	7.5 kg zinc ha ⁻¹	T_7

Plant height : Five plants were selected randomly from each plot and tagged permanently. Height of these five plants was measured at 30, 60DA S and at harvest from the base of the plant to the top of the main shoot by meter scale and their mean was expressed as plant height (cm).

Branches plant⁻¹ : The number of branches plant⁻¹ at harvest were counted on five randomly selected and tagged plants in each plot at periodical interval and then mean was recorded as number of branches plant⁻¹.

Table-1 : Effect of phosphorus and zinc level on plant height of chickpea.

Sr. No.	Treatments	Plant height (cm)		
		30 DAS	60 DAS	Harvest
T ₁	Control	11.24	29.58	40.48
T ₂	20 kg phosphorus ha ⁻¹	11.78	45.64	62.89
T ₃	40 kg phosphorus ha ⁻¹	11.89	46.29	63.40
T ₄	80 kg phosphorus ha ⁻¹	11.96	46.68	64.46
T ₅	2.5 kg zinc ha ⁻¹	11.36	37.19	50.52
T ₆	5.0 kg zinc ha ⁻¹	11.50	37.96	51.65
T ₇	7.5 kg zinc ha ⁻¹	11.62	38.56	52.30
	SEm±	0.61	2.09	2.86
	CD (P = 0.05)	NS	6.46	8.42
	CV (%)	9.02	9.01	9.0

Table-2 : Effect of phosphorus and zinc level on number of branches plant⁻¹ of chickpea.

Sr. No.	Treatments	Number of branches plant ⁻¹
T ₁	Control	6.05
T ₂	20 kg phosphorus ha ⁻¹	9.05
T ₃	40 kg phosphorus ha ⁻¹	9.89
T ₄	80 kg phosphorus ha ⁻¹	10.01
T ₅	2.5 kg zinc ha ⁻¹	7.80
T ₆	5.0 kg zinc ha ⁻¹	7.91
T ₇	7.5 kg zinc ha ⁻¹	8.03
	SEm±	0.46
	CD (P = 0.05)	1.42
	CV (%)	9.41

Results and Discussion

Plant height : The maximum mean plant height at 60 DAS (46.68 cm), at harvest (64.46 cm) was recorded with the application of 80 kg phosphorus ha⁻¹. Plant height of chickpea was significantly increased due to application of 80 kg phosphorus ha⁻¹ was in the tune of 57.78, 25.52, 22.97 and 21.04% at 60 DAS, 59.26, 27.59, 24.81 and 23.26% at 90 DAS and 58.93, 27.44, 24.82 and 23.55% at harvest, respectively over treatment T₁, T₅, T₆ and T₇.

Number of branches : Highest number of branches plant⁻¹ (10.01) at harvest of chickpea as compared to treatment T₁, T₅, T₆ and T₇ but it remained at par with treatment T₃ and T₂. The improvement in number of branches plant⁻¹ at harvest of due to application of 75% RDF + vermicompost 2.5 t ha⁻¹ + PSB (T₇) was 65.40, 28.29, 26.51 and 24.56% at harvest, respectively over treatment T₁, T₃, T₄ and T₅.

The experimental findings revealed that different phosphorus and zinc level treatments bring significant effect on plant height at 60 DAS and at harvest and number of branches plant⁻¹ at harvest of chickpea (Table 4.2, and 4.3) and maximum value of these parameters was recorded with the application of 80 kg phosphorus ha⁻¹ (T₄). The reason for better growth and development in the above treatments might be due to increased availability of all nutrients to the plant through combined application of chemical fertilizers along with phosphorus

and zinc in the cropping season. Similar results were also found by Mustafa, 2008; Dharwe *et al.* 2019 and Singh *et al.* 2017.

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Effect of Nitrogen Scheduling on Growth parameters of barley (*Hordeum vulgare* L.)

Lokesh Saini*, P.K. Sharma and Murari Lal Saini

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : lkmore547@gmail.com

Abstract

Field experiment was conducted at research farm, Vivekananda Global University, Jaipur, during *rabi* season of 2022-23. The experiment consisted of 12 liquid formation treatments viz., T₁: 1/2 at basal + 1/2 at tillering (35-40 DAS), T₂: 1/2 at basal + 1/4 at tillering (35-40 DAS) + 1/4 at flag leaf stage (65-70 DAS), T₃: 1/3 at basal + 1/3 at tillering (35-40 DAS) + 1/3 at flag leaf stage (65-70 DAS), T₄: 1/2 at basal + 1/2 at tillering (21-25 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS), T₅: 1/2 at basal + 1/2 at tillering (21-25 DAS) + 0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS), T₆: 1/2 at basal + 1/2 at tillering (21-25 DAS) + 5.0 % urea + 0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS), T₇: 1/2 at basal + 1/4 at tillering (21-25 DAS) + 1/4 at flag leaf stage (65-70 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS), T₈: 1/2 at basal + 1/4 at tillering (21-25 DAS) + 1/4 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS), T₉: 1/2 at basal + 1/4 at tillering (21-25 DAS) + 1/4 at flag leaf stage (65-70 DAS) + 5.0 % urea + 0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS), T₁₀: 1/3 at basal + 1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS), T₁₁: 1/3 at basal + 1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS) and T₁₂: 1/3 at basal + 1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea + 0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS) that were laid out in a Randomized Block Design and replicated thrice. Protein content in seed and protein yield were improved due to foliar application of T₁₂.

Key Words : Barley, leaf stage, flag leaf stage, anthesis stage and urea.

Introduction

Barley (*Hordeum vulgare* L.) belongs to the family *Poaceae* (formerly called *Graminae* or grass family). It is a self-pollinating, diploid species with 14 chromosomes and comprised of 32 species. The wild ancestor of domesticated barley, *Hordeum vulgare* sub sp. spontaneum, is abundant in grasslands and woodlands throughout the Fertile Crescent area of Western Asia and North-East Africa. It was grown on 0.62 million hectares area with average grain productivity of 2564 kg ha⁻¹ and total production of 1.59 million tonnes in India during 2021-22 (Anonymous, 2021, Annual Report 2021-2022, 4th advance estimates). In Rajasthan, it is grown on 0.26 million hectares area with average grain productivity of 3481 kg per hectare and total production of 0.93 million tonnes during 2020-21 (Anonymous, 2020, Annual Report 2020-2021, 4th advance estimates).

The productivity of crop is controlled by many factors of which the mineral nutrition specifically of nitrogen is most important. The most important factor is that the heavy and imbalanced use of chemical fertilizer has led to think about the use of organic manures in intensively growing areas for sustainable production system. Therefore, to sustain the land and to achieve production potential of crops, the experimental finding in India have clearly indicated that there is a need to integrate both the organic and inorganic substances for sustainable crop

production; maintenance of soil fertility and conservation of natural resources.

Materials and Methods

Experimental site : Research farm, Vivekananda Global University, Jaipur is situated at 26° 5' North latitude and 75° 28' East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIa (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this zone is typically semi-arid characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 46°C, while, in winters, it may fall as low as 1.0 °C. The rainfall of this tract varies from 400-500 mm, most of which is contributed by south-west monsoon during the months of July and August. The mean maximum relative humidity fluctuated from 35 to 69 per cent and mean minimum relative humidity fluctuated from 0 to 46 per cent during the crop season. The mean maximum temperature during the crop growth period of mustard ranged between 20.1 °C to 35.0 °C, while minimum temperature ranged from -0.5 °C to 17 °C during the crop season. The total rainfall received during the crop season was 78.3 mm.

Experimental details : The experiment comprised of 12 treatments involving different nitrogen scheduling were laid down in randomized block design and replicated three times.

S. No.	Treatments	Symbols
1.	1/2 at basal + 1/2 at tillering (35-40 DAS)	T ₁
2.	1/2 at basal + 1/4 at tillering (35-40 DAS)+ 1/4 at flag leaf stage (65-70 DAS)	T ₂
3.	1/3 at basal +1/3 at tillering (35-40 DAS) + 1/3 at flag leaf stage (65-70 DAS)	T ₃
4.	1/2 at basal +1/2 at tillering (21-25 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS)	T ₄
5.	1/2 at basal +1/2 at tillering (21-25 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	T ₅
6.	1/2 at basal +1/2 at tillering (21-25 DAS) + 5.0 % urea +0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	T ₆
7.	1/2 at basal +1/4 at tillering (21-25 DAS)+ 1/4 at flag leaf stage (65-70 DAS) +5.0 % urea spray at anthesis stage (80-90 DAS)	T ₇
8.	1/2 at basal +1/4 at tillering (21-25 DAS) + 1/4 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	T ₈
9.	1/2 at basal +1/4 at tillering (21-25 DAS)+ 1/4 at flag leaf stage (65-70 DAS) + 5.0 % urea + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	T ₉
10.	1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS)	T ₁₀
11.	1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	T ₁₁
12.	1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea +0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	T ₁₂

Table-1 : Effect of nitrogen scheduling on plant height at different stages of barley.

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T1: 1/2 at basal + 1/2 at tillering (35-40 DAS)	17.10	32.15	59.24	71.36
T2 : 1/2 at basal + 1/4 at tillering (35-40 DAS)+ 1/4 at flag leaf stage (65-70 DAS)	17.15	38.5	38.5	71.96
T3 : 1/3 at basal +1/3 at tillering (35-40 DAS) + 1/3 at flag leaf stage (65-70 DAS)	18.01	41.2	41.2	83.42
T4 : 1/2 at basal +1/2 at tillering (21-25 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS)	18.12	37.29	68.14	84.11
T5 : 1/2 at basal +1/2 at tillering (21-25 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	18.35	37.33	68.95	84.65
T6 : 1/2 at basal +1/2 at tillering (21-25 DAS) + 5.0 % urea +0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	18.69	40.12	71	85.00
T7 : 1/2 at basal +1/4 at tillering (21-25 DAS)+ 1/4 at flag leaf stage (65-70 DAS) +5.0 % urea spray at anthesis stage (80-90 DAS)	18.75	40.69	71.62	85.25
T8 : 1/2 at basal +1/4 at tillering (21-25 DAS) + 1/4 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	18.88	40.89	72.19	85.39
T9 : 1/2 at basal +1/4 at tillering (21-25 DAS)+ 1/4 at flag leaf stage (65-70 DAS) + 5.0 % urea + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	19.05	41.45	74.14	89.97
T10 : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS)	20.21	42.3	75.3	92.20
htT11 : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	21.23	43.2	76.23	93.34
T12 : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea +0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	22.30	115.6	175.2	94.45
SEm±	0.95	1.40	2.17	2.63
CD (P=0.05)	2.74	4.07	6.29	7.63
CV (%)	9.56	6.87	5.892	5.90

Pant height : The periodical plant height at 30, 60, 90 DAS and at harvest was measured from the ground level to the top of the main shoot of the selected five plants from each plot.

Dry matter accumulation : To compute the dry matter

accumulation/m row length, the plants from 0.5 m row length from the sampling rows were cut from ground level at 30, 60, 90 DAS and at harvest by keeping them in oven at 65⁰ C till their weight became constant. The dried samples were weighed and dry matter accumulation/m row length was worked out at each stage.

Table-2 : Effect of nitrogen scheduling on dry matter accumulation at different stages of barley.

Treatments	Dry matter accumulation (g per m row length)			
	30 DAS	60 DAS	90 DAS	At harvest
T1: 1/2 at basal + 1/2 at tillering (35-40 DAS)	12.62	45.28	132.62	158.25
T2 : 1/2 at basal + 1/4 at tillering (35-40 DAS)+ 1/4 at flag leaf stage (65-70 DAS)	12.77	46.10	133.98	161.22
T3 : 1/3 at basal +1/3 at tillering (35-40 DAS) + 1/3 at flag leaf stage (65-70 DAS)	13.12	52.14	173.62	192.62
T4 : 1/2 at basal +1/2 at tillering (21-25 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS)	13.19	52.92	177.62	199.45
T5 : 1/2 at basal +1/2 at tillering (21-25 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	13.35	53.64	179.63	206.63
T6 : 1/2 at basal +1/2 at tillering (21-25 DAS) + 5.0 % urea +0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	13.49	54.00	180.14	208.58
T7 : 1/2 at basal +1/4 at tillering (21-25 DAS)+ 1/4 at flag leaf stage (65-70 DAS) +5.0 % urea spray at anthesis stage (80-90 DAS)	13.55	54.92	188.63	217.63
T8 : 1/2 at basal +1/4 at tillering (21-25 DAS) + 1/4 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	13.82	57.24	194.24	229.47
T9 : 1/2 at basal +1/4 at tillering (21-25 DAS)+ 1/4 at flag leaf stage (65-70 DAS) + 5.0 % urea + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	14.10	59.99	207.44	242.87
T10 : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea spray at anthesis stage (80-90 DAS)	15.20	60.30	210.35	245.60
T11 : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	16.20	61.40	212.30	247.50
T12 : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea +0.5 % ZnSO ₄ spray at anthesis stage (80-90 DAS)	16.60	62.30	215.30	248.78
SEm±	0.79	1.30	4.40	5.16
CD (P=0.05)	2.29	3.78	12.78	14.97
CV (%)	7.84	7.53	7.60	7.64

Results and Discussion

Plant height : In the treatment where T12- 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea +0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS), the plant height was recorded highest.

Dry matter accumulation : The dry matter accumulation was found highest in the treatment where T₁₂ : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) + 5.0 % urea +0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS) was applied.

Among various liquid formulations, application of foliar sprays of T12 : 1/3 at basal +1/3 at tillering (21-25 DAS) + 1/3 at flag leaf stage (65-70 DAS) +5.0 % urea +0.5 % ZnSO₄ spray at anthesis stage (80-90 DAS) recorded taller plants during all stages of plant growth and also showed maximum dry matter accumulation. Similar results have been reported by Narolia and Yadav (2014) and Safina (2010), Hundal *et al.* (2014) and Kaur *et al.* (2010)

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Bionomics of Leaf Webber and Capsule Borer, *Antigastra catalaunalis* (Dup.) Infesting Sesame, *Sesamum indicum* (Linn.)

Mamta Devi Choudhary*, K.C. Kumawat and M.K. Yadav

Department of Entomology, SKN College of Agriculture, SKN Agricultural University, Jobner—303329 Rajasthan

*Email : mmtchoudhary233@gmail.com

Abstract

Investigations on “bionomics and biointensive management of sesame leaf and capsule borer, *Antigastra catalaunalis* (Dup.).” were conducted at Agronomy farm and Department of Entomology, S.K.N. College of Agriculture, Jobner during Kharif, 2015 and 2016. *A. catalaunalis* were recorded as major insect pests of sesame during both the years of study. The different parameters of bionomics of *A. catalaunalis* have been presented as egg, larva, pupa and adult. The total life cycle of *A. catalaunalis* varied from 21 to 39 days with an average of 28.1 days. The incubation period varied from 47- 73 hours with an average of 60.6 hours. The larva passed through five instars on sesame leaves under laboratory conditions. Duration of larva was 8.21-12.16 days. Duration of the pre-pupa ranged between 21-121 hours with an average of 100.7 hours and that of pupa 3.10-12.0 days with average 7.18 days. Longevity of adult male varied from 3-5 days with an average of 4.1 days, whereas females lived for 4 - 6 days with an average of 5.8 days.

Key words : Sesame, *Antigastra catalaunalis* (Dup.), Bionomics,

Introduction

Sesamum indicum L. commonly known as sesame or til is an ancient oilseed crop grown in India, and India is the second largest producer of sesame seed (Anon, 2019). Its seeds contain 52- 57 per cent oil and 25 per cent protein (Smith *et al.*, 2000). The important sesame growing countries are India, China, Sudan, Burma and Mexico. In India, the cultivation is mainly confined to Uttar Pradesh, Rajasthan, Madhya Pradesh, Andhra Pradesh, Odisha, Gujarat, Tamil Nadu and Karnataka. In India, production of sesame was estimated to be 8.11 lakh tonnes during 2014-15 (Anonymous, 2015a).

The total area under cultivation of sesame in Rajasthan was about 3.30 lakh hectares with annual production to the tune of 9.49 thousand tonnes and average productivity of 288 kg (Anonymous, 2015b). Its cultivation gained impetus because of high quality edible oil, rich source of carbohydrate, protein, calcium and phosphorus (Seegeler, 1983) and, therefore, considered to be the ‘queen of oil seeds’. The pests attack tolls a heavy loss (25- 90%) in seed yield (Ahuja and Kalyan, 2002). Among 67 insect pests damaging sesame crop, the leaf insect pests, viz., leaf and capsule borer, *Antigastra catalaunalis* (Dup.); jassid, *Orosius albicinctus* Distant; whitefly, *Bemisia tabaci* (Genn.) and mirid bug, *Nesidiocoris tenuis* (Reuter) are considered to be key pests (Ahirwar *et al.*, 2009). The *A. catalaunalis* is an important pest because this attacks the crop in all the growth stages after about two weeks of emergence (Suliman *et al.*, 2004). The attack is more severe during

dry seasons and after initiation of flowering. It feeds on tender foliage by webbing the top leaves, bores into the pods and shoots (Narayanan and Nadarajan, 2005). This insect pest causes 10-70 per cent infestation of leaves, 34-62 per cent of flower buds/ flowers and 10-44 per cent infestation of pods resulting in upto 72 per cent loss in yield (Ahirwar *et al.*, 2010a). The bionomics of insect pests lays the foundation for adoption of eco-friendly pest management approaches. As sesame leaf and pod caterpillar feed concealed within leaves and capsules, a correct management strategy using appropriate techniques is vital. As such, the study on bionomics of this serious pest of sesame is necessary for formulating effective and economical management strategy. A meagre amount of work has been carried out on bionomics and management of leaf and capsule borer, *A. catalaunalis* infesting sesame crop in Rajasthan.

Materials and Methods

Studies on the bionomics of leaf roller / capsule borer *Antigastra catalaunalis* Duponchel were undertaken in laboratory at the ambient temperature. For laboratory experiment, the cultivated sesame variety, RT-125 was grown in pots. Full fed caterpillars were collected from the field of sesame crop and reared on the crop grown in pots (covered with muslin cloth) and on sesame leaves, fruiting bodies and other plant parts in the Petri dishes (7.5 cm diameter). The Petri dishes were provided with moist soil in their bottom. The leaves and flowers were changed daily upto the second instar larval stage. Thereafter, the buds, flowers, capsules and leaves were provided as food to the latter larval instars. The moths emerging from pupae

were released in muslin cloth covered pots containing cotton swabs dipped in 20% glucose solution. The moths were kept under constant watch for studying mating, oviposition behavior and egg laying. Freshly laid eggs were counted and placed on fresh sesame leaves with the help of moist soft camel hair brush. Observation was recorded on their colour, size, shape and incubation period.

Results and Discussion

The different parameters of bionomics of *A. catalaunalis* have been presented in the subheads, egg, caterpillar, pupa and adult (Table-1 and 2).

Egg

Site of egg laying : Female moths laid the eggs singly along the midrib and veins of the leaves at lower surface, in between the floral buds, inside the flowers and in grooves of stem and capsules.

Colour, shape and size : Freshly laid eggs were minute and conical in shape. Eggs were cream coloured when freshly laid and turned whitish prior to hatching. The length of eggs varied from 0.38- 0.43 mm with an average of 0.41 mm, while the breadth varied from 0.21- 0.25 mm with an average of 0.23 mm.

Incubation period : The incubation period of eggs varied from 47- 73 hours with an average of 60.6 hours.

Hatching of eggs : The minimum and maximum hatching per cent were 80 and 90, respectively with an average of 85 per cent.

Caterpillar

Damage symptoms and feeding behavior : First instar caterpillar when hatched out from the egg, fed by scraping the epidermis from undersurface of the leaves. Second instar caterpillar also fed on the leaf epidermis, soft parts of branches and fastened the leaves of growing point with webs or together with silken threads and fed from inside. Third instar caterpillar, after initial feeding on the epidermis of leaves and soft parts of the branches, bored into flowers and capsules by scrapping. Fourth instar caterpillar fed on the leaf epidermis, soft parts of the branches and bored into flowers and capsules by scrapping. Fifth instar fed mainly on flowers and capsules by scrapping and causing boring holes.

Number of instars : The caterpillars were found to pass through five instars on sesame leaves under laboratory conditions.

First instar : The newly hatched caterpillar (first instar) was a tiny, cylindrical, semi translucent, cream coloured caterpillar with reddish brown head capsule. Caterpillar

had four pairs of prolegs and one pair of anal proleg besides three pairs of thoracic legs. The length and breadth of first instar caterpillar varied from 4.9 to 5.60 mm with an average of 4.95 mm and 0.80 to 1.00 mm with an average of 0.92 mm, respectively. Developmental period of first instar caterpillar varied from 96.00 to 131.00 hours with an average of 108 hours.

Second instar : The second instar caterpillar was slightly larger than the first instar. Body colour slightly turned into whitish yellow, whereas colour of head capsule was brown. The length of the second instar ranged from 7.10 to 9.00 mm with an average of 7.83 mm, while breadth varied from 0.80 to 1.10 mm with an average of 0.92 mm. Developmental period of second instar varied from 23.00 to 47.00 hours with an average of 32.1 hours.

Third instar : The third instar caterpillar slightly increased in size and the colour changed to pale green. Colour of the head capsule turned into black and brownish black hairs on black dots (setae and tubercles) were found on the abdomen of the caterpillar. The length of the third instar caterpillar ranged from 11.10- 12.00 mm with an average of 11.69 mm, while breadth varied from 1.10- 1.50 mm with an average of 1.31 mm. Developmental period of third instar caterpillar varied from 12.00- 22.00 hours with an average of 16.7 hours.

Fourth instar : Fourth instar caterpillar (including all the prolegs) was pale green in the beginning and became green at the end with black head capsule. Setae and tubercles turned dark black and became prominent. Seta on each tubercle became clearly visible and there were three tubercles on each side of the mid dorsal line of each segment. Length of the fourth instar caterpillar varied from 13.50- 13.90 mm with an average of 13.72 mm and breadth, 1.20- 1.90 mm with an average of 1.57 mm. Duration of the fourth instar caterpillar was 19.00- 21.00 hours with an average of 19.93 hours.

Fifth instar : Fifth instar caterpillar which fed on leaves and other vegetative parts was dark green, whereas caterpillar which fed on flowers and capsules was slightly pink in colour. Colour of prolegs was same as that of the body colour. Prominent mid dorsal line was noticed from thorax to the end of abdomen. Setae and tubercles were similar with that of fourth instar caterpillar. Length of the caterpillar varied from 14.50- 16.00 mm with an average of 15.25 mm. Breadth ranged from 1.50- 2.00 mm with an average of 1.70 mm. The duration of fifth instar caterpillar was 47.00- 71.00 hours with an average of 58.7 hours. The total caterpillar period ranged from 8.21- 12.16 days.

Pre-pupa

When the caterpillar completed development, ceased feeding, became sluggish and the body turned darker and

Table-1 : Morphometrics of different stages of *Antigastra catalaunalis* (Dup.) on sesame, *Sesamum indicum*.

S. No.	Stage	Particulars	Measurement (mm)		
			Minimum	Maximum	Mean+ SD
1.	Egg	Length	0.38	0.43	0.39 ± 0.02
		Width	0.21	0.25	0.23 ± 0.02
2.	Caterpillar				
	1 st instar	Length	4.90	5.60	4.95 ± 0.53
		Width	0.80	1.00	0.92 ± 0.07
	2 nd instar	Length	7.10	9.00	7.83 ± 0.64
		Width	0.80	1.10	0.92 ± 0.08
	3 rd instar	Length	11.10	12.10	11.69 ± 0.43
		Width	1.10	1.50	1.31 ± 0.12
	4 th instar	Length	13.50	13.90	13.72 ± 0.14
		Width	1.20	1.90	1.57 ± 0.27
	5 th instar	Length	14.50	16.00	15.25 ± 0.60
		Width	1.50	2.00	1.70± 0.19
3.	Pre-pupa	Length	12.10	15.10	13.55 ± 1.05
		Width	1.10	2.00	1.53± 0.38
4.	Pupa	Length	6.00	8.00	7.26 ± 0.76
		Width	1.00	1.50	1.30 ± 0.16
5.	Adult				
	Male	Length	7.00	8.00	7.59± 0.39
		(Wing expanded)	22.00	23.00	22.55 ± 0.37
	Female	Length	10.00	12.00	10.96 ± 0.57
		(Wing expanded)	25.10	27.00	26.14 ± 0.79

Mean of 10 replications

Table-2 : Duration of different stages of *Antigastra catalaunalis* (Dup.) on sesame, *Sesamum indicum* in laboratory.

S. No.	Life stages	Period		
		Minimum	Maximum	Mean+ SD
1.	Egg (Hrs.)	47.00	73.00	62.6 ± 9.72
	Hatching (%)	80.00	90.00	84.8± 3.91
2.	Caterpillar			
	1 st instar (Hrs.)	96.00	131.00	108±15.54
	2 nd instar (Hrs.)	23.00	47.00	32.1 ± 10.07
	3 rd instar (Hrs.)	12.00	22.00	16.7 ± 3.49
	4 th instar (Hrs.)	19.00	21.00	19.93 ± 0.75
	5 th instar (Hrs.)	47.00	71.00	58.7 ± 8.51
	Total caterpillar period (Days)	8.21	12.16	-
3.	Pre-pupa (Hrs.)	21.00	121.00	100.7± 61.77
4.	Pupa (Days)	3.10	12.00	7.18 ± 3.56
5.	Adult			
	Pre-oviposition (Hrs.)	9.00	11.00	10.04± 0.73
	Oviposition (Days)	2.00	4.00	3.1± 0.80
	Post oviposition (Hrs.)	23.00	25.00	23.83± 0.96
	Longevity			
	Male (Days)	3.00	5.00	4.1± 1.71
	Female (Days)	4.00	6.00	5.8 ±2.04
6.	Total life span of female (Days)	19.00	39.00	28.1± 6.02
7.	Fecundity (Number)	30.00	75.00	53.8 ± 13.98
8.	Sex ratio (Female: Male)	-	-	1:1

Mean of 10 replications

wrinkled. This moved towards the top of the rearing vial and some towards the leaf folds, flower and capsule debris. This stage was considered as pre-pupal stage. The length of the pre-pupa ranged from 12.10- 15.10 mm with an average of 13.55 mm. Breadth varied from 1.10- 2.00 mm with an average of 1.53 mm. The longevity

(duration) of pre-pupa was in the range of 21.00- 121.00 hours with an average of 100.70 hours.

Pupa

Site of pupation : The caterpillar pupated at the top corner of the rearing vial and sometimes between the leaf folds and other remains in the rearing vial. In field

conditions, pupation was observed to be occurred in between the leaf rolls and among the webbed mass of leaves, flowers and sometimes capsules. The pupation took place in a thin self-spun cocoon.

Colour, shape and size : Freshly formed pupa was soft, slender and green in colour. Prominent black eye spots were noticed after few hours of pupal formation. Pupa turned into brown before eclosion of the adult. The length and breadth of pupa varied from 6.00- 8.00 mm with an average of 7.00 mm and 1.00- 1.50 mm with an average of 1.25 mm, respectively.

Morphometric differences in male and female pup: Males were slender and long, whereas females were comparatively broader and shorter.

Adult

Colour, size and appearance : Adult was small, delicate moth with brick red coloured forewings bearing veins and hind wings were pale yellow and slightly transparent with brownish red markings on them in both the sexes. Males were small with slender abdomen and females were comparatively larger with broad abdomen. The males were smaller in size than the females. Length of the males varied from 7.00- 8.00 mm with an average of 7.59 mm, while the breadth with wing expanded form varied from 22.00- 23.00 mm with an average of 22.55 mm. Length of the female moths varied from 10.00- 12.00 mm with an average of 10.96 mm and breadth with wing expanded form varied from 25.10- 27.00 mm with an average of 26.14 mm.

Pre-oviposition, oviposition, fecundity, post-oviposition and longevity : The pre-oviposition period of female moth varied from 9 to 11 hours with an average of 10.04 hours. The oviposition period of *A. catalaunalis* females ranged from 2- 4 days with an average of 3.1 days. The egg laying capacity of female moths (fecundity) varied from 30-75 eggs with an average of 53.8 eggs. The female moths lived for about 2 days after completion of egg laying. The longevity of the adult male varied from 3- 5 days with an average of 4.1 days, whereas the females lived for 4- 6 days with an average of 5.8 days.

Sex ratio : The sex ratio of male: female was found to be 1: 1 under laboratory conditions.

Total life cycle

The total life cycle of *A. catalaunalis* varied from 19- 39 days.

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Efficacy of Sequences of IPM Practices against Sesame Leaf and Capsule Borer, *Antigastra catalaunalis* (Dup.)

Mamta Devi Choudhary*, K.C. Kumawat and R.G. Samota

Department of Entomology, SKN College of Agriculture, SKN Agricultural University, Jobner—303329 Rajasthan

*Email : mmtchoudhary233@gmail.com

Abstract

Investigations on “Efficacy of Sequences of IPM Practices against Sesame Leaf and Capsule Borer, *Antigastra catalaunalis* (Dup.)” were conducted at Agronomy farm and Department of Entomology, S.K.N. College of Agriculture, Jobner during Kharif, 2015 and 2016. *A. catalaunalis* were recorded as major insect pests of sesame during both the years of study. Total eleven treatments including untreated control were tested against *A. catalaunalis* for their efficacy. The integrated pest management modules viz. T₂ (Hand picking+destruction of larvae/infested plant part+spinosad 45 SC+NSKE), T₄ (Hand picking+destruction of larvae/infested plant part+indoxacarb 14.5SC+NSKE), T₁ (Hand picking+destruction of larvae/infested plant part+acephate 75 SP+NSKE) and standard check (carbaryl) were found effective in the management of *A. catalaunalis*. The highest seed yield of 8.21 q ha⁻¹ was recorded in the plots treated with T₂ (picking+destruction of larvae/infested plant part+spinosad 45 SC SC+NSKE) followed by T₄ (Hand picking+destruction of larvae/infested plant part+indoxacarb 14.5 SC+NSKE), (8.18 q ha⁻¹) and T₁ (Hand picking+destruction of larvae/infested plant part+acephate 75 SP+NSKE) (8.16q ha⁻¹). The highest B: C ratio was recorded in T₉ (Greengram+ HPDL/DIPP+NSKE+ *Chrysoperla zastrowi arabica* (two releases) (8.69), followed by T₈ (Greengram+ HPDL/DIPP+NSKE+ *Trichogramma chilonis* (two releases) (6.31).

Key words : Integrated pest management, sesame, *antigastra catalaunalis* (dup.), ipm modules.

Introduction

Sesame, *Sesamum indicum* (Linn.) (family: Pedaliaceae) is the oldest oilseed crop of world cultivated throughout the India. East Africa and India are considered to be the native home of sesame (Bedigian, 1985 and Nayar and Mehra, 1970). Its seeds contain 52- 57 per cent oil and 25 per cent protein (Smith *et al.*, 2000). The important sesame growing countries are India, China, Sudan, Burma and Mexico. In India, the main sesame cultivation states are Uttar Pradesh, Rajasthan, Madhya Pradesh, Andhra Pradesh, Odisha, Gujarat, Tamil Nadu and Karnataka. In India, production of sesame was estimated to be 8.11 lakh tonnes during 2015-16 (Anonymous, 2015a). The total area under cultivation of sesame in Rajasthan was about 3.30 lakh hectares with annual production to the tune of 9.49 thousand tonnes and average productivity of 288 kg (Anonymous, 2015b). The pests attack tolls a heavy loss (25- 90%) in seed yield (Ahuja and Kalyan, 2002). Among 67 insect pests damaging sesame crop, the leaf insect pests, viz., leaf and capsule borer, *Antigastra catalaunalis* (Dup.); jassid, *Orosius albicinctus* Distant; whitefly, *Bemisia tabaci* (Genn.) and mirid bug, *Nesidiocoris tenuis* (Reuter) are considered to be key pests (Ahirwar *et al.*, 2009). The *A. catalaunalis* is an important pest because this attacks the crop in all the growth stages after about two weeks of emergence (Suliman *et al.*, 2004). The attack is more

severe during dry seasons and after initiation of flowering. It feeds on tender foliage by webbing the top leaves, bores into the pods and shoots (Narayanan and Nadarajan, 2005). This insect pest causes 10-70 per cent infestation of leaves, 34-62 per cent of flower buds/ flowers and 10-44 per cent infestation of pods resulting in upto 72 per cent loss in yield (Ahirwar *et al.*, 2010). The chemical control has been suggested by many workers to combat with the insect pests of sesame crop (Goel and Kumar, 1991; Kumar *et al.*, 1994; Selvanarayanan and Baskaran, 1996; Brar *et al.*, 1999; Tripathi *et al.*, 2007; Kumar and Ali, 2010; Suliman *et al.*, 2013) but due to one or other reasons, could not become panacea in protection of the crop. As the chemical control solely could not become fool proof strategy due to one or the other reasons, the IPM by involving suitable techniques and bioagents were aimed to be studied in order to solve the problem. The insect natural enemies have received much less attention as natural control agents. The sesame ecosystem normally harbours beneficial insects, predators and parasites in numbers that frequently provide partial to satisfactory insect pest suppression. Therefore, the use of predators, parasitoids and pathogens may prove to be better choice among various groups of bioagents for the management of *A. catalaunalis* on sesame. A perusal of available literature revealed that very little attention has been paid to quantify the response of natural enemies against *A. catalaunalis* on sesame crop.

Materials and Methods

The experiment was laid out in simple randomized block design with three replications. Each plot was measured 2.5 x 1.5 m² and the crop was sown at row to row and plant to plant distance of 30 cm and 10 cm, respectively. The sesame variety RT- 125 was taken in this experiment and was grown on 12th July, 2015 and 2016. The recommendations as per package of practices were followed to raise the crop. In this experiment, ten sequences of insecticidal molecules, biopesticides, bioagents and other tactics were used and a control was maintained for comparison. First spray was done on 16th August using a knap sack sprayer and second application was made three weeks after first application. The re-build up of population was observed at this stage. The spray solution used for spraying the crop was 500 and 600 l ha⁻¹ in first and second spray, respectively.

Results and Discussion

During first year (Kharif, 2015), the T₂ (Hand picking + destruction of caterpillar/ infested plant part+ spinosad 45 SC+ NSKE), T₄ (Hand picking+ destruction of caterpillar/ infested plant part+ indoxacarb 14.5 SC+ NSKE) and T₁ (Hand picking+destruction of caterpillar/ infested plant part+acephate 75 SP+ NSKE) revealed population of *A. catalaunalis* ranging from 1.18- 1.51 per five plants which was significantly lower over rest of the integrated pest management (IPM) practices and were found at par among themselves (Table-1). The least effective group comprised T₉ (Intercropping with green gram+ Hand picking+ destruction of caterpillar/ infested plant part+ NSKE+ *Chrysoperla zastrowi arabica*), T₈ (Intercropping with green gram+ Hand picking+ destruction of caterpillar/ infested plant part+ NSKE+ *Trichogramma chilonis*), T₇ (Hand picking+ destruction of caterpillar/ infested plant part+ NSKE+ *Trichogramma chilonis*) and T₆ (Hand picking+ destruction of caterpillar/ infested plant part+ NSKE+ *Chrysoperla zastrowi arabica*) which revealed population of *A. catalaunalis* from 3.45- 4.57 per five plants. Rest of the sequences, T₁₀ (Standard check, carbaryl 50 WP), T₃ (Hand picking+ destruction of caterpillar/ infested plant part+ vertimec 1.9 EC+ NSKE) and T₅ (Hand picking+ destruction of caterpillar/ infested plant part+ Btk 8 L+ NSKE) ranked in the middle order of efficacy. All the sequences of IPM were found significantly superior over control.

In the second year (Kharif, 2016), the lowest population of *A. catalaunalis* was recorded in T₂, T₄ and T₁ (1.20- 1.89/ five plants), IPM sequences were found at par each other and significantly superior over other IPM sequences tested. Maximum population of *A. catalaunalis* was recorded in T₆ (4.76/ five plants) and differed significantly over control, T₁₁ (7.50/ five plants).

In the pooled data (Kharif, 2015 and 2016), the lowest population of *A. catalaunalis* was observed in T₂ (1.19/ five plants), T₄ (1.37/ five plants) and T₁ (1.70/ five plants). Maximum population of 4.67 per five plants was observed in T₆ which differed significantly over control, T₁₁ (7.29/ five plants). The efficacy of IPM sequences with regards to the population of *A. catalaunalis* in decreasing order was T₂, T₄, T₁, T₁₀, T₃, T₅, T₉, T₈, T₇, and T₆. The efficacy of IPM sequences with regards to the population of *A. catalaunalis* in decreasing order was T₂, T₄, T₁, T₁₀, T₃, T₅, T₉, T₈, T₇, and T₆. The IPM practices comprising intercropping of sesame with pearl millet reduced the damage with increased profitability of the crop as pointed out by Baskaran *et al.* (1991). Gupta (2002) reported effective management of *A. catalaunalis* with two foliar sprays of neem oil at 1 per cent and liquid soap+ intercropping of sesame with *Phaseolus mungo* [*Vigna mungo*] cultivar. Jawahar- 2 and pigeon pea cultivar, Jagrati in 3:1 row ratio. Ahiwar *et al.* (2009) reported that larval population of *A. catalaunalis* was significantly reduced in IPM practices comprising intercropping as against sesame sole crop.

Damage indices : In Kharif 2015, lowest leaf damage due to infestation of *A. catalaunalis* (2.05- 2.10%) was recorded in T₂ (Hand picking+ destruction of caterpillar/ infested plant part+ spinosad 45 SC+ NSKE) and T₄ (Hand picking+ destruction of caterpillar/ infested plant part+ indoxacarb 14.5 SC+ NSKE), these IPM sequences were at par each other (Table-2). The leaf damage was highest in the T₆ (Hand picking+ destruction of caterpillar/ infested plant part+ NSKE+ *Chrysoperla zastrowi arabica*), T₇ (Hand picking+ destruction of caterpillar/ infested plant part+ NSKE+ *Trichogramma chilonis*), viz., 3.25- 3.65 per cent which differed significantly over control (27.65% damage). The other IPM sequences resulted in the middle order.

In Kharif 2016, the minimum leaf damage (2.00- 2.50%) occurred in T₂ (Hand picking+ destruction of caterpillar/ infested plant part+ spinosad 45 SC+ NSKE), T₄ (Hand picking+ destruction of caterpillar/ infested plant part+ indoxacarb 14.5 SC+ NSKE) and T₁ (Hand picking+destruction of caterpillar/ infested plant part+acephate 75 SP+NSKE). The maximum leaf damage (3.35- 4.50%) was observed in T₆, T₇ and T₉ which were statistically at par each other and differed significantly over control (29.54%). The rest of the IPM sequences ranked in the middle order.

In the pooled data, the minimum leaf damage was observed in T₂, T₄ and T₁ (2.03- 2.73%), these IPM sequences were found significantly superior over rest of the sequences. It was maximum in the sequence T₇ and T₆ (4.03-4.63%). The remaining IPM sequences were

Table-1 : Efficacy of sequences of IPM practices against sesame leaf and capsule borer, *Antigastra catalaunalis* (Dup.) on sesame.

S.No.	Sequences	Population of leaf and capsule borer, <i>A. catalaunalis</i> / five plants		
		2015	2016	Pooled
T ₁	Hand picking+destruction of larvae/infested plant part+acephate 75 SP+NSKE	1.51 (1.42)	1.89 (1.55)	1.70 (1.48)
T ₂	Hand picking+destruction of larvae/infested plant part+spinosad 45 SC+NSKE	1.18 (1.30)	1.20 (1.30)	1.19 (1.30)
T ₃	Hand picking+destruction of larvae/infested plant part+vertimec 1.9 EC +NSKE	2.96 (1.86)	2.96 (1.86)	2.96 (1.86)
T ₄	Hand picking+destruction of larvae/infested plant part+indoxacarb 14.5 SC +NSKE	1.34 (1.36)	1.39 (1.37)	1.37 (1.35)
T ₅	Hand picking+destruction of larvae/infested plant part+ <i>Btk</i> 8 L+NSKE	3.05 (1.88)	3.01 (1.87)	3.03 (1.88)
T ₆	Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Chrysoperla zastrowi Arabica</i>	4.57 (2.25)	4.76 (2.29)	4.67 (2.27)
T ₇	Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Trichogramma chilonis</i>	4.09 (2.14)	4.12 (2.15)	4.11 (2.15)
T ₈	Intercropping with green gram+ Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Trichogramma chilonis</i>	3.89 (2.10)	3.95 (2.11)	3.92 (2.10)
T ₉	Intercropping with green gram+ Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Chrysoperla zastrowi Arabica</i>	3.45 (1.99)	3.68 (2.04)	3.57 (2.02)
T ₁₀	Standard check (carbaryl 50 WP)	2.61 (1.76)	2.89 (1.84)	2.75 (1.80)
T ₁₁	Control	7.07 2.75	7.50 2.83	7.29 2.79
	S.Em. $\pm$	0.12	0.10	0.09
	CD (p= 0.05)	0.36	0.29	0.25

* Mean of three replications, Figures in parentheses are X+0.5 values

Table-2 : Efficacy of sequences of IPM practices against sesame leaf and capsule borer, *Antigastra catalaunalis* (Dup.) on sesame.

S.No.	Sequences	Leaf damage (%)			Capsule damage (%)		
		2015	2016	Pooled	2015	2016	Pooled
T ₁	Hand picking+destruction of larvae/infested plant part+acephate 75 SP+NSKE	2.95 (9.89)	2.50 (9.10)	2.73 (9.50)	2.50 (9.10)	2.35 (8.82)	2.43 (8.96)
T ₂	Hand picking+destruction of larvae/infested plant part+spinosad 45 SC+NSKE	2.05 (8.23)	2.00 (8.13)	2.03 (8.18)	2.10 (8.33)	2.08 (8.29)	2.09 (8.31)
T ₃	Hand picking+destruction of larvae/infested plant part+vertimec 1.9 EC +NSKE	3.05 (10.06)	3.00 (9.97)	3.03 (10.02)	2.85 (9.72)	2.75 (9.55)	2.80 (9.63)
T ₄	Hand picking+destruction of larvae/infested plant part+indoxacarb 14.5 SC +NSKE	2.10 (8.33)	2.25 (8.63)	2.18 (8.48)	2.25 (8.63)	2.05 (8.23)	2.15 (8.43)
T ₅	Hand picking+destruction of larvae/infested plant part+ <i>Btk</i> 8 L+NSKE	3.65 (11.01)	3.75 (11.17)	3.70 (11.09)	3.35 (10.55)	3.05 (10.06)	3.20 (10.30)
T ₆	Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Chrysoperla zastrowi Arabica</i>	4.75 (12.59)	4.50 (12.25)	4.63 (12.42)	4.05 (11.61)	4.00 (11.54)	4.03 (11.57)
T ₇	Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Trichogramma chilonis</i>	4.00 (11.54)	4.05 (11.61)	4.03 (11.57)	3.50 (10.78)	3.50 (10.78)	3.50 (10.78)
T ₈	Intercropping with green gram+ Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Trichogramma chilonis</i>	3.25 (10.39)	3.35 (10.55)	3.30 (10.47)	3.05 (10.06)	2.95 (9.89)	3.00 (9.97)
T ₉	Intercropping with green gram+ Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Chrysoperla zastrowi Arabica</i>	3.95 (11.46)	3.95 (11.46)	3.95 (11.46)	3.45 (10.70)	3.25 (10.39)	3.35 (10.55)
T ₁₀	Standard check (carbaryl 50 WP)	3.00 (9.97)	2.75 (9.55)	2.88 (9.76)	2.75 (9.55)	2.50 (9.10)	2.63 (9.32)
T ₁₁	Untreated (control)	27.65 (31.72)	29.54 (32.92)	28.59 (32.32)	39.05 (38.67)	41.01 (39.82)	40.03 (39.24)
	S.Em. $\pm$	0.30	0.33	0.30	0.32	0.31	0.25
	CD (p= 0.05)	0.90	0.97	0.88	0.94	0.91	0.72

* Mean of three replications, Figures in parentheses are angular transformed values.

Table-3 : Effect of sequences of IPM practices on the seed yield of sesame, *Sesamum indicum* (Pooled, Kharif 2015 and 2016).

Sequences		Mean seed yield (q ha ⁻¹)		
		2015	2016	Pooled B. C. ratio
T ₁	Hand picking+destruction of larvae/infested plant part+acephate 75 SP+NSKE	7.83	7.85	7.84 5.65
T ₂	Hand picking+destruction of larvae/infested plant part+spinosad 45 SC+NSKE	8.21	8.21	8.21 3.51
T ₃	Hand picking+destruction of larvae/infested plant part+vertimec 1.9 EC +NSKE	6.90	6.94	6.92 4.52
T ₄	Hand picking+destruction of larvae/infested plant part+indoxacarb 14.5 SC +NSKE	8.17	8.19	8.18 3.55
T ₅	Hand picking+destruction of larvae/infested plant part+Btk 8 L+NSKE	6.68	6.70	6.69 3.01
T ₆	Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Chrysoperla zastrowi Arabica</i>	6.00	6.02	6.00 3.08
T ₇	Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Trichogramma chilonis</i>	5.97	6.08	6.04 2.75
T ₈	Intercropping with green gram+ Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Trichogramma chilonis</i>	6.10	6.25	6.18 6.31
T ₉	Intercropping with green gram+ Hand picking+destruction of larvae/infested plant part+NSKE+ <i>Chrysoperla zastrowi Arabica</i>	6.05	6.16	6.11 8.69
T ₁₀	Standard check (carbaryl 50 WP)	7.18	7.22	7.20 6.07
T ₁₁	Untreated (control)	4.00	4.25	4.12 0.31
		0.23	0.10	0.31
		0.69	0.77	0.93

ranked in the middle order. The effectiveness of IPM sequences in decreasing order was: T₂, T₄, T₁, T₁₀, T₃, T₈, T₅, T₉, T₇, and T₆.

In Kharif 2015, the minimum capsule damage of 2.10- 2.50 per cent was observed in plots having IPM sequences T₂ (Hand picking+ destruction of caterpillar/ infested plant part+ spinosad 45 SC+ NSKE), T₄ (Hand picking+ destruction of caterpillar/ infested plant part+ indoxacarb 14.5 SC+ NSKE) and T₁ (Hand picking+destruction of caterpillar/ infested plant part+acephate 75 SP+NSKE) which were found at par each other and significantly superior over rest of the IPM sequences (Table-2). The maximum capsule damage (3.45- 4.05%) was observed in T₆, T₇ and T₉ which were statistically at par each other and differed significantly over control (39.05%). The rest of the IPM sequences ranked in the middle order.

In Kharif 2016, the minimum capsule damage of 2.05-2.35 per cent was observed in plots treated with IPM sequences, T₂ (Hand picking+ destruction of caterpillar/ infested plant part+ spinosad 45 SC+ NSKE), T₄ (Hand picking+ destruction of caterpillar/ infested plant part+ indoxacarb 14.5 SC+ NSKE) and T₁ (Hand picking+destruction of caterpillar/ infested plant part+acephate 75 SP+NSKE) which were found at par each other and significantly superior over rest of the IPM sequences. The maximum capsule damage was observed in T₆ (4.00%), T₇ (3.50%) and T₉ (3.25%) which were statistically at par each other and differed significantly over control (41.01%). The rest of the IPM sequences ranked in the middle order.

In the pooled data, the minimum capsule damage was observed in T₂, T₄ and T₁ (2.03- 2.43%), these IPM sequences were found significantly superior over rest of the sequences. It was maximum in the sequence T₇ and T₆ (3.50-4.03%). The remaining IPM sequences were ranked in the middle order. The effectiveness of IPM sequences against *A. catalaunalis* in decreasing order was: T₂, T₄, T₁, T₁₀, T₃, T₈, T₅, T₉, T₇, and T₆. Nath *et al.* (2003) reported that IPM practice comprising intercropping of sesame with pearl millet significantly reduced the incidence of insect pests except *S. obliqua*.

Seed Yield : The pooled data registered on yield of sesame showed that it was maximum in the T₂ (8.21 q ha⁻¹) followed by T₄ (8.18 q ha⁻¹), T₁ (7.84 q ha⁻¹) and T₁₀ (7.20), these treatments were comparable with each other as well as best in enhanced the yield of sesame (Table-3). The treatment of T₇ proved least effective followed by T₆ and T₈ which registered seed yield of 6.04, 6.00 and 6.18 q ha⁻¹ respectively which were significantly superior over control (4.12 q ha⁻¹).

The plots treated with T₉ gave maximum benefit cost ratio of (8.69) and minimum benefit cost ratio T₇ (2.75) followed by T₅ (3.01). Behra and Jena (2013) reported that IPM practices comprising intercropping of sesame with clusterbean gave highest sesame equivalent yield (2192.38 kg/ha) followed by black gram (777.00 kg/ha). The benefit: cost ratio was 5.79 and 2.85 in case of cluster bean and black gram intercropping systems, respectively. Ahuja *et al.* (2005) reported that 2 sprays of azadirachtin at 0.03 per cent at vegetative and flowering stage of the

crop, and intercropping of sesame with green gram cultivar, K-851 in 1:1 ratio decreased the damage significantly and provided higher seed yield and economic returns (incremental cost benefit ratio was 1:3.44).

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Effect of Bio Regulators on Growth Parameters of Wheat (*Triticum aestivum* L.)

Manish Shekhawat*, P.K. Sharma and Sunil Kumar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : manishshekhawat705@gmail.com

Abstract

A field experimentation was carried out during *rabi* season of the year 2022-23 at research farm, Vivekananda Global University, Jaipur. The objectives were to study the Effect of bio regulators on growth, yield and quality of wheat (*Triticum aestivum* L.). The experiment consisted of 9 treatment combinations comprising three levels of fertilizer (Water spray at tillering and flowering stage (control), Seed soaking in water, Seed soaking in water + water spray at tillering and flowering stage, Seed soaking in 500 ppm thiourea, Seed soaking in 10 ppm kinetin, Foliar spray of 500 ppm thiourea at tillering and flowering stage, Foliar spray of 10 ppm kinetin at tillering and flowering stage, Seed soaking + foliar spray of thiourea at tillering and flowering stage and Seed soaking + foliar spray of kinetin at tillering and flowering stage. The experiment was laid out in Randomized Block Design and replicated thrice. The result showed that T₈ (Seed soaking + foliar spray of thiourea at tillering and flowering stage) recorded significant improvement in yield attributes viz. effective tillers per plant, spike length, number of grains per spike and test weight.

Key Words : Wheat, thiourea, growth regulators, and yield attributes.

Introduction

Wheat [*Triticum aestivum* (L.)] is one of the most important staple food crops of the world as well as India. It is used for making flakes and sweet meats like kheer and shira. Wheat straw is mainly used as fodder for livestock. In terms of area, India contributes highest wheat cultivated area (31.61 million hectares) in the world while acquired second position with respect to production (109.52 million tonnes) after china with the average productivity of 3.46 tonnes ha⁻¹ (Anonymous, 2020-21). In Rajasthan, the crop covers an area of 3.00 million hectares and production of 11.04 million tonnes with an average productivity of 3.68 tonnes ha⁻¹ (Anonymous, 2020-21).

The important constraints of low productivity of wheat are of water stress and other biotic and abiotic stresses. The conserved soil moisture in sandy soils of semi-arid regions of Rajasthan is not enough to replenish the water need and as such the crop suffers from water stress. Hence, intervention for adoption of improved scientific methods for improving the productivity by minimizing the impact of water stress during active growth period with the application of bio-regulators will help to increase the productivity of the crop. In this context 'thiourea, a novel semi-synthetic super absorbent polymer has shown potential to realize higher crop yield with limited water.

Materials and Methods

Experimental site : The experiment was laid out at

Research Farm, Vivekananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26°05' N latitude and 75°28' E longitude and at an altitude of 427 metres above mean sea level.. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 27.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 88.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 46 to 70 per cent, while the average sunshine hours ranged between 4.1 to 9.2 hrs/day

Experimental details : The experiment comprised of 9 treatments involving thiopurea and kinetin used to seed soaking and foliar spray their combinations that were laid down in randomized block design and replicated three times.

S.No.	Treatments	Symbols
1.	Water spray at tillering and flowering stage (control)	T ₁
2.	Seed soaking in water	T ₂
3.	Seed soaking in water + water spray at tillering and flowering stage	T ₃
4.	Seed soaking in 500 ppm thiourea	T ₄
5.	Seed soaking in 10 ppm kinetin	T ₅
6.	Foliar spray of 500 ppm thiourea at tillering and flowering stage	T ₆
7.	Foliar spray of 10 ppm kinetin at tillering and flowering stage	T ₇
8.	Seed soaking + foliar spray of thiourea at tillering and flowering stage	T ₈
9.	Seed soaking + foliar spray of kinetin at tillering and flowering stage	T ₉

Pant height : The periodical plant height at 30, 60, 90 DAS and at harvest was measured from the ground level to the top of the main shoot of the selected five plants from each plot. Average values for each plot at harvest were computed and recorded.

Dry matter accumulation : The periodical change in dry matter accumulation at 30, 60, 90 DAS and at harvest was recorded by collecting whole plant samples from randomly selected observational rows of each plot in 0.5 m running length of row. These samples were dried in sunlight for 2-3 days and finally dried in an oven at 70°C till a constant weight was obtained. Thereafter, the samples were weighed for estimating total dry matter accumulation and expressed in g per m row length.

Table-1 : Effect of bio-regulators on plant height at different stages of wheat.

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T ₁ -Water spray at tillering and flowering stage (control)	20.25	51.11	70.69	72.62
T ₂ -Seed soaking in water	20.31	51.15	70.88	72.69
T ₃ -Seed soaking in water + water spray at tillering and flowering stage	20.33	51.23	70.91	72.73
T ₄ -Seed soaking in 500 ppm thiourea	20.92	58.61	78.92	81.00
T ₅ -Seed soaking in 10 ppm kinetin	20.96	59.11	80.12	81.65
T ₆ -Foliar spray of 500 ppm thiourea at tillering and flowering stage	21.16	66.62	85.61	89.00
T ₇ -Foliar spray of 10 ppm kinetin at tillering and flowering stage	21.06	65.00	83.61	85.64
T ₈ -Seed soaking + foliar spray of thiourea at tillering and flowering stage	21.38	68.92	87.92	89.90
T ₉ -Seed soaking + foliar spray of kinetin at tillering and flowering stage	21.32	65.82	84.14	88.14
SEm±	1.00	2.37	2.58	2.74
CD (P=0.05)	3.00	7.09	7.75	8.21
CV (%)	8.31	6.86	5.65	5.82

Table-2 : Effect of bioregulators on dry matter accumulation at different stages of wheat.

Treatments	Dry matter accumulation/m row length (g)			
	30 DAS	60 DAS	90 DAS	At harvest
T ₁ -Water spray at tillering and flowering stage (control)	18.01	131.25	171.62	204.61
T ₂ -Seed soaking in water	18.10	131.82	172.32	205.11
T ₃ -Seed soaking in water + water spray at tillering and flowering stage	18.15	132.00	172.36	205.39
T ₄ -Seed soaking in 500 ppm thiourea	18.65	147.61	187.32	226.34
T ₅ -Seed soaking in 10 ppm kinetin	18.69	148.00	188.00	227.38
T ₆ -Foliar spray of 500 ppm thiourea at tillering and flowering stage	18.75	157.62	200.00	244.62
T ₇ -Foliar spray of 10 ppm kinetin at tillering and flowering stage	18.82	152.61	192.48	240.00
T ₈ -Seed soaking + foliar spray of thiourea at tillering and flowering stage	18.91	161.62	204.62	250.14
T ₉ -Seed soaking + foliar spray of kinetin at tillering and flowering stage	18.80	155.62	198.35	242.14
SEm±	0.64	5.02	4.63	6.81
CD (P=0.05)	1.93	15.06	13.88	20.42
CV (%)	6.02	5.94	4.28	5.19

Table-3 : Effect of bioregulators on chlorophyll content in leaf of wheat.

Treatments	Chlorophyll content (%)
T ₁ -Water spray at tillering and flowering stage (control)	1.84
T ₂ -Seed soaking in water	1.84
T ₃ -Seed soaking in water + water spray at tillering and flowering stage	1.85
T ₄ -Seed soaking in 500 ppm thiourea	2.07
T ₅ -Seed soaking in 10 ppm kinetin	2.08
T ₆ -Foliar spray of 500 ppm thiourea at tillering and flowering stage	2.26
T ₇ -Foliar spray of 10 ppm kinetin at tillering and flowering stage	2.21
T ₈ -Seed soaking + foliar spray of thiourea at tillering and flowering stage	2.29
T ₉ -Seed soaking + foliar spray of kinetin at tillering and flowering stage	2.22
SEm±	0.07
CD (P=0.05)	0.20
CV (%)	5.64

Chlorophyll content (mg/g) : Chlorophyll content at 60 days after sowing was determined as per the method advocated by Arnon (1949) by taking 50 mg fresh leaf material, samples were homogenized in 80 per cent acetone and aliquot was taken and centrifuged for 10 minutes at 2000 rpm and the final volume was made to 10 ml. Absorbance of clear supernatant liquid was measured at 652 nm on Spectronic-20.

$$\text{Total chlorophyll} = \frac{A_{(652)} \times 29}{1000} \times \frac{\text{Total volume (ml)}}{\text{Weight of sample (g)}}$$

Where,

is the path length = 1 cm

29 is constant

Results and Discussion

Plant height : At 60, 90 DAS and harvest the treatment T₈ (T₈-Seed soaking + foliar spray of thiourea at tillering and flowering stage) recorded the maximum plant height of 68.92, 87.92 and 89.90 cm at 60, 90 DAS and at harvest of wheat, respectively.

Dry matter accumulation : The higher dry matter accumulation was recorded under treatment T₈ with the respective values of 161.62, 204.62 and 250.14g at 60, 90 DAS and at harvest stage.

Chlorophyll content : The maximum chlorophyll content was recorded under the treatment T₈ (Seed soaking + foliar spray of thiourea at tillering and flowering stage).

The result showed that different levels of bioregulators upto T₈ (Seed soaking + foliar spray of thiourea at tillering and flowering stage) significantly improved plant height, dry matter and chlorophyll content.

The results are in conformity with those of Dadhich *et al.* (2015), Ghosh *et al.* (1999) and Gupta *et al.* (2017b).

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Effect of Nitrogen Scheduling on Yield and Harvest Index of Wheat (*Triticum aestivum* L.)

Murari Lal Saini*, P.K. Sharma and Lokesh Saini

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : sainimurari109@gmail.com

Abstract

Field experiment was conducted at research farm, Vivekananda Global University, Jaipur, during *rabi* season of 2022-23. The experiment consisted of 12 liquid formation treatments viz., T₁: 1/2 at basal + 1/2 at CRI (21-25 DAS), T₂: 1/2 at basal + 1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS), T₃: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS), T₄: 1/2 at basal +1/2 at CRI (21-25 DAS) + 2.0 % urea spray at flag leaf stage (80-90 DAS), T₅: 1/2 at basal +1/2 at CRI (21-25 DAS) + 0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS), T₆: 1/2 at basal +1/2 at CRI (21-25 DAS) + 2.0 % urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS), T₇: 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) +2.0 % urea spray at flag leaf stage (65-70 DAS), T₈: 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) + 0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS), T₉: 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS), T₁₀: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS), T₁₁: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS) and T₁₂: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS) that were laid out in a Randomized Block Design and replicated thrice. Foliar application of T₁₂: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS) showed maximum yield and harvest index.

Key Words : Wheat, jointing stage, flag leaf stage, yield and harvest index.

Introduction

Wheat (*Triticum aestivum* L.) is an important cereal crop belongs to family "Poaceae" and genus *Triticum*. Wheat plays a crucial role during green revolution (1966-67) in India with the supplement irrigation and nutrient application which is most key factor to achieve its yield potential. In terms of area, India contributes highest wheat cultivated area (31.61 million hectares) in the world while acquired second position with respect to production (109.52 million tonnes) after china with the average productivity of 3.46 tonnes ha⁻¹ (Anonymous, 2021a).

Nitrogen is essential nutrient for plant growth and involved in important synthesis and formation of many important substances and compounds in plant such as amino acids, enzymes, DNA, RNA and chlorophyll. It is responsible for greenness, vigorous growth and overall crop development; therefore it must be available for plants in adequate amounts.

The productivity of crop is controlled by many factors of which the mineral nutrition specifically of nitrogen is most important. The most important factor is that the heavy and imbalanced use of chemical fertilizer has led to think about the use of organic manures in intensively growing areas for sustainable production system. Therefore, to sustain the land and to achieve production potential of crops, the experimental finding in India have

clearly indicated that there is a need to integrate both the organic and inorganic substances for sustainable crop production.

Materials and Methods

Experimental site : The experiment was laid out at Agronomy Farm, Vivekananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5' North latitude and 75° 28' East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs/day.

Table-1 : Effect of Nitrogen scheduling on grain yield, stover yield and biological yield of wheat.

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)
T1: 1/2 at basal + 1/2 at CRI (21-25 DAS)	2526	3995	6521
T2 : 1/2 at basal + 1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS)	2594	4098	6692
T3 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS)	3425	5112	8537
T4 : 1/2 at basal +1/2 at CRI (21-25 DAS) + 2.0 % urea spray at flag leaf stage (80-90 DAS)	3472	5194	8666
T5 : 1/2 at basal +1/2 at CRI (21-25 DAS) + 0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	3645	5464	9109
T6 : 1/2 at basal +1/2 at CRI (21-25 DAS) + 2.0 % urea +0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	3665	5554	9219
T7 : 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) +2.0 % urea spray at flag leaf stage (65-70 DAS)	3895	5894	9789
T8 : 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	4062	6021	10083
T9 : 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	4965	6221	11186
T10 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea spray at flag leaf stage (80-90 DAS)	5061	6340	11401
T11 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	5120	6524	11644
T12 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	5230	6634	11864
SEm±	161	329	171
CD (P=0.05)	467	955	497
CV (%)	8	11	3

Table-2 : Effect of Nitrogen scheduling on harvest index of wheat.

Treatments	Harvest index
T1: 1/2 at basal + 1/2 at CRI (21-25 DAS)	38.74
T2 : 1/2 at basal + 1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS)	38.76
T3 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS)	40.12
T4 : 1/2 at basal +1/2 at CRI (21-25 DAS) + 2.0 % urea spray at flag leaf stage (80-90 DAS)	40.06
T5 : 1/2 at basal +1/2 at CRI (21-25 DAS) + 0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	40.02
T6 : 1/2 at basal +1/2 at CRI (21-25 DAS) + 2.0 % urea +0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	39.75
T7 : 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) +2.0 % urea spray at flag leaf stage (65-70 DAS)	39.79
T8 : 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	40.29
T9 : 1/2 at basal +1/4 at CRI (21-25 DAS)+ 1/4 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	44.39
T10 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea spray at flag leaf stage (80-90 DAS)	44.39
T11 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	43.97
T12 : 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO ₄ spray at flag leaf stage (80-90 DAS)	44.08
SEm±	1.86
CD (P=0.05)	5.39
CV (%)	8.57

Experimental details : The experiment comprised of 12 treatments involving different nitrogen scheduling were laid down in randomized block design and replicated three times.

Grain yield (kg/ha) : Under each experimental plot after discarding border and sampling rows, crop was harvested and produce was bundled. After sun drying these were weighed to record biological yield. The material was threshed manually and winnowed. The clean seed obtained from individual plots was weighed and the weight recorded as grain yield in terms of kg/ha.

Straw yield (kg/ha) : Straw yield was obtained by subtracting the grain yield from biological yield. The grain and straw recorded under each plot were converted into kg/ha.

Biological yield (kg/ha) : After complete sun drying, harvested bundles of each net plot (3.0 m x 1.35 m) were weighed for biological yield and converted in terms of kg/ha.

Harvest index (%) : Harvest index was computed by using the formula outlined by Singh and Stoskopf (1971).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg / ha)}}{\text{Biological yield (kg / ha)}} \times 100$$

Results and Discussion

Grain yield : T₁₂: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS) recorded the maximum grain yield of wheat (5230 kg/ha).

Stover yield : T₁₂: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS), recorded the maximum straw yield of wheat (6634 kg/ha)

Harvest index : Treatment T₁₂: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 %

urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS), recorded the maximum straw yield of wheat (6634 kg/ha)

Liquid sprays of T₁₂: 1/3 at basal +1/3 at CRI (21-25 DAS) + 1/3 at Jointing stage (65-70 DAS) + 2.0 % urea +0.5 % ZnSO₄ spray at flag leaf stage (80-90 DAS) recorded the significantly highest seed yield, straw yield, biological yield and harvest index.. Similar results have been reported by Abedi *et al* (2011), Meena and Mann (2010), Ram *et al.*, 2012 and Dubey *et al* (2018a).

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The Extent of Adoption of Recommended Interventions of Gram Crops by the Respondents in Bikaner District of Rajasthan

Ramdhan Ghaswa¹, S.K. Sharma², Amit Kumar¹ and S.S. Bana³

¹Krishi Vigyan Kendra-Jaora, Ratlam-457339, Madhya Pradesh

²Swami Keshwanand Rajasthan Agricultural University Bikaner, Rajasthan

³School of Agricultural Science, Raffles University, Neemrana, Rajasthan

Corresponding Author Email : ramdhanhorti@gmail.com

Abstract

The findings revealed that 52.40 per cent of the total gram respondents were in the medium level of adoption group, whereas, 23.80 per cent respondents were in high level of adoption group and remaining 23.80 per cent gram growers were observed in the low level of adoption about recommended gram interventions. In case of gram beneficiary farmers difference was found among three categories i.e. low, medium and high level of adoption group with 17.46 per cent, 46.03 per cent and 36.51 per cent respectively. Further, in case of gram non-beneficiary farmers, i.e. 30.15 per cent of the farmers belonged to low adoption category followed by medium adoption level 58.73 per cent. Only 11.12 per cent non-beneficiary farmers were found with high level of adoption about gram cultivation practices.

Key words : *Extent of adoption, beneficiary, non-beneficiary gram crops, production, technology.*

Introduction

Pulses are the main source of quality protein and a rich source of energy, minerals and certain vitamins. They help in balancing the cereal dominated diet of low and middle income families by supplementing the essential amino acids profile of cereal proteins economically. Among pulses chickpea is the premier pulse crop of India, popularly known as Gram or Bengal gram, mainly grown in Rabi season. There are two main kinds of chickpea Desi and Kabuli. Desi has small, darker seeds and a rough coat, cultivated mostly in the Indian continent, Ethiopia, Mexico and Iran. Kabuli has lighter colored, larger seeds and a smoother coat, mainly grown in Southern Europe, Northern Africa, Afghanistan, Pakistan and Chile also introduced during the 18th century to the Indian continent. Chickpea is a rich source of highly digestible dietary protein (17-21 percent), carbohydrate (61.5 percent) and fat (4.5 per cent). It is also rich in calcium, iron, niacin, vitamin-B and vitamin-C. Its leaves contain malic acid which is very useful for stomach ailments and blood purification. Its straws are rich in nutrients and are mostly used as productive ratio. During 2015-16 chickpea covered an area of 8.40 M. ha producing 7.06 Mt at an average productivity of 841 Kg ha⁻¹ (Economic survey 2016-17, Govt. of India). In the state of Rajasthan during 2015-16 chickpea cultivated in 12.97 lakh ha area and produced 9.88 Mt (Directorate of Agriculture, Govt. of Rajasthan).

The National Food Security Mission (NFSM) during

the 12th five year plan has five components i.e. NFSM-Rice, NFSM- Wheat, NFSM- Pulse, NFSM-Course Cereals and NFSM- Commercial Crops. The overall objective of the NFSM is to facilitate and accelerates the sustainable transformation of the Indian agriculture so that it can support poverty alleviations and income generation through collaborative development and application of agricultural innovations by the public organizations in partnership with farmers groups, the private sectors and other stakeholders.

Materials and Methods

The present study was conducted in Bikaner district of Rajasthan. The National Food Security Mission is in operation in all panchayat samities of Bikaner district, out of which three panchayat samities were taken for study. For selection of villages a list of villages were prepared from the selected panchayat samities for the study purpose where the interventions of gram were taken under NFSM. There were 12 villages in the selected panchayat samities where NFSM activities have been in operations in the last year 2014-15. Out of the list three villages were selected randomly for the study purpose from each selected panchayat samity. This way a total of 9 villages were selected from this identified panchayat samities. To know the impact of National Food Security Mission, a control group of villages was also required. Therefore, three distant villages where the National Food Security Mission was not in operation were also selected on the basis of random sampling technique. Thus, in total 9 villages were selected from all the identified panchayat

Table-1 : Distribution of respondents according to their level of adoption about gram production technology. n=126

S.No.	Adoption Level	Beneficiary respondents		Non-beneficiary respondent		Total	
		F	%	f	%	F	%
1.	Low (<36.05)	11	17.46	19	30.15	30	23.80
2.	Medium (36.05 to 72.17)	29	46.03	37	58.74	66	52.40
3.	High (>72.17)	23	36.51	7	11.11	30	23.80
	Total	63	100	63	100	126	100

f = Frequency, % = percent mean 54.11 S.D. 18.06

Table-2 : Practice wise Adoption level of beneficiary and non- beneficiary respondents about Gram production technology. n=126

S.N.	Gram Practices	Beneficiary Respondents		Non-Beneficiary Respondents		Pooled	
		MPS	Rank	MPS	Rank	MPS	Rank
1.	Field Preparation	70.63	3	59.52	3	65.08	3
2.	Use of High Yielding Varieties	77.78	1	43.65	5	60.71	4
3.	Seed Sowing, Seed rate and Spacing	68.25	5	48.41	4	58.33	5
4.	Seed Treatment	46.49	9	33.79	9	40.14	9
5.	Manure and Fertilizer Application	51.85	8	40.48	7	46.16	7
6.	Irrigation Management	75.40	2	64.29	1	69.84	1
7.	Weed Management	57.78	6	42.86	6	50.32	6
8.	Plant Protection Measures	53.97	7	38.10	8	46.03	8
9.	Harvesting, Threshing and Storage	70.24	4	63.89	2	67.06	2
	Over all	63.60		48.33		55.96	

r 0.80 t0.05 2.26

t 3.53 t0.01 3.25

Table-3 : Practice wise comparison between beneficiary and non-beneficiary respondents about extent of adoption of gram production technology. n=126

S. No.	Package of practices	Beneficiary respondents (n=63)		Non-beneficiary respondents (n=63)		Z' Value
		Mean +	S.D.	Mean +	S.D.	
1.	Field Preparation	5.65	1.74	4.76	1.50	3.87**
2.	Use of High Yielding Varieties	9.33	5.02	4.57	5.87	6.16**
3.	Seed Sowing, Seed rate and Spacing	8.19	2.48	5.81	2.63	6.58**
4.	Seed Treatment	6.51	3.48	4.73	3.72	3.49**
5.	Manure and Fertilizer Application	6.22	2.13	4.86	1.93	4.76**
6.	Irrigation Management	6.03	2.26	5.14	2.21	2.82*
7.	Weed Management	5.78	2.78	4.29	2.18	4.22**
8.	Plant Protection Measures	8.63	3.31	6.98	3.64	3.35**
9.	Harvesting, Threshing and Storage	5.62	1.52	5.11	1.79	2.17ns
	Overall	6.89	2.75	5.14	2.83	4.43

** Significance at 1 percent level * Significance at 5 percent level

samities and these villages were considered as non-beneficiaries villages.

For selection of beneficiary respondents, a comprehensive list of gram growers who were benefitted under National Food Security Mission in 2014-15 was prepared separately. From the lists so prepared, 7 gram respondents were selected randomly from each identified village. Thus, a total of 63 gram beneficiary respondents were selected on the basis of random sampling method from the identified villages.

Likewise, 7 gram respondents were selected on the basis of random sampling technique from the each identified non- beneficiary village. Total 63 Gram respondents were selected from all the non- beneficiary villages.

An interview schedule was prepared consisting of tools to measure the dependent and independent variables. The reliability and validity of the schedule were measured in order to record the authentic information from the respondents. Responses of the respondents were recorded by personal interview method by the

investigator himself. The responses were then converted in to scores and transferred in master table. Data were analyzed by applying appropriate statistical tests.

finally nine adoption parameters were selected. For each parameter, several adoption question were drafted accordingly. In order to fix the weightage of each parameters of the whole adoptions scale, the investigator personally contacted the 20 experts of different disciplines including staff member of Department of Agronomy and Extension Education (SKRAU) Bikaner, Department of Agronomy and Extension Education (SKNCOA) Jobner, and requested them to award the score of these parameters including the question out of 100 scores on the basis difficulty and easiness in adoption of these parameters. Later on the scores awarded by 20 experts were summed and the average score for the individuals parameters were workout. The average score were rounded to nearest whole number. In this way the weightage of individual parameter was fixed and the scores were awarded to the individuals respondent accordingly. The responses of respondent were recorded and weightage assigned for the adoption of parameter and zero score for non-adoption of parameter. Maximum possible score for each respondent was 100. The adoption quotient was calculated by means of adoption index using following formula :

$$\text{Adoption index} = \frac{\text{Adoption score obtained}}{\text{Possible maximum obtained score}}$$

Results and Discussion

Distribution of respondents according to their level of adoption about gram production technology : To get an overview of adoption level, the respondents were divided into three categories as presented in table-1.

Table-1 depicts that 52.40 percent of the total respondents were in the medium level of adoption group, whereas, 23.80 percent respondents were in high level of adoption group and remaining 23.80 percent gram respondents to be observed in the low level of adoption about recommended gram production technology.

Further, among the categories of gram respondents, it was observed that 46.03 percent beneficiary respondents and 58.73 percent non-beneficiary respondents were in medium level of adoption category. Whereas, 17.46 percent beneficiary respondents and 30.15 percent non-beneficiary respondents were noted in the low level of adoption category. Likewise, 36.50 percent and 11.12 percent beneficiary and non-beneficiary respondents possessed high level of adoption respectively about recommended gram production technology. Thus, from the above results it can be concluded that beneficiary gram respondents had

more adoption about recommended gram production technology than non-beneficiary gram respondents in the study area. The similar findings are reported by Sarada and Kumar (2013) concluded that more than fifty percent of beneficiary chickpea respondents had medium level of adoption with respect to Integrated Pest Management practices, followed by 36.00 percent of beneficiary respondents under high category. Whereas 48.00 percent of the non-beneficiary respondents were in low adoption category, Sirohiya et al. (2012) and Vashishtha et al. (2010).

Practice wise extent of beneficiary and non-beneficiary respondents about gram production technology :

The production technology of field preparation, use of high yielding varieties, seed sowing seed rate and spacing, seed treatment, manure and fertilizer application, irrigation management, weed management, plant protection measures and harvesting, threshing and storage were introduced under National Food Security Mission in the study area. Therefore, an effort was made to assess the intervention-wise extent of adoption among gram respondents. The results of the same have been given in subsequent table-2.

The adoption level of beneficiary and non-beneficiary respondents with regard to package of practices of gram production technology were measured in terms of Mean Percent Score (MPS). The data presented in table 5.23 shows that beneficiary respondents possessed very good adoption level (>70 MPS) regarding practices like use of high yielding varieties, irrigation management field preparation and harvesting, threshing & storage with 77.78, 75.40, 70.63 and 70.24 MPS, respectively. Beneficiary gram growing respondents had good adoption level (>50 MPS) regarding practices like seed sowing, seed rate & spacing, weed management, plant protection and manure and fertilizer with 68.25, 57.78, 53.97, and 51.85 MPS, respectively. They had low adoption level in practices like seed treatment 46.49 MPS. In case of non-beneficiary gram respondents, they possessed high adoption level regarding practices like irrigation management and harvesting, threshing & storage with 64.29 and 63.89 MPS, respectively. They had low adoption level regarding field preparation, seed sowing, seed rate & spacing, use of high yielding varieties, weed management, manure and fertilizer, plant protection, and seed treatment with 59.52, 48.41, 43.65, 42.86, 40.48, 38.10 and 33.79 MPS, respectively.

The overall extent of adoption of the beneficiary respondents (63.60 MPS) was higher than the non-beneficiary respondents (48.33 MPS). The value of calculated rank correlation (r_s) was 0.80 which is positive

and significant at 1 percent level of significance, leading to conclusion that there was a similarity in rank assignment pattern of adoption level of beneficiary and non-beneficiary respondents about gram production technology, though there was a difference in the magnitude of MPS of beneficiary and non-beneficiary respondents.

Form above discussion, it can be concluded that the most of the beneficiary farmers possessed more adoption than non-beneficiary farmers in all aspects Gram production technology. It can be concluded that the extent of adoption in beneficiary farmers was 46.49 to 77.78 percent, while in case of non-beneficiary farmers the extent of adoption was 40.14 to 69.84 percent in all aspects Gram production technology. To improve the more extent of adoption in both the categories of farmers, intensive training programmes should be organized timely and should be location specific for the study area. The present findings are in accordance with the findings of Samota (2011) Sirohiya *et al.* (2012) and Vashishtha *et al.* (2010).

Practice wise comparison between beneficiary and non-beneficiary respondents about extent of adoption of gram production technology : To find out the variation or similarity in the adoption of recommended gram production technology between beneficiary and non-beneficiary respondents, 'Z' test was applied. The results were presented in Table-3.

The data related to extent of adoption of both beneficiary and non-beneficiary respondents incorporated in the table 5.24 shows that calculated 'Z' value was higher than the tabulated value at 1 percent level of significance in seven packages of practices of gram production technology and z value was higher than the tabulated value at 5 percent of significance in one package of practices. This showed that in eight practices of gram, beneficiary and non-beneficiary respondents had wide difference in their adoption level. It means that beneficiary respondents possessed more adoption as compared to the non-beneficiary respondents in the above mentioned eight packages of practices as well as overall adoption of beneficiary and non-beneficiary respondents regarding gram cultivation practices. In remaining one cultivation practices of gram production viz. harvesting, threshing & storage, the value of 'z' test was found non-significant. This means that there is no difference in the adoption of both categories of gram respondents.

The mean value further indicates that beneficiary respondents had higher adoption than non-beneficiary respondents about gram production technology. This difference in the level of adoption of gram respondents might be due to the reason that beneficiary respondents

had participated in the activities of National Food Security Mission and acquired understanding about gram production technology which resulted in adoption. The significant difference between beneficiary and non-beneficiary respondents regarding adoption of recommended gram production technology highlights that there was positive impact of NFSM on beneficiary respondents with regard to increase in adoption of recommended gram production technology in the study area. Similar findings are reported by Vashishtha *et al.* (2010) and Kumar (2013).

Conclusions

Majority of the farmers were medium adopters of the gram and moth production technology under NFSM. There was significant difference between the beneficiaries and non-beneficiaries with regard to adoption of package of practices of gram and moth cultivation. Beneficiaries were found adopting the practices at higher rate as compared to the non-beneficiaries.

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Knowledge Level of Beneficiary and Non-Beneficiary Farmers of Gram Production Technology in Bikaner District of Rajasthan

Ramdhan Ghaswa¹, S.K. Sharma², Amit Kumar¹ and S.S. Bana³

¹Krishi Vigyan Kendra-Jaora, Ratlam-457339, Madhya Pradesh

²Swami Keshwanand Rajasthan Agricultural University Bikaner, Rajasthan

³School of Agricultural Science, Raffles University, Neemrana, Rajasthan

Corresponding Author Email : ramdhanhorti@gmail.com

Abstract

Gram is a versatile crop that is grown in almost every part of the world. It is the most largely production pulse crop in India. Pulses are the main source of quality protein and a rich source of energy, minerals and certain vitamins. The study was conducted in Bikaner district of Rajasthan. The National Food Security Mission is in operation in all six panchayat samities of Bikaner district. Out of which fifty percent panchayat samities, i.e. three panchayat samities Nokha, Lunkarnshar, Sri Dungargarh were selected purposely. Out of selected panchayat samities three gram panchayats were selected randomly from each panchayat samities on the basis of random sampling method. Thus, the total 9 villages were selected. To know the impact of National Food Security Mission, a control group of villages were also be required. Therefore, three distant villages where the National Food Security Mission was not in operation were also selected on the basis of random sampling technique from each identified panchayat samity. 7 beneficiary and 7 non-beneficiary gram respondents were selected randomly from each identified village. Thus, a total of 63 beneficiary respondents and 63 non-beneficiary gram respondents. The study found that majority of gram respondent (53.96%) had medium level of knowledge, whereas 25.40 per cent and 20.64per cent were having high and low knowledge level about recommended production technology of gram. The study revealed that 38.09 per cent beneficiary farmers and 12.70 per cent non-beneficiary farmers had high level of knowledge about gram interventions. Whereas, 47.62 per cent beneficiary farmers and 60.32 per cent non-beneficiary farmers possessed medium level of knowledge about recommended gram interventions. On the other hand, 14.29 per cent beneficiary farmers and 26.98 per cent non-beneficiary farmers were categorized in the low level knowledge group as this category of respondents had poor knowledge about recommended gram interventions.

Key words : Beneficiary, non- beneficiary, gram production technology, knowledge level.

Introduction

The National Food Security Mission (NFSM) during the 12th five year plan has five components i.e. NFSM-Rice, NFSM- Wheat, NFSM- Pulse, NFSM-Course Cereals and NFSM- Commercial Crops. The overall objective of the NFSM is to facilitate and accelerates the sustainable transformation of the Indian agriculture so that it can support poverty alleviations and income generation through collaborative development and application of agricultural innovations by the public organizations in partnership with farmers groups, the private sectors and other stakeholders.

Pulse crops play an important role in Indian agriculture. Besides being rich in protein, pulses are the main sources of essential amino acids for predominantly vegetarian population of India. They contain 22-24 per cent of protein, which is almost twice the protein in wheat and thrice as that of rice. In India, owing to its diverse

agro-climatic conditions, pulses are grown throughout the year and plays an important role in crop rotation, mixed and inter-cropping, maintaining soil fertility through nitrogen fixation, release of soil-bound phosphorus and thus contribute significantly to sustainability of the farming systems. In the production process, pulses require less water than cereals.

Among pulses chickpea is the premier pulse crop of India, popularly known as Gram or Bengal gram, mainly grown in Rabi season. There are two main kinds of chickpea Desi and Kabuli. Desi has small, darker seeds and a rough coat, cultivated mostly in the Indian continent, Ethiopia, Mexico and Iran. Kabuli has lighter colored, larger seeds and a smoother coat, mainly grown in Southern Europe, Northern Africa, Afghanistan, Pakistan and Chile also introduced during the 18th century to the Indian continent. Chickpea is a rich source of highly digestible dietary protein (17-21 percent), carbohydrate (61.5 percent) and fat (4.5 per cent). It is also rich in

Table-1 : Knowledge level of beneficiary and non-beneficiary respondents about gram production technology. N=126

S.No.	Knowledge Level	Non-beneficiary Respondent		Beneficiary Respondents		Total	
		F	%	F	%	F	%
1.	Low (<30.92)	17	26.98	9	14.28	26	20.64
2.	Medium (30.92 to 52.20)	38	60.32	30	47.62	68	53.96
3.	High (> 52.20)	8	12.70	24	38.10	32	25.40
	Total	63	100	63	100	126	100

Mean 41.56, S. D. 10.64 F = Frequency, % = percent

Table-2 : Practice wise knowledge level of beneficiary and non-beneficiary respondents about gram production technology. N=126

S.N.	Gram Practices	Non-beneficiary Respondents		Beneficiary Respondents		Pooled	
		MPS	Rank	MPS	Rank	MPS	Rank
1.	Field Preparation	72.33	1	82.53	1	77.43	1
2.	Use of High Yielding Varieties	56.87	5	81.48	2	69.17	5
3.	Seed Sowing, Seed rate and Spacing	71.42	2	77.77	3	74.60	2
4.	Seed Treatment	42.06	9	53.17	9	47.61	9
5.	Manure and Fertilizer Application	53.67	6	75.46	6	64.57	6
6.	Irrigation Management	66.13	4	76.71	4	71.42	4
7.	Weed Management	44.84	8	65.07	7	54.96	7
8.	Plant Protection Measures	49.32	7	60.43	8	54.88	8
9.	Harvesting, Threshing and Storage	69.84	3	75.92	5	72.88	3
	Over all	58.50		72.06		65.28	

r 0.866667 t0.05 2.262157

t 4.596194 t0.01 3.249836

Table-3 : Practice wise comparison between beneficiary and non-beneficiary respondents about knowledge of gram production technology.

S. No.	Package of practices	Non-beneficiary Respondents		Beneficiary Respondents		Z' Value
		(n=63)		(n=63)		
		Mean +	S.D.	Mean +	S.D.	
1.	Field Preparation	5.06	1.25	5.77	1.08	4.31**
2.	Use of High Yielding Varieties	6.82	1.32	9.77	1.63	14.01**
3.	Seed Sowing, Seed rate and Spacing	2.85	0.77	3.11	0.80	2.27ns
4.	Seed Treatment	1.68	0.83	2.13	1.32	2.83*
5.	Manure and Fertilizer Application	5.90	3.71	8.30	2.17	5.57**
6.	Irrigation Management	1.98	0.68	2.30	0.73	3.17*
7.	Weed Management	1.79	1.19	2.60	1.07	5.05**
8.	Plant Protection Measures	6.41	2.85	7.85	2.68	3.68**
9.	Harvesting ,Threshing and Storage	4.19	1.29	4.55	1.14	2.11ns
	Overall	4.08	1.55	5.16	1.41	5.15**

** Significance at 1 percent level * Significance at 5 percent level

calcium, iron, niacin, vitamin-B and vitamin-C. Its leaves contain malic acid which is very useful for stomach ailments and blood purification. Its straws are rich in nutrients and are mostly used as productive ratio. During 2015-16 chickpea covered an area of 8.40 M. ha producing 7.06 Mt at an average productivity of 841 Kg ha⁻¹ (Economic survey 2016-17, Govt. of India). In the state of Rajasthan during 2015-16 chickpea cultivated in 12.97 lakh ha area and produced 9.88 Mt (Directorate of Agriculture, Govt. of Rajasthan).

Material and methods

The present study was conducted in Bikaner district of Rajasthan. The National Food Security Mission is in operation in all panchayat samities of Bikaner district, out of which three panchayat samities were taken for study. For selection of villages a list of villages were prepared from the selected panchayat samities for the study purpose where the interventions of gram were taken under NFSM. There were 12 villages in the selected

panchayat samities where NFSM activities have been in operations in the last year 2014-15. Out of the list three villages were selected randomly for the study purpose from each selected panchayat samity. This way a total of 9 villages were selected from this identified panchayat samities. To know the impact of National Food Security Mission, a control group of villages was also required. Therefore, three distant villages where the National Food Security Mission was not in operation were also selected on the basis of random sampling technique. Thus, in total 9 villages were selected from all the identified panchayat samities and these villages were considered as non-beneficiaries villages.

For selection of beneficiary respondents, a comprehensive list of gram growers who were benefitted under National Food Security Mission in 2014-15 was prepared separately. From the lists so prepared, 7 gram respondents were selected randomly from each identified village. Thus, a total of 63 gram beneficiary respondents were selected on the basis of random sampling method from the identified villages.

Likewise, 7 gram respondents were selected on the basis of random sampling technique from the each identified non-beneficiary village. Total 63 Gram respondents were selected from all the non-beneficiary villages.

An interview schedule was prepared consisting of tools to measure the dependent and independent variables. The reliability and validity of the schedule were measured in order to record the authentic information from the respondents. Responses of the respondents were recorded by personal interview method by the investigator himself. The responses were then converted in to scores and transferred in master table. Data were analyzed by applying appropriate statistical tests.

Nine major aspects were included in the knowledge test viz. (i) field preparation (ii) use of high yielding varieties (iii) seed sowing, seed rate and spacing (iv) seed treatment (v) manure and fertilizer application (vi) irrigation management (vii) weed management (viii) plant protection measures (ix) harvesting, threshing and storage. Each aspect was divided into several question and sub-question for knowledge assessment. Thus this test included nine aspect and 43 knowledge based question. The questions were alternative and dichotomize type. The respondent were awarded one score for each right answer and zero for each wrong answer. Therefore, the possible maximum obtainable knowledge score was 64 and minimum was zero. The responses obtained from the respondents were counted and converted in to mean and mean per cent score. The knowledge index for each respondent was calculated by using the following formula:

$$\text{Adoption index} = \frac{\text{Knowledge score obtained}}{\text{Possible maximum obtained score}}$$

Results and Discussion

Distribution of the respondents according to their knowledge level regarding gram production technology : To get an overview of the knowledge level, the respondents were classified into three categories. The distribution of respondents in each category is given in table-1.

Table-1 reveals that out of 126 respondents, majority of respondents (53.96 %) fell in medium level of knowledge group whereas, 20.64 percent respondents were observed in low level of knowledge group and remaining 25.40 percent respondents possessed high level of knowledge about recommended gram production technology under NFSM.

Further analysis of table-1 clearly indicates that 38.10 percent beneficiary respondents and 12.70 percent non-beneficiary respondents had high level of knowledge about gram production technology. Whereas, 47.62 percent beneficiary respondents and 60.32 percent non-beneficiary respondents possessed medium level of knowledge about recommended gram production technology. On the other hand, 14.28 percent beneficiary respondents and 26.98 percent non-beneficiary respondents were kept in the low level knowledge group as this category of respondents had poor knowledge about recommended gram production technology.

On the basis of above data majority of the respondents were having medium level of knowledge about gram production technology under NFSM. Further it was inferred that the existing knowledge of beneficiary respondents is comparatively higher than the non-beneficiary respondents in the study area. It means that NFSM had positive and significant impact on beneficiary respondents with regards to possession of knowledge about various production technology introduced during the programme. The findings are similar to the results of Choudhary and Yadav (2012) and Pandey *et al.* (2011).

Practice wise knowledge level of beneficiary and non-beneficiary respondents about gram production technology : The National Food Security Mission has a focused approach. Therefore, the important production technology of gram namely field preparation, use of high yielding varieties, seed sowing seed rate and spacing, seed treatment, manure and fertilizer application, irrigation management, weed management, plan protection measures and harvesting, threshing and storage were introduced under the NFSM. An effort was also made to assess the knowledge of respondents about

important technologies diffused in each major intervention through NFSM in the study area. The intervention-wise results have been presented in table-2.

The knowledge level of beneficiary and non-beneficiary respondents with regard to package of practices of gram production technology were measured in terms of Mean Percent Score (MPS). The data presented in table 5.17 shows that beneficiary respondents possessed very good knowledge (above 80%) regarding field preparation with 82.53 MPS, hence, it was ranked first. The second highest knowledge of the beneficiary respondents was awarded to use of high yielding varieties with 81.48 MPS was rank second. This was followed by “seed sowing seed rate and spacing”, “irrigation management”, “harvesting, threshing and storage”, and “manure and fertilizer application” which were ranked third, fourth, fifth and sixth with 77.77, 76.71, 75.92 and 75.46 MPS respectively.

The table further shows that, beneficiary respondents had least knowledge towards practices of great concern like “weed management”, “plant protection measures” and seed treatment with 65.07, 60.43 and 53.17 MPS and stood seventh, eight, and ninth ranked in positions respectively.

In case of non-beneficiary gram respondents, they possessed very good knowledge regarding field preparation with 77.43 MPS; hence, it was ranked first. The second highest knowledge of the non-beneficiary respondents was towards “seed sowing, seed rate and spacing” with 74.60 MPS was rank second followed by “harvesting, threshing and storage”, “irrigation management”, “use of high yielding varieties”, and “manure and fertilizer application” which were ranked third, fourth, fifth and sixth with 69.84, 66.13, 56.87 and 53.67 MPS respectively.

The table further shows that, non-beneficiary respondents had poor knowledge towards practices like “plant protection measures”, “weed management” and seed treatment with 49.32, 44.84 and 42.06 MPS and stood seventh, eight, and ninth ranked positions respectively.

An effort was also made to determine the relationship between the ranks assigned by beneficiary and non-beneficiary gram growing respondents by applying rank correlation test. The value of rank correlation (r_s) was 0.87 which shows positive correlation, the significance of r_s was tested by ‘t’ test and it was observed that calculated ‘t’ value (4.60) was higher than its tabulated value. This leads to conclusion that there was a similarity in the rank assignment pattern of knowledge possessed by beneficiary and non-beneficiary

gram respondents about gram production technology, though there was difference in magnitude of Mean Percent Score of beneficiary and non-beneficiary respondents.

It can be concluded that the beneficiary respondents under NFSM in the study area possessed relatively more knowledge about gram production technology. Thus, from the above discussion it can be inferred that the extent of knowledge in beneficiary respondents was from 53.17 to 82.53 MPS. Whereas, in case of non-beneficiary respondents the extent knowledge was observed to be from 47.61 to 77.43 MPS in all the aspects gram production technology. The present findings are supported by the findings of Patodiya *et al* (2013) Choudhary and Yadav (2012) and Badhala *et al* (2014).

Practice wise comparison between beneficiary and non-beneficiary respondents about knowledge of gram production technology :

In addition to study of knowledge level of beneficiary and non-beneficiary gram respondents with regards to recommended production technology under NFSM, further efforts were made to study the difference in knowledge between beneficiary and non-beneficiary respondents about gram production technology. To find out the variation in the knowledge of respondents ‘Z’ test was applied. The results are presented in table-3.

The data related to level of knowledge of both beneficiary and non-beneficiary respondents incorporated in the table 5.18 shows that calculated ‘Z’ value was higher than the tabulated value at 1 percent level of significance in five packages of practices of gram production technology and z value was higher than the tabulated value at 5 percent of significance in two package of practices. This showed that in seven practices of gram, beneficiary and non-beneficiary respondents had wide difference in their knowledge level. It means that beneficiary respondents possessed more knowledge as compared to the non-beneficiary respondents in the above mentioned seven packages of practices as well as overall knowledge of beneficiary and non-beneficiary respondents regarding gram cultivation practices. In remaining two cultivation practices of gram production viz. seed sowing, seed rate and spacing, and harvesting, threshing & storage, the value of ‘z’ test was found non-significant. This means that there is no difference in the knowledge of both categories of gram respondents.

The mean value further indicates that beneficiary respondents had higher knowledge than non-beneficiary respondents about gram production technology. This difference in the level of knowledge of gram respondents might be due to the reason that beneficiary respondents had contact with functionaries of National Food Security

Mission. The significant difference between beneficiary and non-beneficiary respondents regarding knowledge of recommended gram production technology highlights that there was positive impact of NFSM on beneficiary respondents with regard to increase in knowledge of recommended gram production technology in the study area.

The present results are in line with the findings of Choudhary and Yadav (2012) and Badhala *et al* (2014) who reported that there was highly significant difference between beneficiary and non-beneficiary respondents regarding extent of knowledge about wheat production technology.

Conclusions

Findings indicated that there was a significant difference in level of knowledge between beneficiary and non-beneficiary farmers about recommended gram interventions. The beneficiary farmers had more knowledge than non-beneficiary farmers about recommended gram interventions. It indicates that there was positive impact of NFSM on beneficiary farmers in gain in knowledge about recommended gram interventions.

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Effect of Organic Manures and Nutrient Application on Quality of Wheat (*Triticum aestivum* L.)

Rohit Kumar Meena*, P.K. Sharma and Amarjeet Singh

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : kumarrohit24041998@gmail.com

Abstract

A study was carried out at Agronomy farm, Vevakananda Global University, Jagatpura, Jaipur entitled "Effect of Organic Manures and Nutrient Application on Growth, Yield and Quality of Wheat (*Triticum aestivum* L.)" was conducted at during *rabi* seasons of the years 2022-23. The experiment was carried out in Randomized Block Design with three replications and 9 treatments viz., Control, FYM @ 10 t/ha, Neem cake @ 5 t/ha, T₁ + ZnSO₄ @ 25 kg/ha, T₂ + ZnSO₄ @ 25 kg/ha, T₃ + ZnSO₄ @ 25 kg/ha, T₁ + Sulphur @ 40 kg/ha, T₂ + Sulphur @ 40 kg/ha, T₃ + Sulphur @ 40 kg/ha. Among the treatments the maximum Protein content (%) was observed under the treatment T₅ T₂ + ZnSO₄ @ 25 kg/ha.

Key words : Wheat, organic manures, nutrient, protein content and protein yield.

Introduction

Wheat [*Triticum aestivum* (L.)] is the most important widely cultivated staple food crop of world due to its adaptability under diversified climatic conditions. Wheat play a major role towards meeting 40 % of world global food demand of world population and act as a boon for mankind to provide half of the dietary protein as well as more than half of the calories (Meena *et al.*, 2017).

In terms of area, India contributes highest wheat cultivated area (31.45 million hectares) in the world while acquired second position with respect to production (107.59 million tonnes) after china with the average productivity of 3.42 tonnes ha⁻¹ (Anonymous, 2021a). In Rajasthan, the crop covers an area of 3.49 million hectares and production of 13.88 million tonnes with an average productivity of 3.97 tonnes ha⁻¹ (Anonymous, 2021b).

Although organic amendments can provide available nutrients for plants and nutrient transformation during organic matter decomposition strongly interacts with plant nutrient uptake, leading to a competition for nutrients between soil microorganisms and plants. Further, these systems are beneficial for the overall health of the agro-environment. Development and management of effective crop nutrition practices such as by manipulating the quantity and type of organic amendments, improve soil ecosystems and fertility.

Materials and Methods

Experimental site : The experiment was laid out at Agronomy Farm, Vivekananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of

427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs/day.

Experimental details : The treatments comprised different levels of sulphur and zinc (40 kg and 25 kg) in association with different levels of organic manure. Nine treatment combinations that were laid out in Randomized Block Design (RBD) and replicated three times.

S. No.	Treatments	Symbols
1.	Control	T ₁
2.	FYM @ 10 t/ha	T ₂
3.	Neem cake @ 5 t/ha	T ₃
4.	T ₁ + ZnSO ₄ @ 25 kg/ha	T ₄
5.	T ₁ + Sulphur @ 40 kg/ha	T ₅
6.	T ₂ + ZnSO ₄ @ 25 kg/ha	T ₆
7.	T ₂ + Sulphur @ 40 kg/ha	T ₇
8.	T ₃ + ZnSO ₄ @ 25 kg/ha	T ₈
9.	T ₃ + Sulphur @ 40 kg/ha	T ₉

Table-1 : Effect of organic manures and nutrient application protein content of wheat.

S.No.	Treatments	Protein content (%)
T ₁	Control	10.63
T ₂	FYM @ 10 t/ha	11.81
T ₃	Neem cake @ 5 t/ha	11.00
T ₄	T ₁ + ZnSO ₄ @ 25 kg/ha	11.75
T ₅	T ₁ + Sulphur @ 40 kg/ha	11.63
T ₆	T ₂ + ZnSO ₄ @ 25 kg/ha	12.06
T ₇	T ₂ + Sulphur @ 40 kg/ha	11.94
T ₈	T ₃ + ZnSO ₄ @ 25 kg/ha	12.00
T ₉	T ₃ + Sulphur @ 40 kg/ha	11.88
	SEm±	0.23
	CD (P=0.5)	0.69
	CV (%)	3.43

Table-2 : Effect of organic manures and nutrient application protein yield of wheat.

S.No.	Treatments	Protein yield (kg/ha)
T ₁	Control	263.50
T ₂	FYM @ 10 t/ha	505.58
T ₃	Neem cake @ 5 t/ha	455.40
T ₄	T ₁ + ZnSO ₄ @ 25 kg/ha	495.85
T ₅	T ₁ + Sulphur @ 40 kg/ha	482.44
T ₆	T ₂ + ZnSO ₄ @ 25 kg/ha	546.43
T ₇	T ₂ + Sulphur @ 40 kg/ha	520.48
T ₈	T ₃ + ZnSO ₄ @ 25 kg/ha	530.40
T ₉	T ₃ + Sulphur @ 40 kg/ha	515.38
	SEm±	20.98
00	CD (P=0.5)	62.90
	CV (%)	7.58

Protein content : The per cent crude protein content in grain was calculated by multiplying per cent of nitrogen content in grain with a factor 5.75 (A.O.A.C., 1990).

Protein yield : Protein yield was calculated by using following expression.

Protein yield (kg/ha)

$$= \frac{\text{Protein content in grain (\%)} \times \text{Grain yield (kg / ha)}}{100}$$

Results and Discussion

Protein content (%) : The data revealed that adoption of nutrient management practices increased the protein content (%) of wheat over control treatment. The

maximum protein content (12.06%) was recorded under treatment T₆ (T₂ + ZnSO₄ @ 25 kg/ha). The lowest protein content (10.63%) was recorded under control treatment.

Protein yield (kg ha⁻¹) : The maximum protein yield (546.43 kg ha⁻¹) was observed in treatment T₆ (T₂ + ZnSO₄ @ 25 kg/ha). The lowest protein yield (263.50 kg ha⁻¹) had been recorded under control treatment.

The treatment T₆-(T₂ + ZnSO₄ @ 25 kg/ha) has recorded highest protein content (12.06%) and protein yield (546.43 kg ha⁻¹). nutrient application through chemical fertilizer, organic manure improved the nutrient availability to crop, which increased the nitrogen content in grains resulting in higher protein content in grains. Higher protein content and grain yield under treatment T₆-(T₂ + ZnSO₄ @ 25 kg/ha) resulted into higher protein yield. Similar results have been reported by Maqsood *et al.* (2000), Patil and Bhilare (2000), Kharub and Chander (2008).

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A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Dean, Faculty of Agriculture, Head, Department of Agriculture, university authorities and management personnel's and faculty members and non-teaching staff of Department of Agriculture, Vivekananda Global University, Jaipur for providing me the necessary help and suggestions during the course of the study.

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Risk Assessment of a Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulator Spinosad Toxicity against *Callosobruchus chinensis* L., Pulse Beetle (Chrysomelidea-Coleoptera) under Laboratory Conditions

A.N. Warghat^{1*}, S.S. Munje², A.R. Tayde¹ and G.D. Chandankar²

¹Department of Entomology, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, U.P.

²AICRP-Regional Research Centre (Soybean), Amravati (Dr. PDKV, Akola, M.S.)

*Corresponding Author Email : anandwarghat07@gmail.com

Abstract

The present investigation entitled "Risk assessment of a Nicotinic Acetylcholine Receptor (nAChR) Allosteric Modulator Spinosad Toxicity against *Callosobruchus chinensis* L., Pulse beetle (Chrysomelidea-Coleoptera) under laboratory conditions" was conducted in insect toxicology laboratory of Department of Entomology, AICRP (Soybean)- Regional Research Centre, Amravati, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, (M.S.), during the year of (2020-21) with objective to develop homogeneous population and from that to evaluate relative toxicity Spinosad 45% SC, against pulse beetle, *C. chinensis* on the basis of per cent adult mortality at 24, 48 and 72 hours after treatment (HAT). The bioassay was conducted by impregnated filter paper method with five concentrations of each four treatments including control and replicated thrice Spinosad 45% SC showed best efficiency at both LC₅₀ and LC₉₀ and it was more toxic than other insecticides at 24, 48 and 72 hours of exposure. The highest mortality (20.00 %) was observed with spinosad at 650 ppm concentration with LC₅₀ values being (3227.40 ppm). In the toxicity of spinosad at higher concentration was found more superior than lower doses of concentrations and mortality percent has been observed promptly at 24 Hours after treatment in 1 DAIR (day/s after insect release), in 400 ppm concentration the average mortality was (13.33 %) followed by next treatment 450 ppm i.e., (15.00 %) followed by 500 ppm showed that (16.67 %) followed by, 600 ppm showed (18.33 %) next to 650 ppm showed (20.00 %) mortality has been found compared with control (water spray). At 48 Hours after treatment in 2 DAIR (day/s after insect release), in 400 ppm concentration the average mortality was (15.00 %) followed by next treatment 450 ppm i.e., (16.67 %) followed by 500 ppm showed that (18.33 %) followed by, 600 ppm showed (20.00 %) next to 650 ppm showed (25.00 %) mortality has been found compared with control (water spray) was found and at 72 Hours after treatment in 3 DAIR (day/s after insect release), in 400 ppm concentration the average mortality was (48.33 %) followed by next treatment 450 ppm i.e., (50.00 %) followed by 500 ppm showed that (53.33 %) followed by, 600 ppm showed (58.33 %) next to 650 ppm showed (63.33 %) mortality has been found compared with control (water spray) was (3.33%) found least respectively. The insect mortality and toxicity of insecticides increase marginally at 48 hours and then at 72 hours after exposure.

Key words : Toxicity, Spinosad, Resistance, bioassay, *Callosobruchus chinensis* L., In vivo condition, pulse beetle, stored grain pest.

Introduction

India contributes about 25–28% of the world's total production of pulses as both a producer and consumer. Due to its suitability for rainfed environments and low resource requirements, farmers around the nation prefer to plant pulses for economic reasons Sushmita *et al.*, (2019). With a total production of 26.96 million tonnes and a cultivation area of more than 28 million hectares, India will be the world's top producer of pulses in the years 2021–2022. With 31% and 21% of the total area and production, respectively, it comes in first place (Annual report, Government of India: 2021-22). During the rabi season, one of the most significant pulse crops farmed in India is the chickpea (*Cicer arietinum* L.). It is classified as "smart-food" for its essential significance to the food basket and plays a crucial part in addressing the national food and nutritional security in India due to its high protein

content. With a share of almost 70% in terms of area and 67% in terms of global production, India is the world's largest producer of chickpeas Dixit *et al.*, (2017).

The total loss of chickpea produces at national level during harvest and post-harvest handling was 8.41% with an estimated monetary loss of Rs. 2453 Crore which includes 1.18% loss in storage; where in the storage losses were mainly attributed to bruchids (*Callosobruchus* spp.) which cause substantial losses even up to 100 per cent and render the grain unsuitable for food or seed within 4-6 months Jha *et al.*, (2015); Srinivasan *et al.*, (2008).

It is known that pulses have been cultivated for sustenance for more than 8000 years. They are regarded as the second most significant group of crops worldwide and are a significant source of protein in many developing

nations. They are biologically rich sources of protein and important minerals that, because to their high lysine content, go well with a diet based on grains. The Indian Council of Medical Research has suggested consuming 40 grams of pulses on a daily basis. Therefore, there is a pressing need to increase pulse output to keep up with the rising consumer demand Ramazeame *et al.*, (2014). There is a need to limit their use globally in light of these issues and the upcoming WTO regulations, as well as to implement safe substitutes for traditional insecticides or appropriate new insecticide molecules that are effective against insecticide-resistant insect species to protect stored grains from insect infestations Govindan *et al.*, (2020).

Materials and Methods

The current study, “Risk assessment of a Nicotinic Acetylcholine Receptor (nachr) Allosteric Modulator Spinosad Toxicity against *Callosobruchus chinensis* L., Pulse beetle (Chrysomelidea- Coleoptera) under laboratory conditions” was conducted in 2020–21 at the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Insect Toxicology Laboratory, Department of Entomology, AICRP (Soybean)- Regional Research Centre, Amravati. The goal of the study was to determine the toxicity of biological insecticide Spinosad on pulse beetle and to determine an efficient treatment for pulse beetle management.

Procurement of treatments of insecticidal : In this investigation, a biological pesticide called Spinosad was utilized to conduct a bioassay. Regarding Table 1. To make a stock solution, 100 milliliters of distilled water were used to dissolve the individual pesticide formulations. As an illustration, 35.71 ml of Spinosad 45% EC was added to a 100 ml volumetric flask to make it equal to 100 ml. Similar to this, stock solutions for additional insecticides were made while taking the formulation’s real toxin into account. Distilled water was used to prepare the appropriate concentrations of each pesticide from a 1% stock solution. Initially, the insects were subjected to a broad range of pesticide concentrations. Subsequently, the test doses of the insecticide were chosen so that the percentage of mortality varied from around 10% at lower concentrations to approximately 95% at higher concentrations. There were three replications of the treatments.

Impregnated filter paper technique for bioassay : Using the impregnated filter paper dip technique, adult *C. chinensis* L. beetles that were 3–5 days old were treated to a bioassay using test pesticides. Using a pipette, 600 µl of each pesticide solution were put on Whatman No. 1 filter paper, which has a diameter of roughly 9 cm. In this experiment, distilled water was used to create repeated

dilutions of the pesticides. The distilled water was then used as a control and left to evaporate for ten minutes to ensure that it had completely dried. After that, 20 mature adult insects were released onto a petri dish containing filter paper that had been treated with insecticides for this experiment. The process was also carried out for Spinosad to determine the relative toxicity of the insecticide and to determine the LC₅₀ value at all test concentrations. After treatment, mortality was measured 24, 48, and 72 hours later, and the LC₅₀ values were determined using the probit analysis approach (Finney, 1971).

$$V = \frac{C}{a.i. (\%)} \times A$$

Where,

V= Quantity of required solution to be collected from stock solution

C= Required concentration of chemical

A= Total volume of the solution required (dH₂O)

a.i.= Active ingredients in chemical

Experimental details :

1. Year of Experiment: 2020-21
2. Types of experiment: Laboratory (*In-vivo*)
3. Number of insecticides used: 01
4. Number of Concentration: 05
5. Number of replications: 03
6. Test insect: *Callosobruchus chinensis* L.

Table-1 : Details of insecticide used in present investigation.

Sr. No.	Common Name	Trade Name	Strength of insecticide	Source of supply
1.	Spinosad	Tracer	45% SC	Dow Agro Chemicals, New Delhi

Table-2 : Details of treatments.

Sr. No.	Treatments	Concentrations in (ppm)
1.	T ₁	400 ppm
2.	T ₂	450 ppm
3.	T ₃	500 ppm
4.	T ₄	600 ppm
5.	T ₅	650 ppm
6.	T ₆ (Control)	Control

Analysis of Data : The mortality count of insects in three replications of each concentration was recorded and the average per cent mortality in each concentration was calculated. The per cent mortality in the control, if any, was corrected using Abbot’s formula (1925).

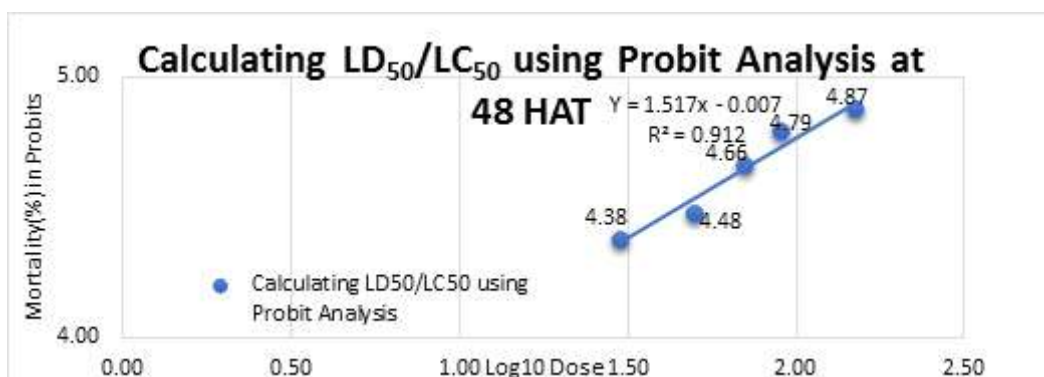


Figure-1 : Regression model of toxicity of Spinosad against *Callosobruchus chinensis* L. after 48 HAT.

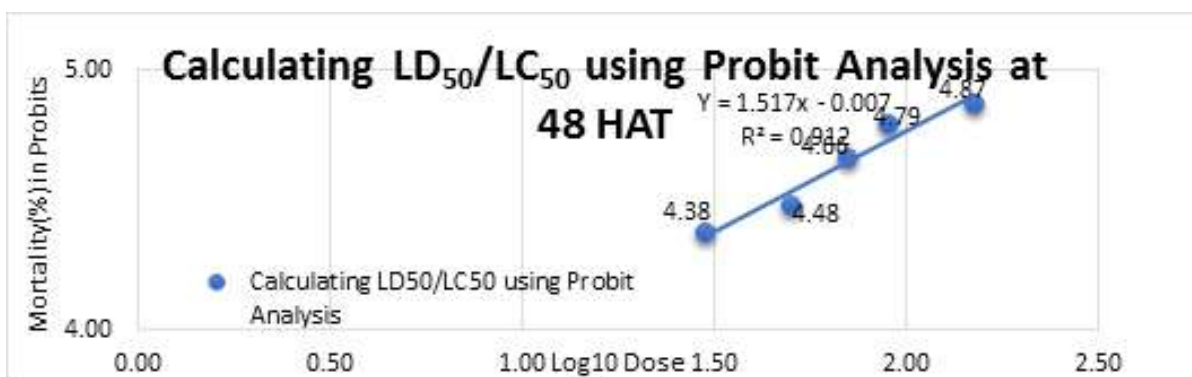


Figure-2 : Regression model of toxicity of Spinosad against *Callosobruchus chinensis* L. after 48 HAT.

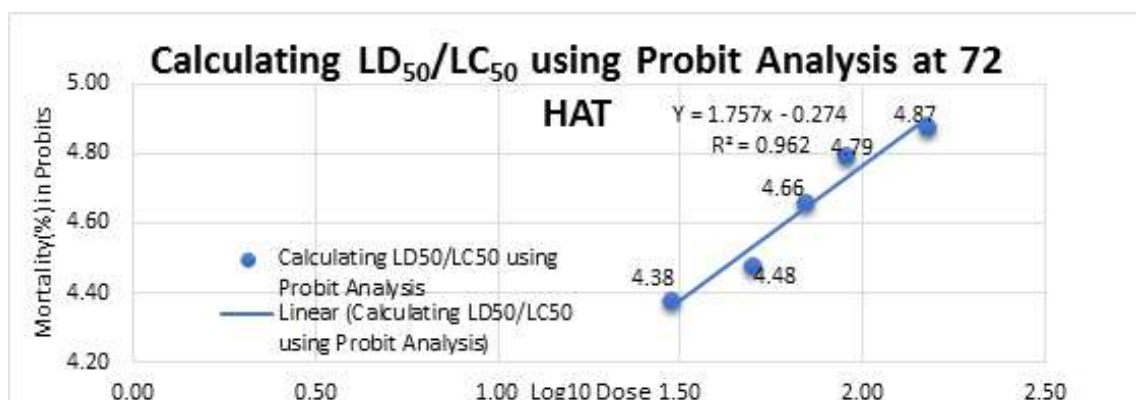


Figure-3 : Regression model of toxicity of Spinosad against *Callosobruchus chinensis* L. after 72 HAT.

$$\text{Corrected mortality (\%)} = \frac{(\text{Mortality in treatment (\%)} - \text{Mortality in control})}{100 - \text{Mortality in control (\%)}}$$

Results and Discussion

When probit regression lines of the Spinosad resistant (S₇) and (R₃) populations were calculated, they showed a linear relationship between mortality percentage and extract concentration in fig no. (1,2 and 3) at 24, 48 and 72 hours after treatment. From the analysis, the regression line equations at 24 hours after treatment were $Y = 1.4941x + 0.351$ for (T₅) 450 ppm, The calculated χ^2 values in selected insecticides tested were less than that

of table value (0.943) suggesting that the adult population was homogeneous. At 48 hours after treatment, the regression line equations were calculated as $Y = 1.289x + 0.990$ for (T₅) 450 ppm., The calculated χ^2 values in selected insecticides tested were less than that of table value (0.978) suggesting that the adult population was homogeneous. At 72 HAT, the regression line equations were calculated as $Y = 1.722x + 0.404$ for (T₅) 450 ppm. The calculated χ^2 values in selected insecticides tested were less than that of table value (0.978) suggesting that the adult population was homogeneous.

Comparing all regression lines at 24, 48 and 72 hours after treatment, the regression lines (in Table 3) for

Table-3 : Mortality responses of selected Insecticide of Spinosad 45% SC at 24, 48 and 72 HAT.

Sr. No.	Concentrations (ppm)	% Mortality Spinosad at 24 HAT	% Mortality Spinosad at 48 HAT	% Mortality Spinosad at 72 HAT
T ₁	400 ppm	13.33	15.00	48.33
T ₂	450 ppm	15	16.67	50
T ₃	500 ppm	16.67	18.33	53.33
T ₄	600 ppm	18.33	20.00	58.33
T ₅	650 ppm	20.00	25.00	63.33
T ₆	Control	0.00	0.00	3.33
Probability Level	-	NS	NS	NS

N.S. not significant (= 0.05)

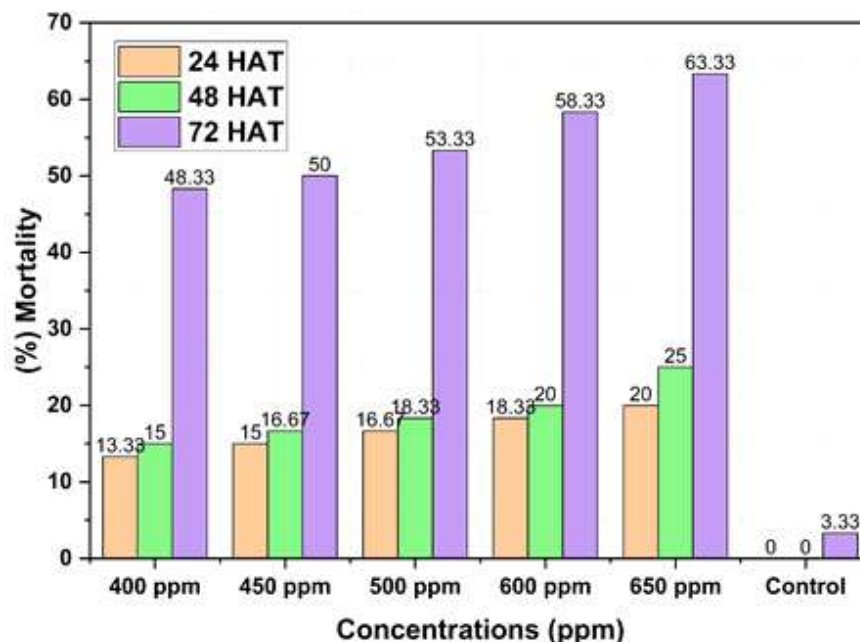


Figure-4 : Mortality responses of selected Insecticide of Spinosad 45% SC at 24, 48 and 72 HAT.

treatment (T₅) and 450 ppm showed higher probit mortality in every case. The higher dosage of treatment was more effective at providing immediate control of *C. chinensis*, but its effectiveness decreased over time. In contrast, the resistance to chemicals increased with time (as per Fig No.4). The difference among different dosages and extracts were not significant statistically. As per Begum *et al.*, (2017); Mondal *et al.*, (2018) Mortality percentage was found directly proportional to the level of doses and time after treatments. Warghat *et al.*, (2022) Higher concentrations resulted in a greater percentage of *C. chinensis* L. mortality, whereas lower concentrations were compared to the treatment control (Distilled water).

Conclusions

In this study, a bioassay was carried out using the biological insecticide Spinosad. pertaining to Table-1. The different pesticide formulations were dissolved in 100 milliliters of distilled water to create a stock solution. As an example, to construct a volumetric flask equivalent to 100

ml, 35.71 ml of Spinosad 45% EC was added. Similar stock solutions were prepared for additional insecticides while taking into account the true toxicity of the composition. The required concentrations of each insecticide were prepared from a 1% stock solution using distilled water. The insects were initially exposed to a variety of pesticide concentrations. The study aimed to assess the toxicity of Spinosad 45% SC, a nicotine acetylcholine receptor allosteric modulator, against the pulse beetle, *Callosobruchus chinensis* L., under laboratory conditions. The insect mortality and toxicity of insecticides increased marginally at 48 hours and 72 hours after exposure. As the using chemicals may contaminates the food grains in future reference so in this study confirms that the breakdown the resistance in pest through the above-mentioned eco-friendly management could be beneficial to store the food grains for longer periods of time.

Conflict of Interest : The Authors are declaring no conflicts in future.

Table-4 : Toxicity of Spinosad 45% SC on the adults of *C. chinensis* L., at 24, 48 and 72 hours after exposure.

Chemical exposure	Heterogeneity (χ^2) [df = 3]	Regression Equations (Y=mx+c)	LC ₅₀ (ppm) (95% FL)	LC ₉₀ (ppm) (95% FL)	Slope b (+ SE)
Spinosad 45% SC at 24 HAT	0.987 (1.000)*	Y = 1.215x + 0.737	3227.40 (1471.60 - 7078.07)	9326.57 (5040.89-17255.85)	1.215 ± 0.174
Spinosad 45% SC at 48 HAT	0.912 (0.989)*	Y = 1.517x + 0.007	1947.27 (1057.51-3585.64)	13513.34 (7338.73-24883.10)	1.517 ± 0.135
Spinosad 45% SC at 72 HAT	0.962 (0.999)*	Y = 1.757x + 0.274	489.50 (309.96 - 773.03)	2627.56 (1663.83-4149.50)	1.757 ± 0.101

(*Chi-square for heterogeneity-tabular value at 0.05 level)

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Effect of Germination on Physiochemical and Morphological Properties of Proso Millet (*Panicum miliaceum* L.)

Aditya Shree and Sukhcharn Singh*

Department of Food Engineering and Technology, SLIET, Longowal-148106, Punjab, India

*Corresponding Author Email : sukhcharns@yahoo.com

Abstract

Proso millet (*Panicum miliaceum* L.) is a minor millet with significantly higher amounts of protein, minerals and fibre. It also contains anti-nutritional factors which hinder nutrient availability. The germination of the millet at the time interval of 24, 48, and 72 hr significantly affects the nutritional composition, phytochemicals, and morphology properties. The results revealed notable changes in the nutritional composition of the germinated millet flour. As the germination time increased, the crude protein, total ash, crude fibre, and total carbohydrate content increased, whereas crude fat content decreased. Total phenolic content (TPC) and total flavonoid content (TFC) were found in increasing trends with increased germination times, resulting in enhanced antioxidant activity in the proso millet. The germination process led to a reduction in anti-nutritional factors present in millet seeds. Phytic acid and tannin levels decreased during germination, which is advantageous as these compounds can interfere with nutrient absorption and utilization. These alterations could be attributed to the enzymatic activity occurring during germination, which leads to the breakdown of complex substances into smaller units. Morphological analysis of the germinated millet flour revealed changes in the starch granules. Fourier-transformed infrared spectroscopy (FTIR) analysis demonstrated similarities in the functional groups in germinated millet flour.

Key words : Proso millet, germination, anti-nutritional, morphology, FTIR

Introduction

Proso millet (*Panicum miliaceum* L.) is a minor millet cultivated in temperate regions under drought conditions. It is a good source of crude protein (10-13%), dietary fibre (2-9%) and mineral content (2-4%). The high fibre content helps in constipation and regulates bowel movements. It is a good source of essential minerals such as iron, magnesium, and phosphorus, ranging from 1.5 to 5 mg/g, 0.2 to 0.5 mg/g, and 0.3 to 1 mg/g, respectively. These minerals are crucial in maintaining strong bones, muscles, and blood cells. It is a good source of B vitamins, particularly niacin (2 to 5 mg/g). Niacin is essential for maintaining healthy skin, proper nerve function, and optimal digestion. It also helps reduce the risk of cardiovascular diseases. Its nutritional composition makes it valuable for a balanced and healthy diet.

Proso millet contains anti-nutritional factors, but their presence does not negate the overall nutritional value of the grain. Proper processing and preparation methods can help to mitigate the content of anti-nutritional factors and ensure that proso millet contributes to a balanced and nutrient-rich diet. Germination, a traditional and economical processing method, is commonly used to improve the nutritional quality of millet-based meals. It involves the controlled sprouting of cereals, leading to specific physical and biochemical changes within the grain. These changes are then stabilized through grain drying.

The aim of germination as a biotechnological technique is to optimize the activation of enzyme systems and facilitate the hydrolysis of reserved food materials within the grain. This enzymatic activity enables the extraction of fermentable materials from the grain, such as sugars and other nutrients, that become more accessible and beneficial for human consumption. The nutritional drawbacks associated with the grain can be mitigated by subjecting millet-based meals to germination. Germination leads to improved digestibility, increased availability of essential nutrients, and enhanced flavour of the grains. It is an age-old method that harnesses the natural potential of grains and has been widely practised throughout history. Germination promotes the synthesis and accumulation of bioactive compounds in seeds. These compounds include ascorbic acid (vitamin C), tocopherols, tocotrienols, and phenolic compounds. These substances act as antioxidants, helping to neutralize harmful free radicals and protect the body against oxidative stress. The increased presence of these antioxidant compounds enhances the overall antioxidant activity of germinated seeds, contributing to their potential health benefits. Germinated seeds exhibit higher protein content compared to non-germinated seeds. During germination, the breakdown of reserve proteins occurs, leading to an increase in the availability of amino acids and peptides. This increase in protein content enhances the nutritional value of germinated seeds, as proteins are essential for various physiological

functions in the body, including tissue repair, enzyme synthesis, and immune system support. Germination processes can decrease unsaturated fatty acids, particularly polyunsaturated fatty acids (PUFAs). This reduction is beneficial as excessive intake of PUFAs may have adverse health effects. By decreasing the levels of unsaturated fatty acids, germination contributes to a more balanced fatty acid profile in the seeds. Germination also results in a decrease in carbohydrate content. Carbohydrates are broken down into simpler sugars during germination, utilized by the growing embryo. This carbohydrate reduction can benefit individuals following low-carbohydrate diets or those seeking to manage blood sugar levels. Germinated seeds are enriched with minerals and vitamins compared to non-germinated seeds.

Anti-nutritional factors, such as phytic acid and tannins, are naturally present in seeds and can interfere with nutrient absorption. Germination activates enzymes that degrade these anti-nutrients, leading to a reduction in their levels. By reducing anti-nutrient content, germinated seeds enhance the bioavailability of essential nutrients, improving their overall nutritional quality. Germination processes result in improved protein quality and digestibility. This research aimed to find the effect of nutritional components, phytochemicals, and anti-nutritional factors. Changes in functional groups and morphological properties were also studied.

Materials and Methods

The Proso millet (cv. BR7) was procured from a farmer's field in Nalanda, Bihar. The grains were cleaned with the help of an aspirator to remove shrivelled, immature, damaged grains and impurities. The cleaned grains were stored in an airtight container for further analysis. All chemicals, solvents, and reagents used for analysis were of analytical grade.

Germination of millets : Cleaned millets were washed in tap water and soaked for 12 hr. After soaking, millets were placed in a germinator box, as shown in Figure 1. In the germinator box, the bottom layer was filled with water to maintain relative humidity, and millets were kept in all other layers. Millets were germinated at 30°C for three different intervals: 24, 48 and 72 hr. Millets were dried at 45°C to reduce the enzyme deactivation in the germinated millets.

Preparation of millet flour: The cleaned and dried germinated grains were ground directly using a hammer mill (Natraj Aatamker, model – Elegant) on bajra mode and sieved through a 52-mesh sieve to obtain flour. The flour obtained was stored in sealed polythene bags for further use.

Estimation of physical properties of prepared flour

Bulk density : The 10 ml graduated cylinder was carefully filled with two grams of flour. Once the sample level had stopped dropping, the volume of the cylinder was measured. The weight of the sample divided by sample volume was used to obtain bulk density (g/cm^3). Triplicate measurements were taken.

True Density : True density was calculated by filling two grams of flour sample in a burette containing toluene. Then, a rise in toluene level was measured, and an average of three readings was recorded. The true density was calculated by using the equation 1.

$$\text{True density } \frac{\text{g}}{\text{cm}^3} = \frac{\text{Weight of flour sample (gm)}}{\text{Rise in toluene level (cm}^3\text{)}} \quad \dots(1)$$

Porosity: The porosity was calculated by using the equation 2.

$$\text{Porosity (\%)} = \frac{\text{Bulk density}}{\text{True density}} \quad \dots(2)$$

Proximate composition analysis : The moisture, crude protein, crude fat and total ash content in the raw and germinated proso millet samples were estimated. Total carbohydrate content was calculated by deducting the sum of the values for moisture, crude protein, crude fat, total ash, and crude fibre content from 100.

Crude fibre content : The method was used to estimate crude fibre content. A 600 ml beaker containing 2 g of fat-free dried flour, 200 ml of 1.25% H_2SO_4 , and a few drops of an antifoaming agent were filled. Bumping chips were added, and the beaker was set on the digestion apparatus with the hot plate already adjusted. On crude fibre assembly, the mixture boiled within a minute. The mixture was precisely boiled for 20 minutes. The Buchner funnel was immediately used to filter the beaker's contents back. The beaker was washed via a Buchner funnel and rinsed with 75 ml of boiling water. After that, 200 ml of 1.25% NaOH were added to the beaker with the residue. Once more heated, it boiled for precisely 30 minutes. The mixture was poured into a sintered glass crucible, rinsed three times with boiling water and alcohol, and then dried at 100°C in a hot air oven. The weight of the crucible with residue was recorded after cooling in a desiccator. The crucible was moved to a muffle furnace for ashing and heated to 550°C for one hour. After cooling in the desiccator, the crucible was reweighed. The crude fibre content was estimated based on the weight of the crucible lost during combustion in the furnace. Equation 3 was used to estimate the crude fibre content in prepared samples.

$$\text{Crude fiber (\%)} = \frac{W_1 - W_2}{W} \times 100 \quad \dots(3)$$

Where, W is the weight of the sample, W_1 is the weight of the crucible + weight of the treated sample after oven drying, and W_2 is the weight of the crucible + weight of the sample after ashing.

Estimation of total phenolic content (TPC) and Total flavonoid content (TFC) in raw and germinated millet flour : The extraction of millet flour extract was prepared using a solvent extraction method. In the process, 1.0 g of millet flour was soaked in 25 ml of 90% methanol (v/v) containing 0.01N HCl solution. The mixture solution was kept at room temperature for 7-8 hours and then centrifuged for 15 min at 9000 rpm. The resulting supernatant was decanted and stored in a glass vial at a refrigerated temperature to estimate the TPC and TFC.

The Folin-Ciocalteu reagent method was slightly modified to determine the TPC in the millet flour extract. In brief, 1 ml of millet flour extract was mixed with 5 ml of diluted Folin-Ciocalteu reagent. Then, 4 ml of Na_2CO_3 solution (7.5% w/v) was added, and the mixture was incubated in the dark room for 90 minutes. A UV-Vis spectrophotometer measured the absorbance at 765 nm against a blank sample. A standard solution of gallic acid was used to create the TPC curve. Instead of the millet flour extract sample, the standard curve was created using various amounts of gallic acid (0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08 and 0.09 mg/ml). The concentration of gallic acid was estimated, and TPC was calculated in terms of mg of gallic acid per gram of fresh millet flour using equation 4.

$$\text{TPC} = \frac{\text{Concentration of gallic acid} \times \text{Volume of millet flour extract taken}}{\text{Weight to millet flour}} \quad \dots(4)$$

The spectrophotometric approach was applied to evaluate the TFC of the millet flour extract. In brief, 4.0 ml of distilled water was combined with 1.0 ml of millet flour extract at the start of the experiment. After 5- and 6-minute intervals, 0.3 ml of NaNO_2 (5%, w/v), 0.3 ml of AlCl_3 (10%w/v), and 2 ml of NaOH (1 M), respectively, were added to the same test tube. The final volume was increased by adding distilled water to 10 ml. At 510 nm, the absorbance was calculated compared to a blank sample. A calibration curve was drawn to the standard using quercetin as a reference. The concentration of quercetin was estimated, and TFC was calculated in terms of mg quercetin per gram of fresh millet flour using equation 5.

$$\text{TFC} = \frac{\text{Concentration of quercetin} \times \text{Volume of millet flour extract taken}}{\text{Weight to millet flour}} \quad \dots(5)$$

Estimation of anti-nutritional factors in raw and germinated millet flour

Phytic acid : The titration method was used to estimate the amount of phytic acid in the millet flour samples. In brief, 0.2 g of millet flour sample and 100 ml of a 2% hydrochloric acid solution (v/v) were used to create millet flour extract. Then, 50 ml of the filtered solution, 10 ml of distilled water, and 10 ml of an ammonium thiocyanate solution with a weight-to-volume ratio of 0.3% were added. The ferric chloride solution (0.00195 g Fe/ml) was used to titrate the mixed solution. The appearance of a yellow colour recognized the terminus point. Equation 6 was used to calculate its content as a percentage of phytic acid on a fresh weight basis.

$$\text{Phytic acid (\%)} = \frac{\text{Titre value} \times 0.00195 \times 1.19}{2} \times 100 \quad \dots(6)$$

Tannin : The tannin content of the millet flour sample was estimated using the spectrophotometric method. Briefly, 20 ml of distilled water was used to soak the millet flour sample 2.0 g (approx.). For 30 minutes, an automated shaker was used to combine the millet flour in the test tube thoroughly. The supernatant was then decanted after it had been centrifuged. In a 100 ml volumetric flask, 5 ml of supernatant, 2 ml of the Folin-Denis reagent, and 5 ml of saturated Na_2CO_3 were combined. In addition, 5 ml of tannic acid at a known concentration was used to make the tannic acid standard solution rather than 5 ml of supernatant. Distilled water was used to make the volume 100 ml and was incubated for 90 minutes at room temperature. The blank sample was formed with distilled water, the Folin-Denis reagent, and Na_2CO_3 solution. Absorbance was read at 760 nm in comparison to a blank sample. Equation 7 was used to calculate the percentage of tannin on a fresh weight basis.

$$\text{Tannin (\%)} = \frac{A_{ts} \times V_{ea} \times C}{A_{ss} \times V_e \times W} \quad \dots(7)$$

Where, A_{ts} is the absorbance of the test sample, A_{ss} is the absorbance of the standard solution, C is the concentration of the standard solution, W is the weight of the sample, V_e is the total volume of extract made, and V_{ea} is the volume of extract taken for analysis.

Morphological properties of prepared proso millet flour : The morphological characteristics of flours were examined using a scanning electron microscope (Model No. JSM 6610-LV) at 3000X magnification. Using double-backed cellophane tape, flour samples were mounted on aluminium stubs before being coated with gold-palladium (60:40 g/g) in an auto fine coater, JEOL-JFC- 1600.

Fourier-transformed infrared spectroscopy (FTIR) :

Table-1 : Physical properties of germinated flour sample.

Sample germination time (hr)	Physical property		
	Bulk density (g/cm ³)	True density (g/cm ³)	Porosity
Raw	0.60 ± 0.02 ^a	1.35 ± 0.14 ^a	0.59 ± 0.01 ^a
24	0.56 ± 0.00 ^a	1.23 ± 0.02 ^a	0.53 ± 0.01 ^b
48	0.46 ± 0.06 ^b	1.20 ± 0.08 ^a	0.50 ± 0.01 ^{bc}
72	0.43 ± 0.06 ^b	1.03 ± 0.05 ^b	0.49 ± 0.01 ^c

Values are mean ± s.d. followed by different letters are significantly ($p = 0.05$) different ($n = 3$).

Table-2 : Changes in proximate composition of germinated flour sample.

Sample germination time (hr)	Parameters (%)					
	Moisture	Crude Fat	Crude Protein	Ash	Crude fibre	Total Carbohydrate
Raw	6.23 ± 0.04 ^d	5.11 ± 0.04 ^a	12.52 ± 0.50 ^b	3.39 ± 0.03 ^c	8.71 ± 0.04 ^a	64.05 ± 0.4 ^a
24	6.73 ± 0.07 ^c	4.44 ± 0.02 ^b	13.28 ± 0.16 ^a	3.75 ± 0.05 ^b	9.38 ± 0.03 ^b	62.41 ± 0.10 ^b
48	7.27 ± 0.07 ^b	4.21 ± 0.05 ^c	13.47 ± 0.10 ^a	3.85 ± 0.07 ^b	9.45 ± 0.03 ^c	61.69 ± 0.25 ^c
72	7.70 ± 0.09 ^a	3.83 ± 0.06 ^d	13.75 ± 0.10 ^a	4.08 ± 0.03 ^a	9.53 ± 0.04 ^d	61.14 ± 0.26 ^c

Table-3 : Changes in TPC and TFC of germination samples.

Sample germination time (hr)	Parameters (%)	
	Total phenolic content (mg GAE/100 g)	Total flavonoid content (mg QE/100 g)
Raw	35.77 ± 0.011 ^c	19.10 ± 0.153 ^c
24	52.66 ± 0.196 ^b	24.27 ± 0.071 ^b
48	55.28 ± 0.012 ^a	24.77 ± 0.100 ^a
72	55.31 ± 0.005 ^a	24.85 ± 0.144 ^a

Values are mean ± s.d. followed by different letters are significantly ($p = 0.05$) different ($n = 3$).

Table-4 : Changes in anti-nutritional factors composition during germination.

Sample germination time (hr)	Parameters (%)	
	Phytic acid (mg/100 g)	Tannin (mg/100 g)
Raw	6.73 ± 0.062 ^a	0.13 ± 0.06 ^a
24	3.83 ± 0.085 ^b	0.08 ± 0.01 ^b
48	3.36 ± 0.208 ^c	0.07 ± 0.002 ^c
72	3.30 ± 0.012 ^c	0.06 ± 0.005 ^d

Values are mean ± s.d. followed by different letters are significantly ($p = 0.05$) different ($n = 3$).

The Agilent Technologies Cary 660 FTIR spectrometer was used to analyze the FTIR spectroscopy of flours. At 25°C room temperature, the samples were scanned at the wavenumber of 4000 cm⁻¹ to 600 cm⁻¹, and the spectra of each were recorded in transmittance mode.

Statistical methods : All the experiments were performed in triplicate. MS Excel, version Office 2019, calculated the mean and standard deviation values. Statistical analysis (ANOVA Analysis of Variance) was conducted using the IBM SPSS Software by applying Duncan's test at a significance level of $p = 0.05$.

Results and Discussion

Changes in physical properties of developed proso millet flour : The change in physical properties of proso millet is depicted in Table-1. The bulk density of millet flour was decreased and found to be 0.51, 0.45, 0.42 and 0.39 g/cm³ at germination times of 0, 24, 48 and 72 hr,

respectively. The true density of millet flour was also decreased from 1.27 to 1.03 g/cm³ during a germination time of 72 hr. The porosity of millet flour was found to be 0.59, 0.53, 0.50, and 0.49 at germination times of 0, 24, 48 and 72 hr, respectively. The decrease in densities was due to the breakdown of complex substances into smaller units during the enzymatic activity of the cells. reported a decrease in the bulk density of foxtail millet flour from 732 to 592 g/l when germinated for 72 hr. Similar results were also observed by for raw and germinated millet flours with respect to time.

Changes in the chemical composition of developed proso millet flour : Germination leads to the breakdown of complex nutrients into simpler forms, making them available to be absorbed by the emerging embryo of the seed. The changes observed during seed germination of proso millet at different time intervals are shown in Figure



Figure-1 : Germinator box.



Figure-2 : Different stages of germinated proso millet.

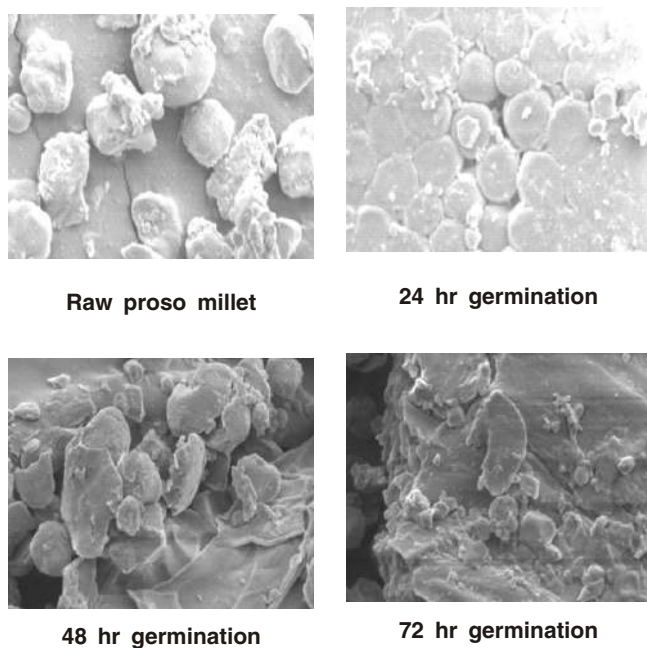


Figure-3 : SEM images of germinated proso millet flour at different time intervals

2. The changes in the proximate composition of proso millet are depicted in Table 2.

Proximate composition : The moisture content of millet increased from 6.23% to 6.73, 7.27 and 7.70% during germination time of 24, 48 and 72 hr, respectively. The increase in the number of hydrated cells within the cells during the germination process was responsible for the increase in moisture content

The crude protein of millet increased from 12.52% to 13.28, 13.47 and 13.75% during germination time of 24, 48 and 72 hr, respectively. During germination, the protein content of millet increases with an increase in germination time. The result showed an increase in crude protein from 15.06% to 15.56 % during the germination of amaranth grains for 24 hr. This is due to the conversion of stored proteins into simpler amino acids, making it more readily available to the growing embryo of the seed. The observation shows that increasing germination time improves protein content.

Crude fat of millet decreased from 5.11% to 4.44, 4.21 and 3.83% during germination time of 24, 48 and 72 hr, respectively. The observation for germination of proso millet showed a decrease in crude fat content from 5.5% to 4.7, 4.6 and 4.2% when germination time was increased to 24, 48 and 72 hr, respectively. The fat content of seeds decreases after germination. Lipids break down into simpler forms to fulfil the energy required by the growing embryo of the seed .

The total ash content of millet increased from 3.39% to 3.75, 3.85 and 4.08% during germination time of 24, 48 and 72 hr, respectively. The result reported by for the germination of proso millet shows that the ash content of millet increased from 5.5% to 6.0, 7.0 and 8.4% during germination time of 24, 48 and 72 hr, respectively. The ash content of millet increases during germination because protein, fat and carbohydrates break down into simpler forms to complete the energy requirement of the growing embryo.

The total carbohydrate of millet decreased from 64.05% to 62.41, 61.69 and 61.14% during germination time of 24, 48 and 72 hr, respectively. Starch molecules break into soluble sugars during germination, decreasing the total carbohydrate of millets.

The crude fibre of millet increased from 8.71% to 9.38, 9.45 and 9.53% during germination time of 24, 48 and 72 hr, respectively. The enzymes released during the breakdown of starch molecules also lead to the breakdown of cellulose and hemicellulose, which increases the fibre content of millet. The result reported by showed an increase in crude fibre from 4.40% to 6.96 % during the germination of amaranth grains for 24 hr also

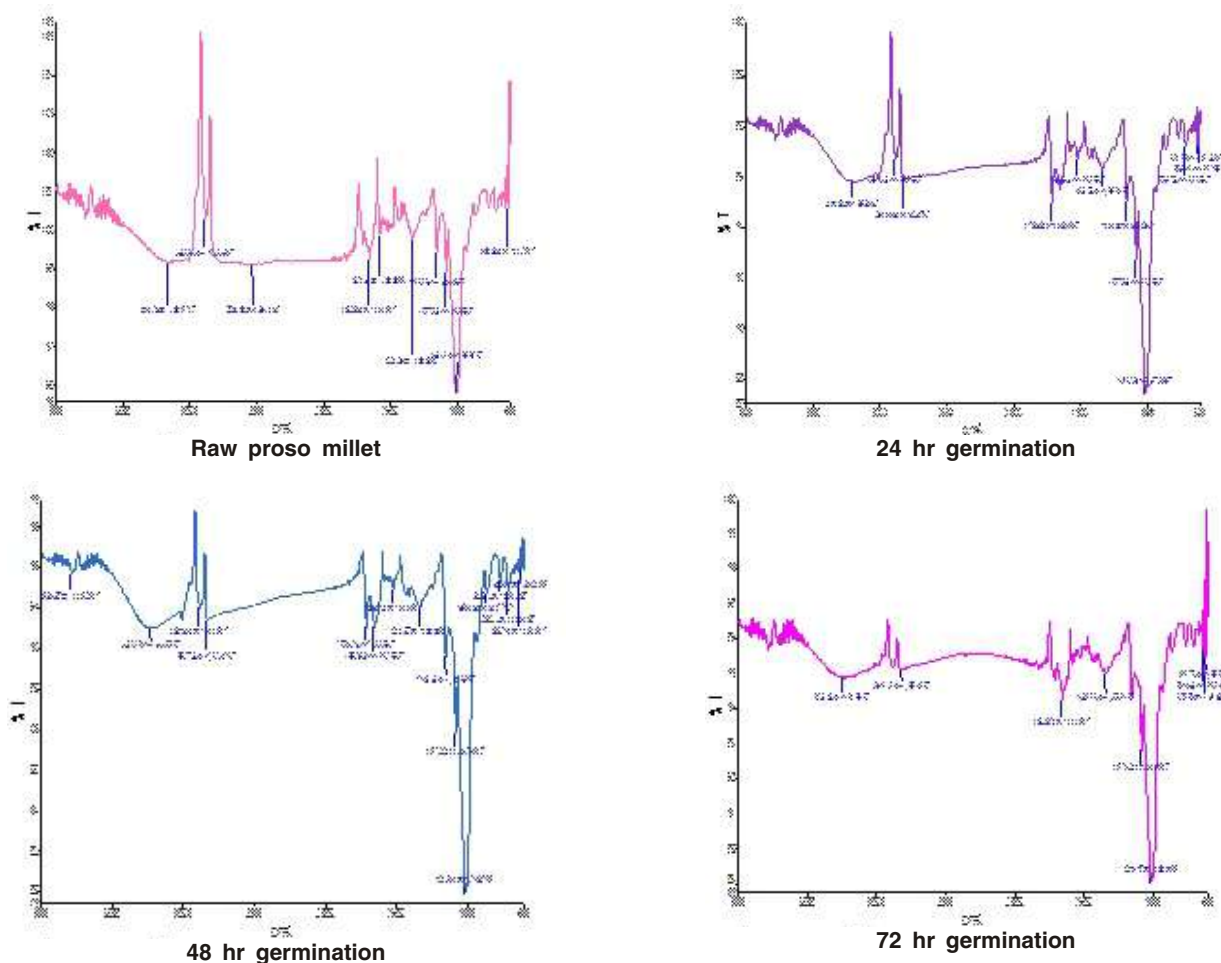


Figure-4 : FTIR spectra of germinated proso millet flour at different time intervals.

reported that germination effectively improves fibre content.

Changes in the phytochemical composition of millet after germination : The germination process increases the antioxidant activity of seeds, which leads to the formation of new phenolic compounds that increase TPC and TFC of germination seeds, as depicted in Table-3.

Total phenolic content (TPC) : TPC of millet increases from 35.77 mg GAE/100g to 52.66, 55.28 and 55.31 mg GAE/100g during germination time of 24, 48 and 72 hr, respectively. The result of showed an increase in TPC of buckwheat from 323mg GAE/100g to 670 mg GAE/100g when germinated for 96 hr TPC increases due to the liberation of bound phenolic by the action of enzymes, which are responsible for the breakdown of the cell wall, mainly esterase .

Total flavonoid content (TFC) : TFC content in millet increases when the germinating embryo releases enzymes that break down the cell wall and release polyphenols. TFC of millet increases from 19.10 mg QE/100g to 24.27, 24.77 and 24.85 mg QE/100g during

germination time of 24, 48 and 72 hr, respectively. reported an increase in TFC from 25.8 mg CAE/100g to 88.1 mg CAE/100g during germination of amaranth grains from 14 hr to 67 hr.

Changes in the anti-nutritional composition of millet after germination : The change in the anti-nutrient composition of proso millet is depicted in Table-4.

Phytic acid : Phytic acid of millet decreases from 6.73 mg/100g to 3.83, 3.36 and 3.30 mg/100g during germination time of 24, 48 and 72 hr, respectively. The result reported by showed that the phytic acid of sorghum decreased from 0.034 to 0.021 g/100g during germination of 72 hr. The germination process activates the phytase enzyme, which breaks the phytic acid and releases minerals for the growing embryo of the seed .

Tannin : Tannin of millet decreases from 0.13 mg/100g to 0.08, 0.07 and 0.06 mg/100g during germination time of 24, 48 and 72 hr, respectively. Polyphenol oxidase and catechol oxidase enzymes are activated during germination, breaking down the tannins and providing characteristic colour. Tannins are water-soluble

compounds that are reduced when seeds are soaked in water. The result reported by showed tannins in pearl millet decreased from 0.459 to 0.032 mg/100g during germination of 72 hr.

Morphology of flours : The morphological structure of the flour samples was analyzed at 3000X and shown in Figure-3. The starch granules in raw millet flour have significant intermolecular gaps and a slightly rough surface. After 24 hr of germination, the starch granules swelled, and intermolecular gaps were less visible. Also, the surface was smooth compared to the raw millet flour. As the germination time increases to 48 and 72 hr, a breakdown and flattening in starch granules is observed. The result reported by showed an irregular shape with some dents and hollows on the surface of the granules of sorghum and millet starch granules. Some pins were found on the surface of the sorghum starch granules after 24 hr of germination. After 48 h of germination, many more pins and pores were found on the surface of the sorghum starch granules. It may be due to the enzymatic activity, which breaks down the starch and protein into smaller units to provide nutrition for the growing embryo during germination.

Fourier-transformed infrared (FTIR) spectroscopy analysis of flours for pasta : The FTIR spectrum for germinated millet flour was observed to determine the various similarities and is shown in Figure 4. The analysis of infrared spectra reveals a prominent peak at wavelength 3223.17 cm^{-1} for germinated millet flour, which signifies the existence of O-H. In addition, C-H₂ compounds were detected towards the right side of the peak, with values of 2881.64 cm^{-1} for germinated millet flour. A peak at 2827.36 cm^{-1} in germinated millet flour was observed showing the presence of an alcoholic -OH group. Within the $1700\text{--}600\text{ cm}^{-1}$ range, germinated millet flours exhibited various peaks, indicating the presence of amines in the first band. The interpretation of infrared, as observed by , showed a very strong peak denoting the presence of O-H for finger millet and pearl millet flour but in the region of 3468.48 cm^{-1} and 3466.95 cm^{-1} respectively.

Conclusions

The germination process of millet at different time intervals (24, 48, and 72 hr) improved the nutritional and phytochemical composition. It was observed in the reduction of anti-nutritional factors compared to raw millet. Germination of proso millet also affected the morphological and functional properties. These findings suggest that germinated millet flour can be a valuable and nutritious ingredient for various food products, offering potential health benefits and expanding the utilization of millet in the food industry.

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Effect of FYM, Vermicompost and Jeevamrut on Growth, Yield of Okra (*Abelmoschus esculentus* L. Moench)

Anamika Meena¹, B.G. Chhipa¹, S.S. Lakhawat¹, K.D. Ameta¹, K.K. Yadav², J. Choudhary³ and Neha Meena¹

¹Department of Horticulture, RCA, MPUAT, Udaipur, Rajasthan

²Department of Soil Science and Agricultural Chemistry, RCA, MPUAT, Udaipur, Rajasthan

³Department of Agronomy, RCA, MPUAT, Udaipur, Rajasthan

Corresponding Email : anumeena8010@gmail.com

Abstract

A field experiment was carried out during kharif season 2022 at technology park CTAE, MPUAT, Udaipur to study "Effect of FYM, Vermicompost and Jeevamrut on Growth, Yield of okra (*Abelmoschus esculentus* L. Moench)". The 16 treatment combinations, comprising four types of organic manures and four levels of jeevamrut, were evaluated on okra crop with three replications under factorial RBD. In the organic manure treatment OM₃ (50 % RDN FYM + 50 % RDN VC) and in jeevamrut J₂ treatment (jeevamrut @ 10 % spray) were reported significantly higher in growth parameters like plant height, number of leaves, days taken for first flowering. Yield parameters, fruit weight, number of fruits per plant, yield per plant, yield per plot, yield per ha.

Key words : FYM, okra, jeevamrut, vermicompost, yield.

Introduction

Okra (*Abelmoschus esculentus* L. Moench) belongs to the family of Malvaceae. Being economically important vegetable crop grown in subtropical and tropical parts of the world. It is generally an annual plant. It is also known as lady's finger or bhindi, originated in tropical Africa. Okra is one of the most popular vegetable in all sections of people. Okra is cultivated for its fibrous fruits or pods containing round, and circular seeds. Okra is a good source of vitamins, minerals, calories, and amino acids found in seeds. (Schipper, 2000). All parts of okra like fresh leaves, buds, flowers, pods, stems and seeds can be used for different purposes and hence it is a multipurpose crop in terms of its uses (Gemede, 2015). Because of its richness in nutrition, taste, medicinal and industrial value. It is one of the most important consumable crops of India; immature and tender pods can be consumed as the boiled and fried vegetables or could be utilized as it may be added to soups and stews.

India is the largest producer of okra in the world. The major okra growing states are Uttar Pradesh, Odisha, Bihar, Andhra Pradesh and West Bengal. According to National Horticulture Board's Statistical Report 2021-2022 (First Advance Estimate), the area of okra cultivation is 523 thousand ha and has a production of 6416 thousand MT across India. Dried fruit contains 13-22% edible oil and 20-24% protein and is used for refined edible oil. Dry fruit skin and fibers are used in manufacture of paper, cardboard and fibers. The seed

cake is also used as an animal feed. Fresh okra fruits contain 89.6 g moisture, 6.4 g carbohydrates, 1.9 g protein, 0.2 g fat, 0.07 mg thiamine, 13 g vitamin C, 0.1 mg riboflavin, 66 mg calcium and 1.5 mg iron per 100 gm of okra. (Thamburaj, S. 2014). Farm yard Manure (FYM) is a decomposed mixture of cattle dung and urine with straw and litter used as bedding material and residues from the fodder fed to the cattle. In India, FYM contains about 0.5 % nitrogen (N), 0.25 % phosphorus (P), 0.5 % potassium (K). Application of well-rotten FYM improves the soil structure. It increases the soil fertility and adds humus to the soil. It also improves the soil productivity. Vermicomposting is a process of recycling of organic wastes in an environmentally safe method with the help of earthworms. The worm casts apart from increasing the density of microbes also provide the required nutrients of plants. It contains plant growth promoting substances such as NAA, Cytokinins, gibberellins etc.

Materials and Methods

The experiment was conducted during the year 2022 at Technology Park CTAE Farm, Udaipur, MPUAT, Udaipur. Udaipur is situated at 24° 34' N latitude and 73° 42' E longitude at an elevation of 582.17 meter above mean sea level. The region falls under agro climatic zone IV (Sub-Humid Southern plain and Aravalli Hills) of Rajasthan. The experiment was laid out in randomized block design with 16 treatments and each replicated thrice and applied randomly in plots. The recommended dose of fertilizer for okra crop is 100:50:50 kg NPK per hectare.

The plot size was 7.0 m × 1.0 m and spacing followed by 45 cm × 30 cm. The land was prepared by ploughing with disc plough and cross harrowing was done with tractor followed by planking to bring the field to a good tilth condition. Stubbles and weeds were collected and disposed of from the experimental area. Plots were laid out as per the plan. At the time of sowing 100 per cent of recommended dose of nitrogen (*i.e.* 100 kg/ha) were applied through FYM and vermicompost as per described in treatments. Jeevamrut @ 5 per cent, 10 per cent and 15 per cent was applied as foliar spray at 30 and 45 days after sowing. The seeds of okra variety “BSS -1019 Red” were used in the experiment. The details of used organic manures and jeevamrut are given as under:

Organic manure

OM₀: Control

OM₁: 100% RDN through FYM

OM₂: 100% RDN through Vermicompost

OM₃: 50% RDN through FYM + 50% RDN through Vermicompost

Jeevamrut

J₀: 0% (Water spray) at 30 and 45 DAS

J₁: 5% Jeevamrut spray at 30 and 45 DAS

J₂: 10% Jeevamrut spray at 30 and 45 DAS

J₃: 15% Jeevamrut spray at 30 and 45 DAS

Preparation of liquid organic input

Jeevamrut : Two hundred liters of water is put in a barrel; ten kg of fresh deshi cow dung is added followed by ten liters of aged cow's urine; to this two kg of pulse flour (gram), 2 kg of jiggery and a handful of live soil from under canopy of the banyan tree are also added. Stir the solution well and let it ferment for 48 hours in the shade. Now jeevamrut is prepared for application. Two hundred liters of jeevamrut is enough for one acre of land (Palekar, 2006). It supplies nutrients but most important, it acts as a catalytic agent that enhances the activity of soil microorganisms as well as enhances earthworm activity. It is used mostly as foliar spray and also applied for seed treatment.

The plant height was measured from the lower cotyledonary node to growing tip and average mean of five plants was taken and expressed in centimeters at 30 and 60 DAS. The number of nodes on the main stem of each tagged plant was counted, and average of five plants was expressed as number of nodes on main stem. The number of fresh fruit harvested from five randomly selected plants was recorded at each harvesting and per plant average number of fruits was calculated. The data

generated during the investigation was subjected to statistical analysis to test the significance among the treatments on various characters of okra under study was done according to the procedure given by Panse and Sukhatmane (1985).

Result and Discussion

Plant height (cm) at 30 and 60 DAS

The plant height of okra was significantly affected by organic manures and jeevamrut application during investigation (Table-1). The maximum plant height *i.e.* 34.27 cm and 74.43 cm were found on 30 and 60 DAS were recorded significant in OM₃ treatment (50 % RDN through FYM + 50 % RDN through vermicompost), respectively. Moreover, the organic manures are also significant sources of major and micronutrients much needed by the plants as reported by Rafi *et al* (2002). The minimum plant height 26.33 cm and 67.29 cm were reported on 30 and 60 DAS OM₀ (control). And The maximum plant height *i.e.* 32.06 cm and 73.06 cm were found on 30 and 60 DAS were recorded significant in J₃ treatment (15 % jeevamrut), respectively. However, it was statistically at par with the application of 10 per cent jeevamrut (31.86, 72.45 cm). The minimum plant height 29.17 cm and 68.53 cm were reported on 30 and 60 DAS J₀ (control). Plant height of okra is genetically determined IAR (1995). The height of the okra studied is perhaps more of genetic than an environmental trait. The positive effect of organic manure on plant height could be due to the contribution made by manure to fertility status of the soils as the soils were low inorganic carbon content. Manure when decomposed increases both macro and micro nutrients as well as enhances the physico-chemical properties of the soil. This could have led to its high vegetative growth.

Number of leaves per plant : The maximum number of leaves per plant were recorded in OM₃ (13.79 and 26.89), respectively in 50 % FYM + 50 % vermicompost at 30 and 60 DAS. This might be due to the fact that N in readily available form vigorously activated the vegetative development of plants (Patel *et al.*, 2009) and minimum in control (11.02 and 22.31) at 30 and 60 DAS (Table-2). The maximum number of leaves (13.30 and 25.52) at 30 and 60 DAS, respectively were recorded with J₃ *i.e.* 15 % Jeevamrut. However, it was statistically at par with the application of 10 per cent jeevamrut (13.08 and 25.34) at 30 and 60 DAS.

Days taken for first flowering : The number of days to first flowering was noticed significantly maximum *i.e.* 45.53 days with OM₃ (50 % FYM + 50 % vermicompost) and the minimum number of days to first flowering *i.e.* 43.17 days was reported in OM₀ *i.e.* control (Table 2).

Table-1 : Effect of organic manures and jeevamrut on plant height of okra.

Treatments	Plant height	
	30 DAS	60 DAS
Organic Manure		
(OM ₀) control	26.33	67.29
(OM ₁) 100 % RDN FYM	30.96	70.94
(OM ₂) 100 % RDN Vermicompost	32.24	71.61
(OM ₃) 50 % FYM + 50 % Vermicompost	34.27	74.43
S.Em.±	0.46	0.44
C.D.(p=0.05)	1.34	1.27
Jeevamrut		
(J ₀) control	29.17	68.53
(J ₁) 5 % Jeevamrut	30.70	70.23
(J ₂) 10 % Jeevamrut	31.86	72.45
(J ₃) 15 % Jeevamrut	32.06	73.06
S.Em.±	0.46	0.44
C.D.(P=0.05)	1.34	1.27

Table-2 : Effect of organic manures and jeevamrut on number of leaves per plant and days taken for first flowering of okra.

Treatments	Number of leaves per plant		Days taken for first flowering
	30 DAS	60 DAS	
Organic Manure			
(OM ₀) Control	11.02	22.31	43.17
(OM ₁) 100 % RDN FYM	12.71	24.29	44.95
(OM ₂) 100 % RDN Vermicompost	13.33	25.72	45.25
(OM ₃) 50 % FYM + 50 % Vermicompost	13.79	26.89	45.53
S.Em.±	0.15	0.31	0.53
C.D.(p=0.05)	0.43	0.89	1.53
Jeevamrut			
(J ₀) Control	11.94	23.96	42.87
(J ₁) 5 % Jeevamrut	12.53	24.37	44.75
(J ₂) 10 % Jeevamrut	13.08	25.34	45.04
(J ₃) 15 % Jeevamrut	13.30	25.52	46.25
S.Em.±	0.15	0.31	0.53
C.D.(P=0.05)	0.43	0.89	1.53

Average fruit weight (g) : It is explicit from data that the effect of organic manure at different concentration significantly increase the fruit weight of okra. The maximum fruit weight *i.e.* 12.19 g was found in OM₃ (50 % FYM + 50 % vermicompost). The maximum fruit weight *i.e.* 11.85 g was found in J₃ (15 per cent jeevamrut). However, it was found statistically at par with 11.54 g measured with J₂ (10 per cent jeevamrut). The minimum fruit weight of okra *i.e.* 10.22 g was reported in J₀ (control) in Table 3.

Number of fruits per plant : The highest number of fruits per plant *i.e.* 23.16 was recorded with OM₃ (50% FYM +50% vermicompost) contrastingly, the lowest number of fruits per plant *i.e.* 17.99 in OM₀ (control). The highest

number of fruits per plant *i.e.* 21.94 was found in J₃ (15 per cent jeevamrut) in Table 3.

Yield per plant, per plot, per ha : The maximum yield per plant *i.e.* 283.63 g was recorded with OM₃ which was significantly higher over OM₂ (248.42 g) and OM₁ (217.79 g). The minimum yield per plant *i.e.* 177.48 g was reported in OM₀ *i.e.* control and the maximum yield per plant of 261.42 g was found in J₃. However, it was statistically at par with yield per plant 251.39 g recorded with 10 per cent jeevamrut (J₂). The minimum yield per plant 194.14 g was reported in J₀ (control). The maximum fruit yield per plot *i.e.* 14.47 kg was found in OM₃ and minimum fruit yield per plot of okra *i.e.* 9.05 kg was reported in OM₀ (control). maximum fruit yield per plot *i.e.* 13.33 kg was found in J₃ (15 per cent jeevamrut). The maximum yield per ha (q) of

Table-3 : Effect of organic manures and jeevamrut on average fruit weight and number of fruits per plant of okra.

Treatments	Average fruits weight (g)	Number of fruits per plant
Organic Manure		
(OM ₀) Control	9.80	17.99
(OM ₁)100 % RDN FYM	10.86	20.02
(OM ₂) 100 % RDN Vermicompost	11.50	21.59
(OM ₃)50 % FYM + 50 % Vermicompost	12.19	23.16
S.Em.±	0.20	0.41
C.D.(p=0.05)	0.58	1.19
Jeevamrut		
(J ₀) Control	10.22	18.87
(J ₁) 5 % Jeevamrut	10.75	20.32
(J ₂) 10 % Jeevamrut	11.54	21.62
(J ₃)15 % Jeevamrut	11.85	21.94
S.Em.±	0.20	0.41
C.D.(p=0.05)	0.58	1.19

Table-4 : Effect of organic manures and jeevamrut on yield parameters of okra.

Treatments	Yield per plant (g)	Fruit yield per plot (kg)	Fruit yield per ha (q)
Organic Manure			
(OM ₀) Control	177.48	9.05	131.47
(OM ₁)100 % RDN FYM	217.79	11.11	161.32
(OM ₂) 100 % RDN Vermicompost	248.42	12.67	184.02
(OM ₃)50% FYM + 50 % Vermicompost	283.63	14.47	210.10
S.Em.±	5.89	0.30	4.36
C.D.(p=0.05)	17.01	0.87	12.60
Jeevamrit			
(J ₀) Control	194.14	9.90	143.81
(J ₁) 5 % Jeevamrut	220.37	11.24	163.24
(J ₂) 10 % Jeevamrut	251.39	12.82	186.22
(J ₃)15 % Jeevamrut	261.42	13.33	193.65
S.Em.±	5.89	0.30	4.36
C.D.(p=0.05)	17.01	0.87	12.60

210.10 q was recorded with OM₃.Whereas, the minimum yield per ha of okra 131.47 q was reported in OM₀ i.e. control and the maximum fruit yield per ha of 193.65 q was recorded with J₃ (15 per cent jeevamrut). Minimum fruit yield per ha (q) of okra 143.81 q was reported in J₀ i.e. control (Table 4.) Premsekhar and Rajashree (2009) in okra (*A. esculentus*) in which they reported that higher yield response of crops due to organic manure application could be attributed to improved physical and biological properties of the soil resulting in better supply of nutrients to the plants.

Conclusions

The treatment OM₃ (50 % FYM + 50 % Vermicompost) was found significantly superior in terms of growth and

yield attributes of okra crop, improved and increased different crop attributes. The used of organic manure in crop production is desirable as it had variable impacts on the growth and yield of crop. Therefore, effect of jeevamrut treatment J₃ (15 per cent jeevamrut) significantly increase for okra crop to obtain superior values of growth, yield parameters. The highest growth and yield parameters was found in J₃ (15 per cent jeevamrut) treatment. However, it was found statistically at per with J₂ (10 per cent jeevamrut) treatment.

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Effect of Fertilizer, FYM and Foliar Application of Nano Urea on Growth, Yield Attributes and Yield of Pearl Millet

Manisha Rar*, P.K. Sharma, Mahipal Dudwal, T.C. Yadav and R.S. Jakhar

Department of Agriculture, VGU, Jaipur-302012, Rajasthan, India

*Email : manisharar12@gmail.com

Abstract

An experiment was conducted at research farm, Vivekananda Global University, Jaipur during *kharif* season of 2022 to find out the "Effect of Fertilizer, FYM and Foliar Application of Nano Urea on Growth, Yield and Quality of Pearl Millet". The experiment consisted of 9 treatment combinations (100% RDF, 75% RDF, 50% RDF, 75% RDF + 5 t ha⁻¹ FYM, 75% RDF + 5 t ha⁻¹ FYM + one spray of nano urea at 4 ml L⁻¹, 75% RDF + 5 t ha⁻¹ FYM + two spray of nano urea at 4 ml L⁻¹, 50% RDF + 5 t ha⁻¹ FYM, 50% RDF + 5 t ha⁻¹ FYM + one spray of nano urea at 4 ml L⁻¹ and 50% RDF + 5 t ha⁻¹ FYM + two spray of nano urea at 4 ml L⁻¹). The experiment was laid out in Randomized Block Design and replicated thrice. The pearl millet var. HHB 299 was used for experimentation. Results revealed that application of 75% RDF + 5 t ha⁻¹ FYM + two spray of nano urea at 4 ml L⁻¹ was observed significantly higher plant height, dry matter accumulation, chlorophyll content in leaf at 60 DAS, number of effective tillers per plant, length of ear, test weight, grain, stover and biological yield of wheat as compared with control and application of nitrogen at 60 kg ha⁻¹. Highest plant height, dry matter accumulation, number of effective tillers, spike length, number of grains spike⁻¹, grain, straw and biological yield of wheat was found with application of silicon at 200 kg ha⁻¹, which was significantly superior over control and application of silicon at 100 kg ha⁻¹.

Key words : Pearl millet, yield, nano urea, FYM, RDF.

Introduction

One of the most significant drought tolerant crops is pearl millet (*Pennisetum glaucum* (L.) R. Br. Emend Stuntz). Among millets, it is regarded as the main food grain and fodder crop. It is a moisture content of 12.4%, protein content of 11.6%, a fat content of 5%, carbohydrate content of 67%, mineral content of 2.7% and 361 kilocalories per 100 g with high levels of vitamins A and B. It is easily digestible and provides the body with significant energy. B vitamins, potassium, phosphorus, magnesium, iron, zinc, copper and manganese are all abundant in pearl millet. For those who have a pearl millet allergy, it is the only grain that retains its alkaline qualities after cooking and is also gluten-free (Chauhan *et al.*, 2015). Due to its endurance for challenging growth circumstances like drought, low soil fertility and high temperatures, it is extensively dispersed throughout the semi-arid and arid tropics of Africa and Asia. Most often planted as a rainfed crop on marginal and sub-marginal land, pearl millet has low productivity due to its poor organic matter content, lack of readily available nitrogen, phosphate and micronutrients. It is produced on an area of 7.57 million ha in India, with a productivity of 1436 kg ha⁻¹ and a production of 10.86 million tonnes (Anonymous 2020).

Applying biological and nanofertilizers can improve soil fertility, crop productivity and simultaneously avoid environmental pollutions, but using excessive amounts of

chemical fertilisers can cause environmental contamination. Foliar spraying with urea, especially in nanoforms, has been shown to be effective for plant nutrition due to its high absorption and utilisation efficiency by plants (Mondal and Mamun, 2011; Manjunatha *et al.*, 2016). This method is preferred to avoid applying excessive rates of nitrogen to crops, especially the edible leafy ones.

Farmyard manure (FYM), an organic material added to the soil, aids in preserving the fertility and productivity of the soil. It boosts soil microbial activity and is essential for nutrient transformation, recycling, and crop availability. Additionally, it enhances the physical characteristics of the soil, such as its structure and porosity, lessens compaction and crusting, and increases its ability to retain water (Oueriemmi *et al.*, 2021).

Urea is a source of N with a high concentration of N nutrients, and foliar spray typically employs minimal levels of fertiliser N (Gul *et al.*, 2011). In contrast to saline fertilisers, it can be applied as a foliar spray to plants without damaging the leaves by scorching (Mondal and Mamun, 2011). According to Manjunatha *et al.* (2016), foliar fertilisation using nanoscale urea performed better than nonnano techniques. Any material that contains nanoparticles has particles that are fewer than 100 nm in size. Since it has been shown to be practicable and very effective (EL-Aila *et al.*, 2010 and Manjunatha *et al.*, 2016), nano-fertilization is becoming more and more popular.

In comparison to conventional urea, foliar application of nano urea (Liquid) during crucial crop growth stages of a plant effectively satisfies its nitrogen requirement and results in higher crop productivity and quality. Nano urea (Liquid) contains nitrogen nanoparticles that are larger and more numerous than those found in regular urea pellets, increasing its potency (Sahu *et al.*, 2022).

Materials and Methods

An experiment was conducted at Vivekananda Global University, Jaipur during *kharif* 2022. It is 427 metres above mean sea level and located at 26°5' North latitude and 75°28' East longitude. The field's soil was loamy sand, with low organic carbon (0.20%), an alkaline pH (pH 8.19), low available nitrogen (133.20 kg ha⁻¹), medium available phosphorus (20.11 kg ha⁻¹) and medium available potassium (203.20 kg ha⁻¹). The experiment consisted of 9 treatment combinations (100% RDF, 75% RDF, 50% RDF, 75% RDF + 5 t ha⁻¹ FYM, 75% RDF + 5 t ha⁻¹ FYM + one spray of nano urea at 4 ml L⁻¹, 75% RDF + 5 t ha⁻¹ FYM + two spray of nano urea at 4 ml L⁻¹, 50% RDF + 5 t ha⁻¹ FYM, 50% RDF + 5 t ha⁻¹ FYM + one spray of nano urea at 4 ml L⁻¹ and 50% RDF + 5 t ha⁻¹ FYM + two spray of nano urea at 4 ml L⁻¹) was laid out in Randomized Block Design with three replication. Plot size was 5.0 m × 3.6 m. Crop variety HHB 299 with 4 kg seed rate ha⁻¹ was taken for experiment.

The pearl millet crop was given urea, DAP, and MOP applications of the required fertiliser dosage (60 kg N, 30 kg P₂O₅ and 30 kg K₂O ha⁻¹). The crop was given a half dose of nitrogen, a full dose of phosphorus, and a full dose of potassium at the time of planting. The remaining dose of nitrogen was top dressed in two splits at the same time of foliar spray of nano urea. Using a knapsack sprayer, the first and second foliar sprays of nano urea were applied at 30 and 45 DAS. Two weeks before to planting, farm yard manure (FYM) was placed in the appropriate beds in accordance with the treatment and completely absorbed into the soil.

On July 24, 2022, the seeds were manually sown in opened furrows at a depth of 1.5 cm in rows spaced 45 cm apart, and after depositing the seed in furrows, it was covered with earth to provide uniform germination and protection from bird damage. One hoeing and weeding was done manually with the help of hoe at 25 DAS to facilitate aeration and removing the weeds during crop growth period. Each plot's crop was collected separately. The harvested plants were tied in bundles, tagged and kept for sun drying on threshing floor. After complete drying these bundles were weighed just before threshing to record biological yield. Threshing of the harvested produce from individual plot was done with the help of mini power operated thresher.

From five randomly chosen rows in each plot, the plant stand was counted at 20 DAS and at harvest, and the average in ha⁻¹ was calculated. At harvest, each plot's final plant stand was noted as well. The plant height was measured from the ground to the tip of the main shoot on five randomly selected plants from each plot at 20, 40, 60 DAS and at harvest to the tip of the upper spikelet of main ear (excluding awns). The average plant height was calculated and expressed in cm. Five plants of from the sample rows of each gross plot were uprooted at 20, 40, 60 DAS and at harvest. The root portion was removed, and the plants were separated into little pieces before being placed in a perforated labelled brown paper bag and dried in the sunlight first, then in the thermostatically controlled oven at 60°C ± 2°C. The drying process was repeated until a steady weight was reached, and the mean dry matter accumulation g plant⁻¹ was calculated.

The method recommended by Arnon (1949) was used to measure the total chlorophyll content of leaves at 60 DAS by taking 50 mg of fresh leaf material. After homogenising the samples in 80% acetone, the supernatant was diluted to a volume of 10 ml by centrifuging the mixture for 10 minutes at 2000 rpm. Using a spectrophotometer, the clear supernatant's subsequent absorbance was determined at 652 nm.

$$\text{Chlorophyll (mg/g)} = \frac{A(652) \times \text{Total volume (ml)}}{100 \times \text{Weight of sample}}$$

Where, A = is the path length = 1 cm

Five tagged plants' total ear-bearing tillers were counted from each plot at harvest, and the average number of tillers m⁻¹ of row length was calculated. From five randomly chosen tagged plants from each plot, the length of the ear head from the neck node to the tip was measured and an average (cm) was calculated. From the harvest of each plot, a tiny sample of seeds was obtained and 1000 seeds were counted, weighed and recorded as the test weight (g). Threshed, winnowed and dried the entire amount of biomass harvested from each plot as well as the ear heads removed from the lot. The grain yield was then calculated by weighing the grain separately in kg plot⁻¹ and kg ha⁻¹. By deducting the grain yield from the biological yield plot⁻¹, the stover yield (kg plot⁻¹) was calculated. It was converted from stover yield (kg plot⁻¹) to stover yield (kg ha⁻¹). Each plot's obtained material was completely sun dried. After drying, the produce from each plot area was weighed using a balance, and the weight was recorded in kg plot⁻¹ of biological yield. Later, the biological yield plot⁻¹ was translated into kg ha⁻¹. Harvest index is the ratio of economic yield (grain yield) to biological yield, and worked out by following formula (Donald and Hamblin, 1976) expressed in percentage.

Table-1 : Effect of fertilizer, FYM and foliar application of nano urea of nutrients on plant population and plant height of pearl millet.

Treatments	Plant population m ⁻¹ row length		Plant height (cm)			
	20 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
T ₁ -100% RDF	8.63	8.55	19.55	64.20	140.52	169.52
T ₂ -75% RDF	8.62	8.48	19.22	62.52	134.82	162.63
T ₃ -50% RDF	8.50	8.62	19.10	60.15	132.52	159.21
T ₄ -75% RDF + 5 t ha ⁻¹ FYM	8.66	8.65	20.69	72.62	159.62	191.62
ItT ₅ -75% RDF + 5 t ha ⁻¹ FYM + One spray of nano urea at 4 ml L ⁻¹	8.69	8.54	20.88	73.14	160.22	192.88
T ₆ -75% RDF + 5 t ha ⁻¹ FYM + Two spray of nano urea at 4 ml L ⁻¹	8.62	8.66	21.34	75.65	161.45	194.32
T ₇ -50% RDF + 5 t ha ⁻¹ FYM	8.72	8.75	20.12	64.55	142.62	172.64
T ₈ -50% RDF + 5 t ha ⁻¹ FYM + One spray of nano urea at 4 ml L ⁻¹	8.89	8.88	20.25	64.88	144.25	173.62
T ₉ -50% RDF + 5 t ha ⁻¹ FYM + Two spray of nano urea at 4 ml L ⁻¹	8.92	0.43	20.55	65.00	144.89	173.92
SEm±	0.52	1.29	0.96	2.13	4.84	5.82
CD (P=0.05)	NS	NS	2.87	6.38	14.51	17.43

Table-2 : Effect of fertilizer, FYM and foliar application of nano urea of nutrients on dry matter accumulation and chlorophyll content of pearl millet.

Treatments	Dry matter accumulation				Chlorophyll content at 60 DAS (mg/g)
	20 DAS	40 DAS	60 DAS	At harvest	
T ₁ -100% RDF	8.69	16.62	23.69	58.92	2.85
T ₂ -75% RDF	8.65	16.10	22.10	57.10	2.80
T ₃ -50% RDF	8.00	15.59	21.96	56.91	2.78
T ₄ -75% RDF + 5 t ha ⁻¹ FYM	8.75	19.96	28.92	66.93	3.25
T ₅ -75% RDF + 5 t ha ⁻¹ FYM + One spray of nano urea at 4 ml L ⁻¹	9.11	20.25	29.12	67.32	3.28
T ₆ -75% RDF + 5 t ha ⁻¹ FYM + Two spray of nano urea at 4 ml L ⁻¹	9.19	20.45	29.32	68.16	3.32
T ₇ -50% RDF + 5 t ha ⁻¹ FYM	8.55	17.10	23.92	59.65	3.01
T ₈ -50% RDF + 5 t ha ⁻¹ FYM + One spray of nano urea at 4 ml L ⁻¹	8.59	17.26	24.10	60.14	3.05
T ₉ -50% RDF + 5 t ha ⁻¹ FYM + Two spray of nano urea at 4 ml L ⁻¹	8.61	17.99	24.62	60.32	3.11
SEm±	0.43	0.65	1.33	2.06	0.13
CD (P=0.05)	1.28	1.96	4.00	6.18	0.39

Table-3 : Effect of fertilizer, FYM and foliar application of nano urea of nutrients on yield attributes and yields of pearl millet.

Treatments	Yield attributes			Yield (kg ha ⁻¹)			Harvest index (%)
	Number of effective tillers plant ⁻¹	Length of ear (cm)	Test weight (g)	Grain	Stover	Biological	
T ₁ -100% RDF	2.15	18.25	5.35	1210	3265	4475	27.04
T ₂ -75% RDF	2.11	18.22	5.20	1163	3214	4377	26.57
T ₃ -50% RDF	2.01	18.16	5.12	1123	3115	4238	26.50
T ₄ -75% RDF + 5 t ha ⁻¹ FYM	2.64	22.10	6.75	1670	4321	5991	27.88
T ₅ -75% RDF + 5 t ha ⁻¹ FYM + One spray of nano urea at 4 ml L ⁻¹	2.66	22.32	6.79	1712	4462	6174	27.73
T ₆ -75% RDF + 5 t ha ⁻¹ FYM + Two spray of nano urea at 4 ml L ⁻¹	2.70	22.93	6.85	1810	4516	6326	28.61
T ₇ -50% RDF + 5 t ha ⁻¹ FYM	2.32	19.10	5.95	1382	3392	4774	28.95
T ₈ -50% RDF + 5 t ha ⁻¹ FYM + One spray of nano urea at 4 ml L ⁻¹	2.36	19.26	6.00	1413	3465	4878	28.97
T ₉ -50% RDF + 5 t ha ⁻¹ FYM + Two spray of nano urea at 4 ml L ⁻¹	2.39	19.71	6.10	1465	3516	4981	29.41
SEm±	0.08	0.66	0.21	74	189	239	1.22
CD (P=0.05)	0.24	1.99	0.64	221	566	716	NS

Fisher (1950) proposed the “Analysis of Variance” technique for conducting statistical analysis of the experimental data acquired for growth, yield, and other features. Each of the factors had a standard error that was

determined to be appropriate. The “F” test was used to determine whether differences in treatment effects were significant. Wherever the difference was determined to be significant at a threshold of 5.0 per cent, the critical difference (CD) was calculated.

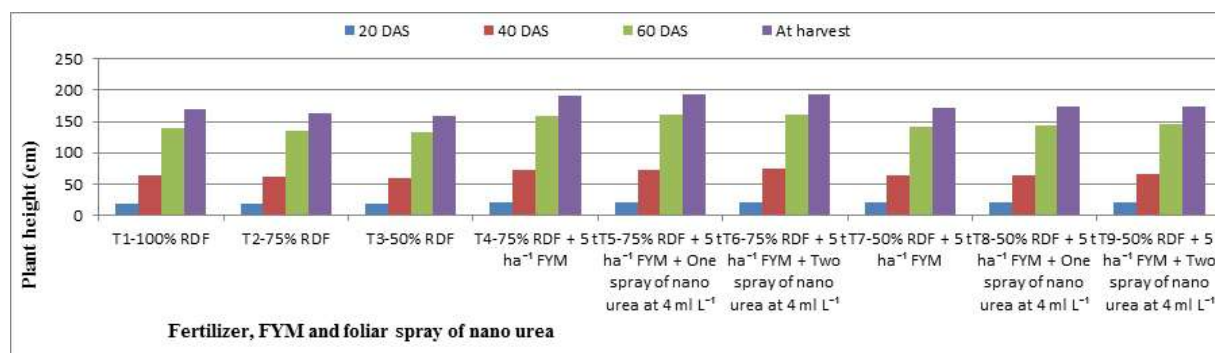


Fig-1 : Effect of organic manures and liquid organic formulations on plant height of pearl millet.

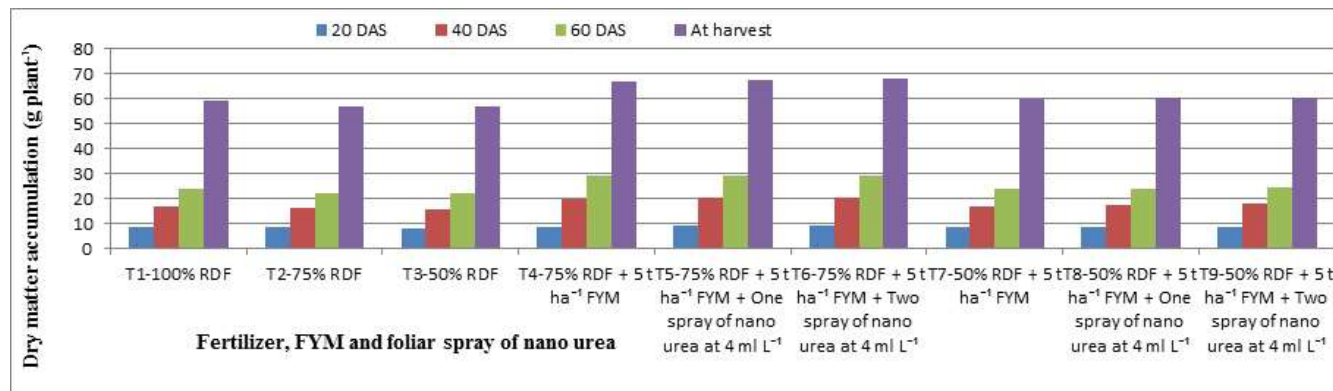


Fig-2 : Effect of organic manures and liquid organic formulations on dry matter accumulation of pearl millet.

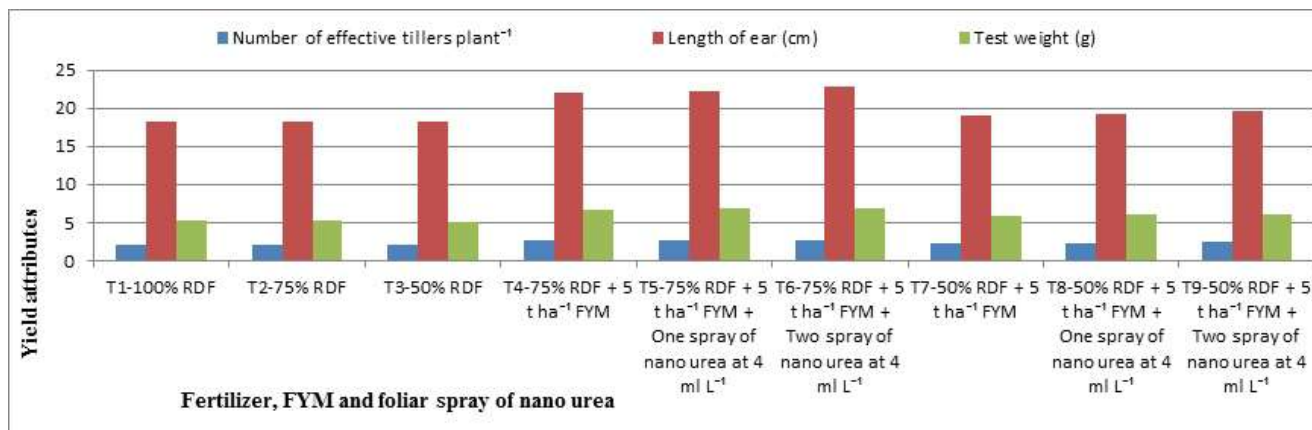


Fig-3 : Effect of organic manures and liquid organic formulations on yield attributes of pearl millet.

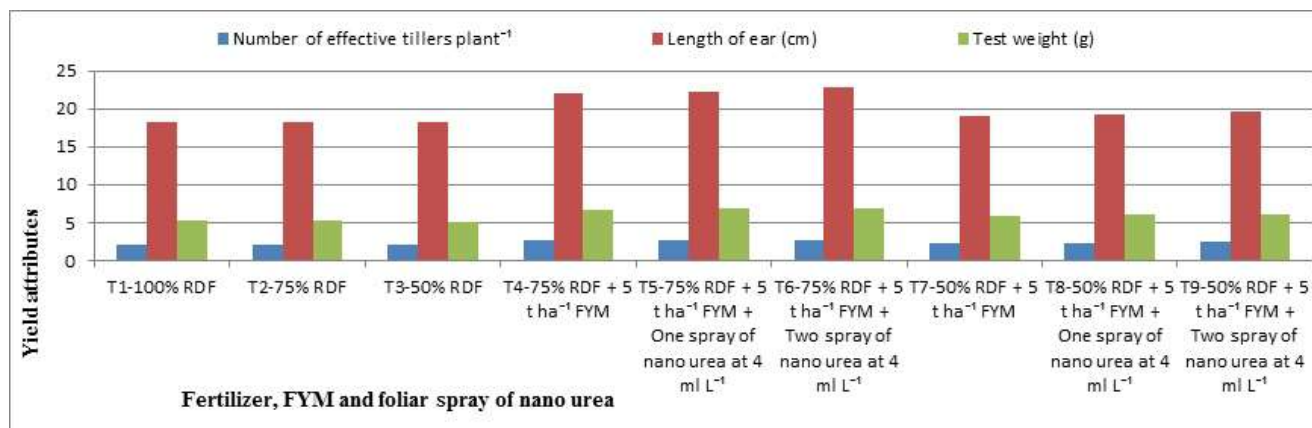


Fig-4 : Effect of organic manures and liquid organic formulations on yield of pearl millet.

Results and Discussion

Growth parameters : Results presented in Table-1 and 2 and Fig-1 and 2 indicated that growth attributes of pearl millet viz., plant height, dry matter accumulation at 20, 40, 60 DAS and at harvest, chlorophyll content at 60 DAS significantly increased with application of T_6 - 75% RDF + 5 t ha⁻¹ FYM + Two spray of nano urea at 4 ml L⁻¹ over rest of the treatments except T_5 - 75% RDF + 5 t ha⁻¹ FYM + One spray of nano urea at 4 ml L⁻¹ and T_4 - 75% RDF + 5 t ha⁻¹ FYM. However, these treatments were at par with each other.

Application of the recommended dose of nitrogen, which assisted in promoting growth during the early stages of crop development and is thought to be a crucial plant nutrient, may be the cause of an increase in growth parameters. Furthermore, it increased the amount of chlorophyll in leaves (Table-2), which is a key absorber of the light energy required for photosynthesis. Additionally, a sufficient supply of nitrogen aided in early vegetative growth as well as the overall development of plants. Nitrogen is regarded as the most important nutrient for plant growth and development as it serves as the foundation for all living matter in plants and plays a significant role in plant metabolism by being a component of many essential compounds like amino acids, proteins, nucleic acids, enzymes, coenzymes, alkaloids and a number of hormones (Ganapati and Guggari, 2018).

Better nutrition may have contributed to the maximum plant height ever observed by increasing cell division and plant growth. Increased synthesis of amino acids, proteins, and other growth-promoting substances may have been caused by the significant improvement in nutrient content and uptake by plant parts. This implies that there was an increase in meristematic activity and cell division, and that the lengthened cells produced higher plant height and dry matter accumulation (Parihar *et al.*, 2012)). Similar findings were also reported by Kumar *et al.* (2012), Parihar *et al.* (2012), Piri and Tavassoli (2012), Meena and Jain (2013), Patil *et al.* (2013), Singh, *et al.* (2013), Patil *et al.* (2014), Rundla and Bairwa (2018), Rana and Prasad (2020) and Kalaliya *et al.* (2022).

Yield Attributes : Data revealed in Table-3 and Fig-3 indicated that application of 75% RDF + 5 t ha⁻¹ FYM + Two spray of nano urea at 4 ml L⁻¹ (T_6) significantly increased in yield attributes viz., effective tillers plant⁻¹, ear head length, test weight with over rest of the treatments except 75% RDF + 5 t ha⁻¹ FYM + One spray of nano urea at 4 ml L⁻¹ and 75% RDF + 5 t ha⁻¹ FYM. However, these treatments were at par with each other. The highest yield attributes of pearl millet might be due to sufficient amount of nitrogen supplied through nano urea at critical growth

stages which would have maintained continuous supply of nitrogen that led to increased meristematic activity and stimulation of cell elongation in plants. The results reported by Patel *et al.* (2009), Ganapati and Guggari (2018), Prasad *et al.* (2018) and Rundla and Bairwa (2018) are all quite similar to the findings of the current study.

Yield : Significantly higher grain, stover and biological yield (Table-3 and Fig-4) were recorded with application of 75% RDF + 5 t ha⁻¹ FYM + Two spray of nano urea at 4 ml L⁻¹ (T_6) that was followed by application of 75% RDF + 5 t ha⁻¹ FYM + One spray of nano urea at 4 ml L⁻¹ (T_5) and 75% RDF + 5 t ha⁻¹ FYM (T_4). The increase in plant height and tiller count, two growth metrics, were mostly responsible for the rise in grain output. Between varying nitrogen levels, pearl millet's grain production and yield-related components differed dramatically. These results are consistent with those of Sakarvadia *et al.* (2012), who found enhanced quality parameters and a higher stover output of pearl millet at higher nitrogen application levels. The application of RDF at the beginning of crop growth may have increased tillering and boosted vegetative growth, which could explain the increase in stover yield. Kumar *et al.* (2020), Kumar *et al.* (2021), Sahu *et al.* (2022) and Midde *et al.* (2022) all reported similar findings.

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Effect of Nitrogen and Silicon on Growth, Yield Attributes and Yield of Wheat (*Triticum aestivum* L.)

Mohammad Reshma*, P.K. Sharma, T.C. Yadav, Mahipal Dudwal and Babu Lal Choudhay

Department of Agriculture, VGU, Jaipur-302012, Rajasthan, India

*Email : reshuprince9018@gmail.com

Abstract

A field experiment was conducted at Vivekananda Global University, Jaipur during *rabi* season of 2022-23 to find out the "Response of Wheat (*Triticum aestivum* L.) to Nitrogen and Silicon Levels under Semi-Arid Regions of Rajasthan". The experiment consists 9 treatment combination *i.e.*, three nitrogen levels (0, 60 and 120 kg ha⁻¹) and three silicon levels (0, 100 and 200 kg ha⁻¹). The experiment was laid out in Randomized Block Design and replicated thrice. The wheat var. HD - 3086 was used for experimentation. Results revealed that application of 120 kg ha⁻¹ was observed significantly higher plant height, dry matter accumulation, number of effective tillers, spike length, number of grains spike⁻¹, grain, straw and biological yield of wheat as compared with control and application of nitrogen at 60 kg ha⁻¹. Highest plant height, dry matter accumulation, number of effective tillers, spike length, number of grains spike⁻¹, grain, straw and biological yield of wheat was found with application of silicon at 200 kg ha⁻¹, which was significantly superior over control and application of silicon at 100 kg ha⁻¹.

Key words : Silicon, yield, nitrogen, wheat.

Introduction

The most significant staple food crop in the world, wheat (*Triticum aestivum* (L.) emend. Fiori & Paol.), has emerged as the foundation of India's food security. It is among the most significant and lucrative *rabi* cereal crops in India, both in terms of area and because of its adaptability to a variety of crop-growing conditions. The largest wheat-producing states in India are UP, M.P., Punjab, Harayan, Rajasthan and Bihar. With a production of 109.52 million tonnes and a productivity of 34.64 q ha⁻¹, wheat is grown on 31.61 million hectares in India (Anonymous, 2022). According to Anonymous in 2022, wheat is produced in Rajasthan on an area of 3.0 million ha, with a yearly yield and productivity of 11.04 million tonnes and 6.76 q ha⁻¹.

Due to varying meteorological conditions, genotypes, sowing times, irrigation water, and other management practises, wheat production is very varied throughout different agro-ecologies in India (Kantwa *et al.*, 2015). Though India's current wheat production is adequate to meet demand, it must be increased to 140 million tonnes annually by 2050 (Vision 2050, IIWBR, Karnal, 2015), necessitating the development of appropriate production technology to meet the demands of processing industries, an adequate buffer stock, and the country's rapidly growing population. Therefore, we should focus our study efforts on removing the obstacles that are the cause of its low output.

In addition to this, nutrient management efforts are crucial for increasing crop output and nutrient usage

effectiveness. Nitrogen (N) is the main macronutrient needed for plant growth and development out of all the important nutrients. Amino acids, nucleic acids, chlorophyll, proteins, and energy molecules like ATP and ADP all contain nitrogen as an essential component. According to Patra *et al.* (2006), nitrogen applied through fertilisers is transformed through biological nitrogen fixation, humus mineralization, immobilisation, nitrification, denitrification, and volatilization. Because of these transformation processes, nitrogen management is extremely complicated, making it challenging to increase nitrogen use efficiency. Nano fertilisers are crucial instruments in agriculture for enhancing crop development, yield, and quality metrics while lowering fertiliser waste and cultivation costs. By increasing the availability of fertiliser nutrients to plants and reducing the pace at which they are lost through leaching, nanotechnology can lessen the pollution of soil and water.

The positive effects of using silicon as fertiliser in crop production may include higher yields, improved disease and pest resistance, as well as tolerance to stressors including cold, drought, and toxic metals. Wheat, maize, paddy, cucurbits, turf grass, and sugarcane are the crops that have been proven to benefit from silicon fertilisation and have grown in popularity as a result. Thus, silicon contributes significantly to the development of biotic and abiotic stress resistance (Zargar *et al.*, 2019). In cases of excessive accumulation, it does not harm the plants. Due to its flexible role in promoting many benefits for plant growth, especially under stressful situations, silicon is regarded as a

multi-talented micronutrient (Zargar *et al.*, 2012). The above facts, this research study was conducted during *rabi* season of 2022-23 at Research Farm, Vivekananda Global University, Jaipur with the objective of to find out the response of wheat (*Triticum aestivum* L.) to nitrogen and silicon levels under semi-arid regions of Rajasthan.

Materials and Methods

An experiment was conducted at Vivekananda Global University, Jaipur during *rabi* 2022-23. The field's soil was loamy sand, with low organic carbon (0.20%), an alkaline pH (pH 8.22), low available nitrogen (136.23 kg ha⁻¹), medium available phosphorus (21.52 kg ha⁻¹) and medium available potassium (237.21 kg ha⁻¹). The experiment consists 9 treatments three nitrogen levels (0, 60 and 120 kg ha⁻¹) and three silicon levels (0, 100 and 200 kg ha⁻¹) was laidout in Randomized Block Design and replicated three time. Plot size was 5.0 m × 3.0 m. Crop variety HD - 3086 with 100 kg seed rate ha⁻¹ was taken for experiment.

The recommended fertilizer dose (nitrogen (0, 60 and 120 kg ha⁻¹) was given as per treatments and common dose of 60 kg P₂O₅ and 40 kg K₂O was applied at the time of sowing) was used. Half of the N were applied as a basal dose at the time of sowing, and the remaining half was applied as a top dressing at the time of the first and second irrigation {as per treatment (1 and 16 December 2022)}. The wheat variety HD 3086 (Pusa Gautami) was seeded at a rate of 100 kg ha⁻¹. On November 10, 2022, the seeds were manually sown in opened furrows at a depth of 5 cm in rows spaced 20 cm apart, and after depositing the seed in furrows, it was covered with earth to provide uniform germination and protection from bird damage. One hoeing and weeding was done manually with the help of hoe at 25 DAS to facilitate aeration and removing the weeds during crop growth period. Each plot's crop was collected separately. The harvested plants were tied in bundles, tagged and kept for sun drying on threshing floor. After complete drying these bundles were weighed just before threshing to record biological yield. Threshing of the harvested produce from individual plot was done with the help of mini power operated thresher.

The plant height was measured from the ground to the tip of the main shoot on five randomly selected plants from each plot at 30, 60, 90 DAS and at harvest to the tip of the upper spikelet of main ear (excluding awns). The average plant height was calculated and expressed in cm. Plants of 0.5 m row length from the sample rows of each gross plot were uprooted at 30, 60, 90 DAS and at harvest. The root portion was removed, and the plants were separated into little pieces before being placed in a perforated labelled brown paper bag and dried in the sunlight first, then in the thermostatically controlled oven

at 60°C ± 2°C. The drying process was repeated until a steady weight was reached, and the mean dry matter accumulation g 0.5 m⁻¹ row length was calculated. At harvest, the number of effective tillers was counted from one-metre row length in three locations over the net plot area. The average of the three values is given as the number of effective tillers per m⁻¹ row length. Five spikes were randomly selected from net plot, threshed and the total number grain was counted and average was taken as number of grain spike⁻¹. The length of spike was measured from five randomly selected ears at the time of crop harvest, and averaged to express in cm. Five samples of 1000 grain in each plot were weighed from the final produce in each plot at the time of threshing, thereafter 1000-grains were counted and weighed and expressed as g. The net plot crop was harvested, threshed and winnowed.

The grains harvested from each net plot were sun dried for 2-3 days to attain 10 per cent moisture and then the weight of grains net plot⁻¹ area was recorded and expressed in kg ha⁻¹. The straw yield from each net plot was sun dried for 4 to 6 days and weighed. Straw yield kg ha⁻¹ was computed from straw yield of each net plot. The unthreshed produce from net plot area, after sun drying was weighed for recoding the biological yield and expressed in terms of yield in kg ha⁻¹. It is the ratio of economic yield (grain yield) to biological yield, and worked out by following formula (Donald and Hamblin, 1976) expressed in percentage.

Experimental data recorded in various parameters were statistically analyzed with the help of Fisher's analysis of variance technique (Panse and Sukhatme, 1985)). The critical difference (CD) for the treatment comparisons was worked out wherever the variance ratio (F test) was found significant at 5% level of significance. To elucidate the nature and magnitude of treatments, summary tables along with S.Em. ± and CD (P=0.05).

Results and Discussion

Effect of nitrogen levels

Growth parameters : An investigation at the data in Table-1 and Fig-1 and 2 reveals that significantly higher plant height 60, 90 DAS and at harvest and dry matter accumulation at 30, 60, 90 DAS and at harvest was recorded under application of 120 kg N ha⁻¹. It is a well-known fact that providing crops with proper fertilisation helps the plant system's numerous physiological and metabolic activities. The fictitious function of nitrogen in the plant body may be responsible for the increase in the growth character indicated above under larger doses of nitrogen. This may also be the result of nitrogen's synergistic effects on plant cell division,

Table-1 : Effect of different sources of irrigation water and nitrogen management on plant population, plant height and dry matter accumulation at different growth stages of wheat.

Treatments	Plant population 20 DAS	Plant height (cm)				Dry matter accumulation (g 0.5 m ⁻¹ row length)			
		30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
Nitrogen (kg ha ⁻¹)									
0	26.96	12.88	42.94	66.64	76.96	124.82	320.81	688.02	891.52
60	28.11	13.26	50.17	77.80	90.30	127.29	376.29	816.62	1063.68
120	28.61	13.69	54.61	86.08	97.53	128.60	417.92	896.38	1170.14
SEm±	0.83	0.38	1.35	2.22	2.67	3.62	9.85	22.38	25.26
CD (p=0.05)	NS	NS	4.03	6.67	7.99	NS	29.52	67.10	75.73
Silicon (kg ha ⁻¹)									
0	27.31	12.80	43.55	67.70	77.81	126.01	328.66	703.59	921.52
100	27.92	13.37	49.76	77.51	88.92	126.93	373.15	809.52	1047.80
120	28.45	13.66	54.41	85.31	98.05	127.77	413.20	887.90	1156.02
SEm±	0.83	0.38	1.35	2.22	2.67	3.62	9.85	22.38	25.26
CD (p=0.05)	NS	NS	4.03	6.67	7.99	NS	29.52	67.10	75.73

Table-2 : Effect of different sources of irrigation water and nitrogen management on yield attributes and yield at harvest of wheat.

Treatments	Yield attributes				Yield (kg ha ⁻¹)			Harvest Index (%)
	Number of effective tillers m ⁻²	Number of grains spike ⁻¹	Spike length (cm)	Test weight (g)	Grain	Straw	Biological	
Nitrogen (kg ha ⁻¹)								
0	339.74	7.28	24.53	36.38	3005	4929	7933	37.78
60	422.05	8.81	30.24	37.45	3726	5898	9623	38.65
120	455.41	9.81	33.43	38.01	4192	6663	10855	38.58
SEm±	10.62	0.24	0.61	1.12	69	111	142	0.64
CD (p=0.05)	31.85	0.73	1.83	NS	206	332	425	NS
Silicon (kg ha ⁻¹)								
0	343.55	7.34	25.22	36.45	3039	5013	8053	37.68
100	412.74	8.70	29.61	37.32	3674	5927	9602	38.19
120	460.90	9.87	33.37	38.07	4209	6549	10758	39.15
SEm±	10.62	0.24	0.61	1.12	69	111	142	0.64
CD (p=0.05)	31.85	0.73	1.83	NS	206	332	425	NS

photosynthetic rate, chlorophyll content, and root activities, which lead to higher nutrient removal and hence higher growth characteristics. Nitrogen is crucial for plant growth and development since it played a significant role in the metabolism of proteins and carbohydrates. The primary functions of nitrogen are cell proliferation, elongation, and tissue differentiation, which improve vegetative growth by increasing plant height and the quantity, size, and area of leaves. Large leaf area increased a plant's ability to capture enough sunlight, which may have led to the creation of more assimilate and accelerated crop growth and development. The plants become taller, create more LAI, and ultimately produce higher total dry matter accumulation when there is an appropriate supply of nitrogen. These findings closely align with those of earlier researchers Yadav *et al.* (2018), Mohanta *et al.* (2020), Ausiku *et al.* (2020), Bhanuchandar *et al.* (2020), Rana and Prasad (2020), Kakarla *et al.* (2021) and Minz *et al.* (2021).

Yield attributes : A perusal of data from Table-2 and Fig-3 shows that yield attributes viz., number of effective

tillers, number of grains spike⁻¹, spike length and test weight of wheat increased significantly with application of 120 kg N ha⁻¹. The rise in yield characteristics may be explained by an increase in tillers due to nitrogen application. Nitrogen administration may have increased meristematic activity, tissue differentiation (from somatic to reproductive), and the development of floral precursors, which may have led to a higher output of flowers that later grew into spikelets. The cumulative effect of a rise in the quantity of productive tillers and grains spike⁻¹ may be responsible for the increase in yield brought on by the application of nitrogen. It could possibly be because nitrogen is now more readily available (Rani *et al.*, 2019). The cumulative effect of a rise in the quantity of productive tillers and grains spike⁻¹ may be responsible for the increase in yield brought on by the application of nitrogen. It could possibly be because nitrogen is now more readily available. The superior growth of the plants in terms of plant height and dry biomass output, which results in increased bearing capacity due to optimum growth as a result of increased nitrogen application, could be linked to

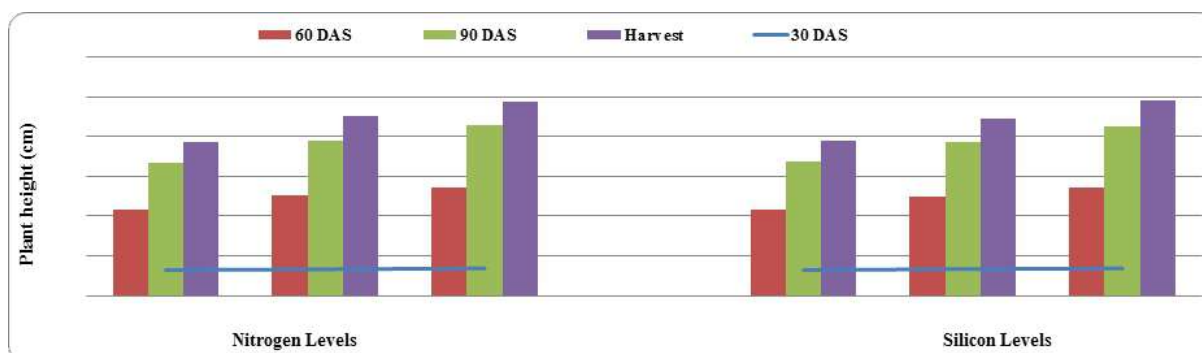


Fig-1 : Effect of different sources of irrigation water and nitrogen management on plant height at different growth stages of wheat.

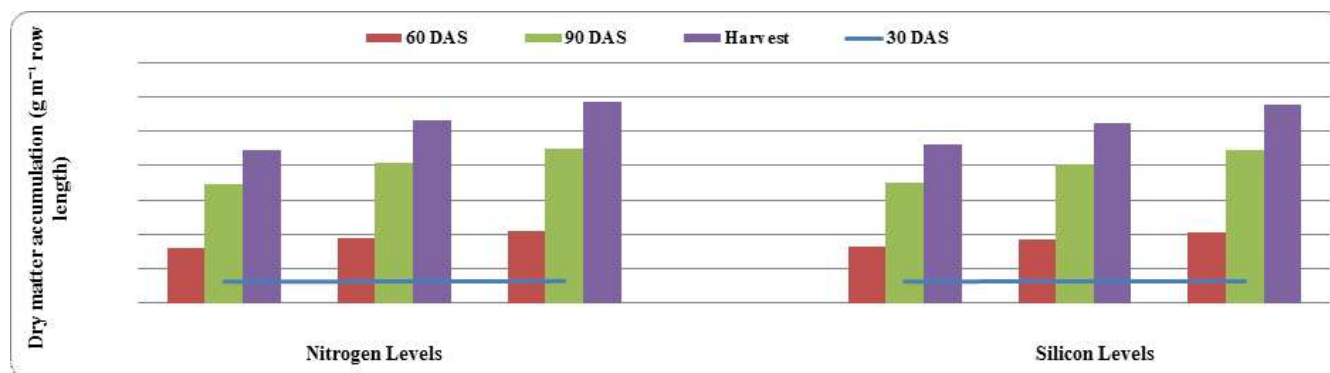


Fig-2 : Effect of different sources of irrigation water and nitrogen management on dry matter accumulation at different growth stages of wheat.

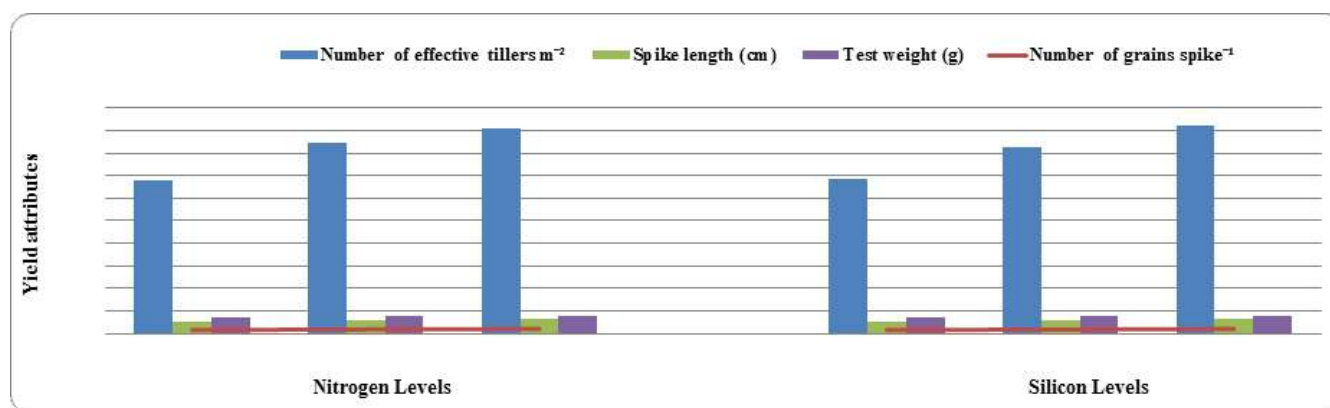


Fig-3 : Effect of different sources of irrigation water and nitrogen management on yield attributes of wheat.

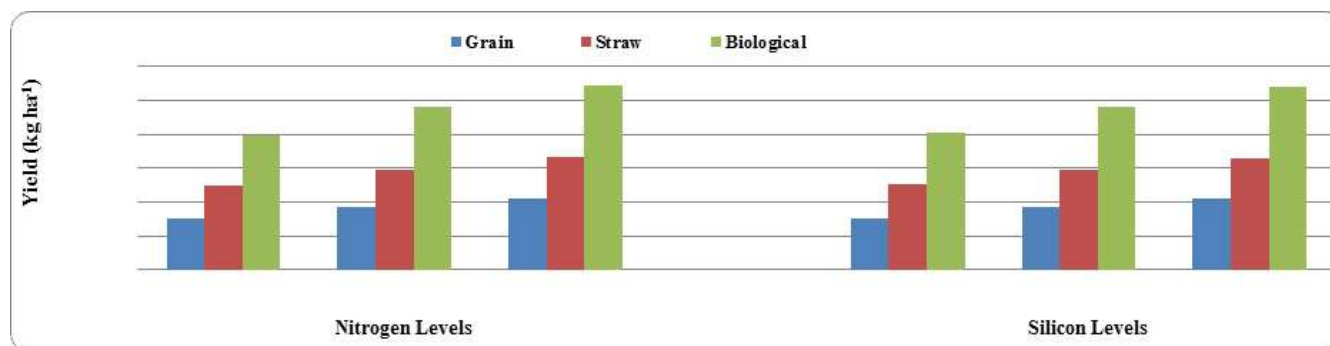


Fig-4 : Effect of different sources of irrigation water and nitrogen management on yield of wheat.

the beneficial influence of nitrogen on sink component. Similar results were also noticed by Dwivedi *et al.* (2017), Dhiman and Dubey (2017), Kakraliya *et al.* (2017), Saharan *et al.* (2017) Ausiku *et al.* (2020), Rana and Prasad (2020) and Kakarla *et al.* (2021).

Yield : Data from Table-2 and Fig-4 indicate that application of 120 kg N ha⁻¹ was found significantly superior in yield viz., grain, straw and biological yield of wheat as compared to application of 60 kg N ha⁻¹ and control. Increases in growth parameters may have led to higher yield qualities and an increase in wheat grain and straw yield. Nitrogen administration may have boosted straw yield in part due to its direct impact on each vegetative part's ability to produce dry matter as well as indirectly due to increased morphological growth parameters (plant height and dry matter accumulation). Since grain and straw yields, which indicate vegetative and reproductive growth of the crop, are a function of biological yield. The significant impact of nitrogen on each of these crop growth factors resulted in a larger biological yield. These findings closely align with those of earlier researchers Dwivedi *et al.* (2017), Dhiman and Dubey (2017), Kakraliya *et al.* (2017), Saharan *et al.* (2017), Ausiku *et al.* (2020), Rana and Prasad (2020) and Kakarla *et al.* (2021).

Effect of silicon

Growth parameters : The data in Table-1 and Fig-1 and 2 show that application of 200 kg silicon ha⁻¹ was increased significantly plant height and dry matter accumulation at 60, 90 DAS and at harvest over application of 100 kg silicon ha⁻¹ and control. However, plant population was remained unchanged with nutrient management. This might be due to increased cell division, elongation and expansion brought on by silicon may be the reason of the increase in plant height. This was in keeping with the findings of Yavarzadeh *et al.* (2008), who stated that the erectness of the leaves and stem was caused by silica deposition on the plant tissues, which may have contributed to the height rise of the plant. According to the data, adding silicon improved the height of the plants because it improves water status and boosts plant photosynthetic rates, which results in a lengthy, firm crop (Ahmed *et al.*, 2013). The same outcomes have been reported by Gerami *et al.* (2012), Chhimpa and Sharma (2018) and Jan *et al.* (2018).

Yield attributes : A perusal of data from Table-2 and Fig-3 shows that yield attributes viz., number of effective tillers, number of grains spike⁻¹, spike length and test weight of wheat increased significantly with application of 200 kg silicon ha⁻¹ as compared to application of 100 kg silicon ha⁻¹ and control. The rise in yield characteristics may be explained by an increase in tillers due to silicon

application. It might be attributed to silicon's readily obtainable form, consistent supply to the crop, and its synergistic interaction with other nutrients, which eventually improved the crop's photosynthetic activity and produced superior yield characteristics and yield. Additionally, the number of branches per plant is strongly correlated with the quantity of pods produced by that plant. The number of filled seeds increased as a result of improved plant glucose absorption. A sufficient supply of silicon may have enhanced photosynthetic activity and allowed the plant to amass enough photosynthates, which led to an increase in the creation of dry matter. With foliar application of silicon at 2%, Chhimpa and Sharma (2018) produced the greatest number of pods plant⁻¹ of urdbean. Similar results were also noticed by Jinger *et al.* (2018), Rao *et al.* (2018), Jawahar *et al.* (2019) and Kandil *et al.* (2019).

Yield : Data from Table-2 and Fig-4 indicate that application of 200 kg silicon ha⁻¹ was found significantly superior in yield viz., grain, straw and biological yield of wheat as compared to application of 100 kg silicon ha⁻¹ and control. Increases in growth parameters may have led to higher yield qualities and an increase in wheat grain and straw yield. These elements, when combined with effective photosynthetic translocation, produced more loaded grains and heavier tests, which eventually boosted seed and straw yield. These findings closely align with those of earlier researchers Jinger *et al.* (2018), Rao *et al.* (2018), Jawahar *et al.* (2019) and Kandil *et al.* (2019).

Conclusions

Basis on our findings, it can be concluded that application of 120 kg N ha⁻¹ in wheat is most efficient preposition, when judged in terms of growth and productivity. Among the silicon levels, maximum and significantly higher growth and yield of wheat was recorded in application of 100 kg silicon ha⁻¹.

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SDS PAGE Analysis of Protein Diversity in Various Life Stages of Polymorphs in Asian Weaver Ant *Oecophylla smaragdina*; Fabricius (Hymenoptera: Formicidae)

Parag P. Masram

Department of Zoology, Elphinstone College, Dr. Homi Bhabha State University, Mumbai

Email : ppmasram@elphinstone.ac.in

Abstract

An SDS PAGE analysis of haemolymph from various life stages in polymorphs of *O. smaragdina* was carried out to study the protein diversity and its effect on caste specific function of members of the colony. The separation of various life stages indicates high protein diversity in the larval period whereas the less diverse proteins in adult stages. A 28 KDa female specific found in all female members of colony and a 66 KDa protein found in the Drone (male) larva and adult indicates role of protein sex determination in *O. smaragdina*.

Introduction

Oecophylla smaragdina is a social Hymenopteran ant also known as Asian Weaver ant. Greenslade (1972), reported about the distribution of Asian weaver ant in Oriental region from India to Queensland and Solomon Islands. Social structure of the colony consists of fertile and infertile castes. The fertile caste comprises of Drone (male) and Queen (female) whereas the infertile caste is of workers. According to Vanderplank (1960), fertile caste of *Oecophylla longinoda*, another species of weaver ants does not require nuptial flight as they mate inside the nest; whereas Peng *et al.*, (2007), reported nuptial flight in *O. smaragdina*. Bolton (1994), stated weaver ant life cycle comprise of four stages i.e. of egg, larva, pupa and adult in the hive and duration of development from egg to adult in weaver ant, *O. smaragdina* is approximately 30 days, three larval instars with a naked pupal period in period in other species of weaver ant *O. longinoda*. Bharti and Silla (2011), reported three instars in *O. smaragdina*.

Diverse range of proteins varying from less than 14KDa to 96 KDa found in larvae to adult stage in Indian meal moth *Plodia interpunctella* (R. Abdul Ela *et al.*, 1991). According to Cavalcante and Cruz (2004) the diversity of protein decreases from larvae to adults. And workers of hymenopteran lack of high molecular weight protein (Oliveira and Landim, 2004). A low molecular weight venom protein of 14 KDa is found in fire ant *Solenopsis geminate* (Srisong *et al.*, 2018). Body pigmentation in adult Ponerine ant *Diacamma sp.* is regulated by a sex specific expression of single gene (Miyazaki *et al.*, 2104). A single gene known as *csd* in honey bees is responsible for sex determination (Beye *et al.*, 2003; Hoff, 2009). A female specific protein is found in queen, workers and Gynandromorphs of several species of social Hymenoptera (Engels, 1974). A female specific protein Vitellogenin is found in female of Hemiptera

(Fortes *et al.*, 2011). A male sex protein of 55KDa from haemolymph of lepidopteran moth *G. mellonella* was identified and purified by Lee *et al.*, (1997).

The present work was carried out to investigate the protein diversity and their specific role in sex determination in the polymorph of the Asian weaver Ants *O. smaragdina*.

Extract preparation : Haemolymph was collected by crushing the polymorphic forms in small vials pre-coated with phenylthiourea to prevent melanization. The Haemolymph sample were centrifuge immediately at 4500 rpm for 15 min. and supernatant was stored at -20°C and supernatant used for biochemical analysis of total soluble protein, carbohydrate, DNA and RNA.

SDS PAGE electrophoresis (Lamelie *et al.*, a)

SDS - PAGE (plate) electrophoresis was carried out by Laemmli, (1970) method with minor modifications.

Statistical Analysis : The data generated during observation was compiled and analyzed using simple measures of central tendency. The mean, standard deviation and $\pm$ standard error was calculated, by using Microsoft Excel 2007 software package. All statistics presented in this study are mean $\pm$ standard error, Student's 't' test made use for testing significance of difference between the means of reading of experimental and control group using 5 percent level of significance.

SDS-PAGE separation of protein : Separation of proteins using SDS Page electrophoresis technique shows presence of unique proteins of 96kDa present only in drone and queen larvae. The drone adult and larval stage shows a unique protein of 66kDa. The queen and worker larva and adult show a unique 28 KDa protein. The queen and drone larvae shows maximum diversity of proteins compared to workers. (Fig.-1).

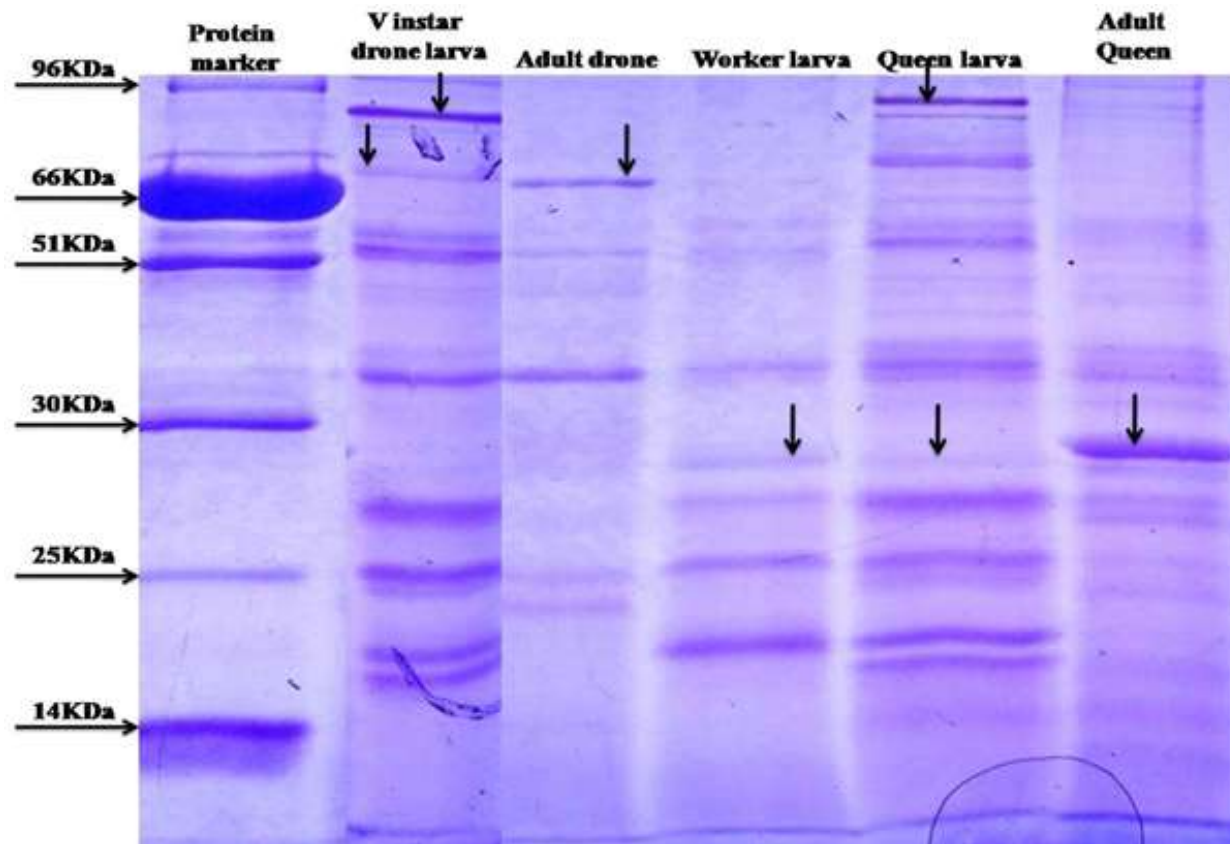


Fig-1 : SDS PAGE showing separation of various proteins from polymorph of *O. smaragdina*.

- Lane-1** : Marker protein. 14KDa to 96 KDa
Lane-2 : Drone larva showing 66 KDa male specific protein.
Lane-3 : Drone adult showing 66 KDa male specific protein.
Lane-4 : Worker larva showing 28 KDa female specific protein.
Lane-5 : Queen larva showing 28 KDa female specific protein.
Lane-6 : Queen adult showing 28 KDa female specific protein.

R. Abdul Ela *et al.*, (1991), reported about diverse range of proteins varying from less than 14KDa to 96 KDa decreased from larvae to adult stage in Indian meal moth *Plodia interpunctella*. According to Cavalcante and Cruz (2004) the diversity of protein decreases from larvae to adults. During the present study, SDS PAGE electrophoretic separation of protein in larvae and adults of polymorphs of *O. smaragdina* show diversity varying 14KDa to 96 KDa proteins and decreased in adult polymorphs compared to larvae. Oliveira and Landim (2004), reported lack of high molecular weight protein in workers of hymenopteran insects. In the present study, the protein diversity observed in the worker larvae of *O. smaragdina*, show low molecular weight protein range. Among them the highest molecular weight protein observed in worker larvae is of about =51KDa. Srisong *et al.*, (2018), reported a low molecular weight protein of 14 KDa as venom protein in fire ant *Solenopsis geminata*. During the present study the queen larva and pupa show a similar protein of 14 KDa although *O. smaragdina* does not show venom production. Miyazaki *et al.*, (2104),

reported regulation of body pigmentation of adult Ponerine ant *Diacamma sp.* by a sex specific expression of single gene. Beye *et al.*, (2003), and Hoff (2009), reported role of single *csd* in sex determination in honey bees. Engels (1974), reported a female specific protein found in queen, workers and Gynandromorphs of several species of social Hymenoptera. Fortes *et al.*, (2010), also found a female specific protein Vitellogenin in Hemiptera. The SDS PAGE study of prominent band of 28KDa was observed with other protein bands. This band is only found in queen and worker of *O. smaragdina*. Therefore, this 28KDa protein is considered to be female specific protein. Lee *et al.*, (1997) identified and purified male sex protein of 55KDa from hemolymph of lepidopteran moth *G. mellonella*. During the present study a male specific protein of 66KDa is observed only in drone larva and adult drone. In the present study, maximum diversity of protein is found in the larval period which is observed to be decreased in the adult stage. The male and female caste of colony show presence of specific protein bands confirming role of protein in sexual dimorphism and sex determination in *O. smaragdina*.

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Response on Growth and Yield Traits of Pearl Millet (*Pennisetum glaucum* L.) to Different Levels of Nitrogen and Zinc on under Rainfed Condition

Om Prakesh Dhaka¹, P.K. Shamra, Hoshiyar Singh and Neha

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

¹Corresponding Author Email : harishdhaka1997@gmail.com

Abstract

A field experiment was conducted at Research Farm, Vivekananda Global University, Jaipur during *kharif*, 2022. The experiment was laid out in Factorial Randomized Block Design with two factors and replicated thrice. Whereas first factor comprises three levels of nitrogen viz., 30, 60 and 90 kg N ha⁻¹ and second factor three levels of zinc viz., 0 (control), 5 and 10 kg Zn ha⁻¹. The results of one year study clearly showed that application of different levels of nitrogen and zinc an additive effect in increasing growth and yield attributes of pearl millet. The application of nitrogen @ 90 kg N ha⁻¹ recorded significantly higher growth and yield attributes over the rest of the levels of nitrogen; however application of nitrogen @ 60 kg N ha⁻¹ showed at par with @ 90 kg N ha⁻¹ in most of the cases. The application of zinc @ 10 kg Zn ha⁻¹ produced significantly higher growth and yield attributes over the rest of the levels of zinc. However, application of zinc @ 5 kg N ha⁻¹ showed at par with @ 10 kg N ha⁻¹ for most of the traits. On the basis of present experiment the most suitable dose of nitrogen may be application 90 kg N ha⁻¹ increasing a grain yield of 1563.64 kg/ha N ha⁻¹. Application of 15 kg Zn ha⁻¹ for pearl millet to produce higher grain yield of 1385.59 kg ha⁻¹.

Key words : Growth, nitrogen, yield and zinc.

Introduction

Pearl millet [*Pennisetum glaucum* (L)] is the most significant cereal food crop after wheat, rice, and maize. Locally, it is referred to as Bajra. It is a member of the Peniceidae subfamily of the gramineae family. It is believed to have originated in Africa, where there is a wide variety of morphological types. In addition to being heat tolerant, high tillering, and well suited to various soil types, pearl millet is a drought-resistant cereal with the greatest potential for grain production under challenging conditions (Fageria, 1992). The pearl millet grains are very nutritious and become a staple diet of approximately 10 per cent of the population in the country.

Pearl millet is typically farmed with minimal nitrogen input. Nitrogen is one of several additional elements included in many different biological compounds. Using fertilizer wisely and appropriately boosts productivity while also improving forage quality, particularly in terms of protein content (Ayub *et al.*, 2007). However, multiple research shown that N application can boost millet production efficiency (Singh *et al.*, 2010). Pearl millet has traditionally been recognised for growing on low N management (Gascho *et al.*, 1995).

Phosphorous is a crucial structural component of cells and is found in phosphoproteins, phospholipids, coenzymes, nucleic acids, and proteins. Root development accelerates early maturation because to energy storage and transpiration. Phosphorus deficiency

inhibits the growth of the shoots and roots, results in older leaves that are blue green or dark green, and suppresses lateral buds. For the preservation of cellular structure and the activation of numerous enzymes, potassium is crucial. It is necessary for both protein synthesis and the metabolism of carbohydrates. It improves resilience to diseases and moisture stress. It also raises the grade of the output.

Plants require zinc for their regular, healthy development and reproduction. Zinc is an essential structural component and regulatory co-factor for a wide variety of enzymes, auxin and protein synthesis, various metabolic activities, and critical biochemical and physiological processes like photosynthesis, disease immunity, sugar synthesis, fertility, and seed production in plants.. Lack of zinc in the plant causes the panicles to grow and mature more slowly, which reduces grain output (Marschner, 1995). According to Singh (2010), there is a 49% Zn deficiency in Indian soils, and applying Zn is said to boost wheat production by 6.3% to 9.3%. Gulati and Yadav (2014) also said that in light soils in western Rajasthan, Zn deficiency was identified in 80-85% of soil samples.

Materials and Methods

The experiment consisting of 9 treatments was carried out in factorial randomized block design and replicated three times during *kharif* season of 2022 at Agricultural Research Farm, Vivekananda Global University, Jaipur. In Rajasthan, this region all under agro- climatic zone III A

(Semi-arid Eastern Plain Zone). The seeds were line sown in furrows opened with the help of a wooden marker at a row spacing of 45 cm X 15 cm, using 4 kg seeds ha⁻¹ and furrow were covered immediately after sowing. The gap filling was done after one week of sowing to ensure uniform plant stand.

Treatment details

Treatment	Symbol	Treatment combination
T1	N1Zn1	Nitrogen levels (30 ha ⁻¹)
T2	N1Zn2	Nitrogen levels (30 ha ⁻¹) + Zinc levels (5 ha ⁻¹)
T3	N1Zn3	Nitrogen levels (30 ha ⁻¹) + Zinc levels (10 ha ⁻¹)
T4	N2Zn1	Nitrogen levels (60 ha ⁻¹)
T5	N2Zn2	Nitrogen levels (60 ha ⁻¹) + Zinc levels (5 ha ⁻¹)
T6	N2Zn3	Nitrogen levels (60 ha ⁻¹) + Zinc levels (10 ha ⁻¹)
T7	N3Zn1	Nitrogen levels (90 ha ⁻¹)
T8	N3Zn2	Nitrogen levels (90 ha ⁻¹) + Zinc levels (5 ha ⁻¹)
T9	N3Zn3	Nitrogen levels (90 ha ⁻¹) + Zinc levels (10 ha ⁻¹)
Nitrogen levels (kg ha ⁻¹)		Zinc levels (kg ha ⁻¹)
30 - N1		0 - Zn1
60 - N2		5 - Zn2
90 - N3		10 - Zn3

Statistical analyses : Data obtained on various variables were analyzed by analysis of variance method (Panse and Sukhatme, 1967). The total variance (S^2) and degree of freedom (n-1) were partitioned into different possible sources. The variance due to various treatments of mulching were compared with error of variance to find out „F? values and ultimately for testing the significance at $p = 0.05$. The standard errors for the treatment based on error variance were calculated. Whenever, the results were found to be significant, critical differences were also calculated for comparison of treatment means at 5 per cent level of significance (CD at $P = 0.05$).

Results and Discussion

Effect of nitrogen : The highest mean plant height due to the application of nitrogen @ 90 kg ha⁻¹ (75.68 cm at 40 DAS, 163.2 at 60 DAS and 177.8 cm at harvest) found to be at par with nitrogen @ 60 kg ha⁻¹. Application of nitrogen @ 90 kg N ha⁻¹ was found maximum dry matter accumulation (18.06 g/m² at 40 DAS, 42.99 g/m² at 60 DAS and 54.25 g/m² at harvest stage) to be at par with 60 kg N ha⁻¹. The significantly highest total number of effective tillers/plant in pearl millet at 60 DAS was recorded with 90 kg/ha N (2.12) which was at par with 60 Kg/ha N.

Plant population, plant height, dry matter accumulation and chlorophyll content all increased considerably with nitrogen administration up to 90 kg ha⁻¹ (Table-1). N's profound influence as involvement in a number of physiological and metabolic processes in the plant system, which are thought to be the primary factors for realizing a plant's inherent genetic potential for growth, could be attributed to the overall improvement in growth of pearl millet plants under the influence of increasing rates of N application up to 90 kg ha⁻¹ (Tisdale *et al.* 1990). Aside from its role in the rapid multiplication of tissues, nitrogen also plays a crucial role in the production of growth factors like phytohormones that occur naturally, the rate of photosynthesis, and an increase in auxin supply when nitrogen levels are high (Thiamann and Schneider, 1983). These factors may have contributed to the current study's significant increases in plant height and leaf chlorophyll content. Sumeriya & Singh (2010) also noted a similar trend in fodder pearl millet. According to Gasim (2001), nitrogen fertilizer increases plant height because it encourages the number of internodes and lengthens those internodes, both of which lead to a gradual rise in plant height. According to Carvalho *et al.* (1982), increased chlorophyll synthesis as a result of higher protein creation under its effect was the cause of the improvement in dry matter production under appropriate N administration. Despite this, the increased nutritional environment in the soil brought on by greater rates of N application may have encouraged plant morphological growth by causing active cells to elongate, which in turn increased plant height. Furthermore, increased protein synthesis and maybe growth hormones may have led to increased chlorophyll production in the leaves of fodder pearl millet. There was a strong correlation between leaf chlorophyll concentration and leaf nitrogen content, which makes sense given that chlorophyll molecules hold the bulk of the nitrogen in leaves (Peterson *et al.* 1993).

The storage capacity of pearl millet depends on the length and girth of ear head, grain weight per ear head, test weight and yields in terms of grain, straw and biological. Number of effective tillers was found to significantly increase with increasing level of nitrogen. This may be due to the fact that the numbers of tillers at higher levels of nitrogen were so high that even after increased mortality, it remained significantly higher than that of lower levels of nitrogen and this consequently led to more number of panicle bearing tillers and ear head at higher level of nitrogen. This finding corroborates the finding of Mesquitas and Pinto (2000), Prasad *et al.* (2014). The length and width of ear head increased significantly due to increase in the levels of nitrogen. The increase in length of ear head at higher level of nitrogen

Table-1 : Response of different levels of nitrogen and zinc on plant population/m row length, plant height, dry matter accumulation (g/m²) of pearl millet.

Treatments	Plant population m ⁻¹ row length		Plant height (cm)				Dry matter accumulation (g/m ²)			
	20 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
Levels of nitrogen (kg/ha)										
30	8.23	8.10	22.25	64.5	116.77	166.67	1.63	12.51	33.31	44.64
60	8.21	8.14	15.08	71.52	154.9	169.61	1.56	17.24	40.39	50.93
90	8.31	8.12	15.07	75.68	163.2	177.8	1.53	18.06	42.99	54.25
SE m±	0.30	0.41	0.36	1.85	3.35	3.27	0.12	0.39	0.99	0.95
CD at 5 %	NS	NS	NS	5.61	9.83	9.71	NS	1.14	2.92	3.19
Zinc levels (kg/ha)										
0	8.11	8.10	15.36	56.54	130.54	150.83	1.48	12.07	27.98	36.85
5	8.22	8.00	16.32	60.12	148.64	159.35	1.64	12.65	30.26	38.72
10	8.13	8.05	16.38	63.26	152.82	162.96	1.44	13.54	30.63	39.51
SE m±	0.25	0.21	0.36	0.40	1.60	1.57	0.09	0.32	0.78	0.66
CD at 5 %	NS	NS	NS	3.56	7.10	7.01	NS	0.93	2.29	1.95
Interaction (N x Zn)										
SE m±	0.51	0.58	0.67	3.14	5.49	5.39	0.22	0.7	1.7	1.44
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table-2 : Response of different levels of nitrogen and zinc on chlorophyll content, yield and yield attributing characters of pearl millet.

Treatments	Chlorophyll content (mg/g) at 60 D	Total number of effective tillers/plant	Yield and yield attributing characters							
			Length of ear head	Girth of ear head	Grain weight (g) per ear head	Test weight	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Levels of nitrogen (kg/ha)										
30	2.75	1.67	17.95	9.67	31.71	8.54	1.63	12.51	33.31	44.64
60	2.56	1.86	18.86	9.85	35.34	8.63	1.56	17.24	40.39	50.93
90	2.95	2.12	20.39	10.08	37.94	8.86	1.53	18.06	42.99	54.25
SE m±	0.12	0.14	0.51	0.25	1.13	0.14	0.12	0.39	0.99	0.95
CD at 5 %	0.37	0.43	1.52	NS	3.31	NS	NS	1.14	2.92	3.19
Zinc levels (kg/ha)										
0	2.31	1.44	16.31	8.84	26.83	8.70	1.48	12.07	27.98	36.85
5	2.34	1.55	17.46	9.08	30.41	8.31	1.64	12.65	30.26	38.72
10	2.53	1.63	18.35	9.12	30.59	8.39	1.44	13.54	30.63	39.51
SE m±	0.09	0.13	0.44	0.17	0.96	0.11	0.09	0.32	0.78	0.66
CD at 5 %	0.26	NS	1.29	NS	2.81	NS	NS	0.93	2.29	1.95
Interaction (N x Zn)										
SE m±	0.12	0.24	1.67	0.38	2.04	0.23	0.22	0.7	1.7	1.44
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

might be attributed to better nutrition of ear head primordial. This is in agreement with the finding of Alkaff and Saeed (2007) and Prasad *et al.* (2014). Grain weight is mainly controlled by genetic makeup of the variety, though it increased significantly with increasing level of nitrogen. This might be due to better nutrition of spikelets. Similar results were recorded by Alkaff and Saeed (2007) and Verma *et al.* (2006). Grain and straw yield was significantly influenced by levels of nitrogen and significantly maximum grain yield was recorded at level (90 kg N ha⁻¹). It is well known fact that grain yield is the

outcome of yield attributing characters, which also increased with increasing levels of nitrogen. Increasing in grain yield may be due to nitrogen being a major nutrient, affected all physicochemical process. The finding of present investigation corroborates with the findings of Yakadri and Reddy (2009).

Effect of Zinc : Application of different levels of zinc significantly increased the growth of plant in terms of plant height at all stage except 20 DAS, dry matter accumulation at all stages except 20 DAS and chlorophyll

content of leaves. However plant population m^{-1} row length was non-significant. The increase in growth parameters of pearl millets due to application of zinc have also reported by Dhaka (1984), and Maliwal *et al.* (1985) who were also reported increased plant height and dry matter accumulation due to zinc application. The increase in growth might be due to role of zinc in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them (Wear and Hayler, 1968).

Due to the widespread lack of zinc in soils and its critical role in the growth and development of many crops, zinc management as a component of balanced plant nutrition has gained significant recognition in recent years (Rattan *et al.* 1997). It has been established that Zn is essential for the production of several enzymes, including peptidases, glutamic acid dehydrogenases, lactic acid dehydrogenases, and carbonic anhydrases. It is also thought to be a precursor for the production of auxin, involved in the metabolism of nitrogen, a number of oxidation-reduction processes, the stability of RNA, and the creation of starch. Therefore, its sufficient supply leads to increased dry matter production, which in turn promotes plant growth and development (Maiti, 1996). Zinc's beneficial role in chlorophyll formation may have increased auxin concentration, which has a stimulating effect on the majority of physiological and metabolic processes. This, along with more nitrogen being readily available, may have increased the amount of photosynthates produced and their distribution to various parts, such as the leaves of fodder pearl millet, which in turn increased the chlorophyll content in the leaves of fodder bajra. The length of ear head increased significantly due to increase in the levels of zinc. The increase in length of ear head at higher level of zinc might be attributed to better nutrition of ear head primordia. Maximum length of ear head (18.35 cm) was recorded with Z3 (10 kg Zn). These findings corroborate the finding of Prasad *et al.* (2014). As the crop was treated with 10 kg Zn per hectare, yields (in terms of seed, straw, and biological production) significantly increased as compared to controls. With Z3 (15 kg N ha^{-1}) the highest grain yield (1892.00 kg ha^{-1}) was reported. Given that the yield depends on the cumulative impact of growth characteristics like plant height, the number of tillers per plant, and the accumulation of dry matter per plant, all of which were greater with 10 kg Zn ha^{-1} , the yield were higher with this treatment. Zinc enhanced the source-sink relationship, which in turn improved the yield qualities because more photosynthates were moving into the reproductive system. This consensus supports the findings of Sammauria *et al.* (2010). The results are in

close conformity with findings of those of Manohar (1991) and Dhadich & Gupta (2005) who were reported significantly increased green and dry fodder yield with application of 10 kg $\text{ZnSO}_4 \text{ ha}^{-1}$. The Zn fertilization appears to have a dramatic impact on the formation of dry matter and the accumulation of nutrients, which may account for the noticeable increase in productivity of individual plants under its influence. As a result, the enhanced availability of both of these growth inputs may have kept supplies in sufficient quantities to meet plants' needs for yield creation. The presence of a favorable nutritional environment above ground (plant parts) and below ground (rhizosphere) as a result of Zn nutrition had a good impact on both crop phases, which eventually resulted in better fodder production.

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Effect of Mineral Nutrient Management on Growth and Productivity of Mustard [*Brassica juncea* (L.)] under Rainfed Conditions

Neha*, P.K. Shamra, Hoshiyar Singh and Om Prakesh Dhaka

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : nehabest000@gmail.com

Abstract

A field experiment was conducted at Research Farm, Vivekananda Global University, Jaipur during *Rabi* season of 2022-23. The experiment was laid out in split block design with three replications, assigning twelve treatment combinations consisting of three major nutrient level (100 % RDF, 125 % RDF and 150 % RDF) and four micro nutrient management treatment (20 S + 2.5 Zn, + 2.5 Kg ZnSO₄, 20 S + 2.5 Zn enriched with 500 Kg FYM, 40 S + 5 Zn and 40 S + 5 Zn enriched with 500 Kg FYM. Results showed that significantly highest plant height, dry matter accumulation, chlorophyll content, number of siliquae per plant and number of seed per siliqua, grain yield, straw yield and biological yield, nitrogen, phosphorus and potassium uptake in grain and straw and crude protein, protein yield of mustard was obtained with major mineral nutrient 150% RDF as compared to 125 % RDF. However, data also revealed that different mineral nutrients did not bring any significant effect on plant population, test weight, harvest index, nitrogen, phosphorus and zinc content in grain and straw in grain of mustard. Results further showed that application of 40 S + 5 Zn enriched with 500 Kg FYM significantly increased the plant height, dry matter accumulation, chlorophyll content, number of siliquae per plant, number of seed per siliqua, grain yield (1752.56 kg ha⁻¹), straw yield (4038.44 kg ha⁻¹) and biological yield (4395.94 kg ha⁻¹) of mustard over 40 S + 5 Zn and 20 S + 2.5 Zn enriched with 500 Kg FYM. However, different micro mineral nutrients treatments did not bring any significant effect on plant population, test weight and harvest index of mustard. The interaction effect of major nutrient and micro nutrients level on number of siliquae per plant and number of seed per siliqua of mustard was found significant, therefore, application of 150% RDF with 40 S + 5 Zn enriched with 500 Kg FYM closely followed by application of 125% RDF with 40 S + 5 Zn enriched with 500 Kg FYM may be recommended for higher productivity of mustard.

Key words : Growth, FYM, nutrient, treatment and yield.

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Cosson.] is an important oilseed crop, next to sunflower. Mustard seed has 21 % protein content with a high nutritive value. It is a winter (*Rabi*) season crop that requires relatively cool temperature, a fair supply of soil moisture during the growing season and a dry harvest period (Banerjee *et al.*, 2010). In Indian cuisine, rapeseed-mustard is a staple vegetable, condiment, and source of edible oil. The range for the oil content is 37% to 49%. Because of the distinctive flavor and pungency provided by “Allyl isothiocynate” and similar chemicals, this oil is widely utilized for edible purposes and is particularly valued for use in frying vegetables and fish. Rape or mustard cake is the leftover meal from recovering the oil from rape and mustard seed. Following groundnut, it is the second-most significant edible oilseed in India, contributing 27.8% of the country's oilseed GDP. Mustard needs sandy loam soil that drains properly.

Rajasthan, Uttar Pradesh, Haryana, Madhya Pradesh, and Gujarat are the main states where Indian mustard is grown. Additionally, it is grown in other less common regions of South India, such as Karnataka, Tamil

Nadu, and Andhra Pradesh. This crop is the main edible oilseed crop in India, producing around one-third of the nation's oil. An estimated 101.10 lakh tonnes of mustard are produced year on a total area of 66.90 lakh hectares in India, with a productivity average of roughly 1511 kg/ha (Anonymous, 2022). Rapeseed and mustard are the most important oilseed crops grown in Rajasthan, taking up 27.20 lakh hectares of space and producing 45.10 lakh tonnes annually with an average productivity of 1659 kg/ha (Anonymous, 2022).

Both in terms of area and national rapeseed and mustard production, Rajasthan comes in despite being a significant oilseed crop, its productivity in the state is well below its achievable yield potential of 2200 to 2400 kg/ha. There is no possibility of expanding the area under this crop at the expense of crops that produce food grains. Therefore, new crop production technology is the only method to boost production and productivity. Nitrogen, phosphorus, and sulfur, the three major nutrients, all play a significant impact in improving the yield and quality of mustard. The majority of metabolic processes and energy transformation are known to be activated by nitrogen. Phosphorus has a crucial function in tissue meristematic development and cell division. Sulfur plays a crucial part

in raising the percentage and output of oil. Application of sulfur has a significant impact on protein, carbohydrate, and chlorophyll production. To enhance the physical, chemical, and biological qualities of the soil, employ organic manure (FYM) or other agricultural waste. The majority of crops take up nitrogen in the form of nitrate, which is only changed by soil microorganisms. Even in soils damaged by salt or soils with high pH, FYM containing humic acid helps to hold plant nutrients in an exchangeable or accessible state. In order to preserve soil fertility and yield stability, FYM has traditionally been utilized in agriculture (Aggarwal and Venkateswarlu, 1989).

Materials and Methods

The experiment consisting of eight treatments was carried out in split plot design and replicated three times during Rabi, 2022-2023 at Agricultural Research Farm, Vivekananda Global University, Jaipur. In Rajasthan, this region all under agro- climatic zone III A (Semi-arid Eastern Plain Zone). Seeds of mustard variety Bio 902 were treated with carbendazim (2 g kg^{-1} seed) as prophylactic measures against seed borne diseases. The crop was sown by “kera” method in rows spaced at 30 cm apart and plant spaced at 10 cm on 4t November 2018 using seed rate of 4 kg ha^{-1} .

Treatments details with their symbols

S. No.	Treatments Symbols	Symbol
Main Plot Fertility Levels (Kg ha^{-1})		
1.	100 % of RDF (60 Kg N + 30 Kg P_2O_5 + 30 Kg K_2O)	F ₁
2.	125 % of RDF	F ₂
3.	150 % of RDF	F ₃
Sub Plot Secondary and Micro Nutrients (kg ha^{-1})		
1.	20 S + 2.5 Zn	S ₀
2.	20 S + 2.5 Zn enriched with 500 Kg FYM	S ₁
3.	40 S + 5 Zn	S ₂
4.	40 S + 5 Zn enriched with 500 Kg FYM	S ₃

Statistical analysis : Experimental data recorded in various observations were statistically analysed with the help of Fisher's analysis of variance technique (Fisher, 1950). The critical difference (CD) for the treatment comparisons were worked out wherever the variance ratio (F test) was found significant at 5% level of significance.

Results and Discussion

Effect of fertility levels on growth parameters : The findings of the present investigation showed that different major nutrients levels significantly enhanced the vegetative growth in terms of plant height, dry matter accumulation and chlorophyll content in mustard. The maximum value of these growth parameters were recorded with 150% of RDF which was significantly

superior over 125% of RDF and 100% of RDF (Table 1). The improved growth and early seedling vigor under the ideal levels of inorganic sources of nutrients may be the cause of the rise in growth parameters with application of 150% RDF, which signals proper nutrient utilization during the crop's early growth phases. Nitrogen is a crucial component of protoplasm, and its favorable impact on leaf chlorophyll content may have increased the synthesis of carbohydrates, amino acids, and other compounds, from which phytohormones like auxins, gibberellins, and cytokinins have been produced, leading to an increase in plant height (Singh et al. 2017). Potassium aids in protein synthesis, chlorophyll synthesis, and enhancing stress resistance, all of which may have benefitted plant growth and development. The findings of Khatkar et al. (2009) and Jat et al. (2000) are closely supported by the results. Faster nutrient availability from a sufficient supply of inorganic fertilizers throughout the cropping period increases the crop's nutrient needs and the number of photosynthesis-active leaves produced, which may have increased the production of carbohydrates and phytohormones and increased plant height, dry matter accumulation and chlorophyll content in mustard crops, the findings of Chaturved et al. (2005), Hadiyal et al. (2017), Verma and Dawson (2018), and Singh et al. (2018) are all very close to the findings of this study.

Effect on yield attributes and yield : In the present investigation, there was significant increase in yield attributes (number of siliques per plant and number of seed per silique) and yield (grain, straw and biological) of mustard with different major nutrients levels. The maximum mean values of number of siliques per plant, and number of seed per silique, grain, straw and biological yield of mustard obtained with the application of 150% of RDF which was significantly superior to 125% of RDF and 100% of RDF (Table 2). As a result, appropriate amounts of plant nutrients were present throughout the crop's growth phase; better nutrient absorption, enhanced plant vigor, and improved yield were the results. This may explain why inorganic sources of nutrients had a positive impact on mustard yield characteristics and output. Greater transfer of photosynthates from leaves via stem to grain site was promoted by higher fertility levels i.e. silique and grain and these resulted in higher number of seed per silique and more numbers of grains. The results are in conformity with that of Pir et al. (2005), Lakhnpal and Pathak (2016) and Tiwari et al. (2017). Due to ideal plant development and improved photosynthetic translocation to the region of silique formation, application of a greater rate of NPK significantly boosted practically all yield parameters and yield. Better nutrient uptake from the soil, which may have contributed to greater dry matter accumulation, may also be to blame for the rise in yield.

Table-1 : Response of different levels of nitrogen and zinc on plant population m⁻¹ row length, plant height, dry matter accumulation (g/m²) of pearl millet.

Treatments	Plant population m ⁻¹ row length		Plant height (cm)				Dry matter accumulation (g/m ²)			
	20 DAS	At harvest	20 DAS	40 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest
Effect of major nutrient levels										
F ₁	33.73	31.30	21.27	71.08	86.70	127.23	14.45	60.26	210.07	271.36
F ₂	33.93	31.90	23.74	82.23	95.49	132.67	16.12	72.64	233.31	306.90
F ₃	34.13	32.21	24.45	82.23	98.28	135.74	16.72	80.03	241.26	323.72
SE m±	0.67	1.02	0.63	1.95	2.26	2.79	0.36	2.04	5.77	7.59
CD at 5 %	NS	NS	NS	11.84	13.77	16.96	NS	12.44	35.14	46.17
Effect of secondary and micro nutrients management										
S ₀	33.70	31.21	21.92	69.81	86.10	128.45	14.59	66.72	214.62	278.62
S ₁	33.90	31.85	23.16	79.07	93.24	131.08	15.74	70.47	227.64	301.52
S ₂	34.05	32.05	23.19	79.63	94.19	133.12	16.01	72.37	229.98	304.68
S ₃	34.08	32.10	24.35	85.54	100.43	134.87	16.71	74.35	240.62	317.82
SE m±	0.97	0.97	0.53	2.66	2.36	2.62	0.32	1.23	5.39	5.77
CD at 5 %	NS	NS	NS	11.95	10.60	11.77	NS	5.54	24.25	25.96

Table-2 : Response of different levels of nitrogen and zinc on chlorophyll content, yield and yield attributing characters of pearl millet.

Treatments	Chlorophyll content (mg/g) at 60 D	Total number of effective tillers/plant	Yield and yield attributing characters						
			Number of siliquae per plant	Number of seeds per siliqua	Test weight	Grain yield	Straw yield	Biological yield	Harvest index (%)
Levels of nitrogen (kg/ha)									
30	2.22	1.67	179.02	10.73	4.11	1428.67	3284.08	3092.82	41.02
60	2.52	1.86	192.03	11.59	4.47	1669.42	3831.67	4278.80	41.14
90	2.56	2.12	216.86	9.83	4.82	1824.50	4155.25	4694.13	41.09
SE m±	0.04	0.14	2.58	0.09	0.12	25.38	28.41	48.83	0.99
CD at 5 %	0.27	0.43	15.68	0.53	NS	154.45	172.86	297.10	NS
Zinc levels (kg/ha)									
S ₀	2.22	1.44	179.68	9.63	4.03	1524.11	3459.11	3633.79	40.99
S ₁	2.45	1.55	190.23	10.34	4.54	1639.78	3756.22	3988.79	41.13
S ₂	2.47	1.63	202.31	11.06	4.44	1647.00	3774.22	4069.15	41.09
S ₃	2.60	0.13	211.66	11.84	4.84	1752.56	4038.44	4395.94	41.13
SE m±	0.04		3.83	0.26	0.10	29.37	105.84	98.91	0.92
CD at 5 %	0.20	NS	17.24	1.16	NS	132.19	476.34	445.14	NS

Similar finding were reported by Jat, et al. (2000), Lakhanpal and Pathak (2016), Hemkalyan et al. (2018), and Singh et al. (2018).

Effect of secondary and micro nutrients management

Effect on growth attributes : The different secondary and micro nutrients management significantly enhanced the vegetative growth in terms of plant height, dry matter accumulation and chlorophyll content at various growth stages in mustard. The maximum value of these growth parameters were recorded with application of 40 S + 5 Zn enriched with 500 Kg FYM which was significantly superior to 40 S + 5 Zn and hydrogel at 20 S + 2.5 Zn enriched with 500 Kg FYM. The application of 40 S + 5 Zn enriched with 500 Kg FYM had a positive impact on plant height and dry weight, according to the results (Table 1). All plant height parameters increased linearly as N and Sulfur levels rose correspondingly. Increased nutrient intake, particularly of N and Sulphur, appeared to have

favorable vegetative growth. Increased leaf area index indicates that higher meristematic activity resulting from N and S fertilization may have promoted greater canopy development. With stronger CO₂ fixation and better radiant energy interception, absorption, and use as a result of the increased leaf area index brought on by N fertilization, the photosynthetic efficiency appeared to have significantly increased. The use of sulphur improves root growth, cell multiplication, elongation, and cell expression in the plant body, which in turn improves the nutritional environment for plant growth at active vegetative stages. Similar result was also reported by Chaubey et al. (2003), Makeen et al. (2008), Lone et al. (2009), Tiwari et al. (2000), Sarkar and Pal (2005), Singh et al. (2006) Verma *et al.* (2012) and Riaj *et al.*, (2018) in mustard.

Effect on yield attributes and yield : In the present investigation, there was significant increase in yield

attributes (number of siliquae per plant and number of seed per silique) and yield (grain, straw and biological) of mustard with application of different mineral nutrients levels. The maximum mean values of number of siliquae per plant, number of seed per silique, grain, straw and biological yield of mustard obtained with the application of 40 S + 5 Zn enriched with 500 Kg FYM which was significantly superior to 40 S + 5 Zn and at 20 S + 2.5 Zn enriched with 500 Kg FYM (Table 2). The primary and secondary branches, which are silique-bearing organs since flowers are produced at the ends of the branches, are enhanced by nitrogen and sulfur. As a result, the number of silique per plant rose along with the number of branches. Sulfur is a crucial component of several biologically active substances, including the amino acids cysteine, methionine, and cysteine, the vitamins thiamine and biotin, lipoic acid, acetyl Co -A, ferredoxin, and methionine. It engages in activation of a number of enzymes participating in dark reaction of photosynthesis via improvement in chlorophyll content of leaves. These results are also in close conformity with the results of Chakraborty and Das (2000), Singh and Mukherjee (2004), Hussain et al. (2008).

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Efficacy of Liquid Formulation on Growth Parameters of Taramira (*Eruca sativa* L.)

Pankaj Dagur*, P.K. Sharma and Chatar Singh Meena

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : pankajdagur147@gmail.com

Abstract

A field experiment was conducted at Research farm, Vivekananda Global University, Jagatpura in Jaipur, Rajasthan during *rabi* season of 2023. The experiment consisted of 8 liquid formulation spray treatments viz., T₁-control (no spray), T₂-water spray, T₃-jeevamrit spray (10%), T₄-panchgavya (10%), T₅-vermiwash spray (10%), T₆-jeevamrit (10%) + panchgavya spray (10%), T₇-jeevamrit spray (10%) + vermin-vash spray (10%), T₈-Jeevamrit spray (10%) + Panchgavya spray (10%) + vermin-vash spray (10%) that were laid out in a Randomized Block Design and replicated thrice. Taramira variety RTM-314 was sown on November, 2022 in the rows spaced 40 cm apart. Results showed that foliar spray of Jeevamrit spray (10%) + Panchgavya spray (10%) + vermi-wash spray (10%) was the most superior treatment in improving most of the growth attributes viz., plant height, dry matter accumulation/m row length.

Key Words : Taramira, liquid formulation, growth parameters, plant height and dry matter.

Introduction

Taramira (*Eruca sativa* L.) belongs to the family *Brassicaceae* serves as a catch crop in the situation of late harvesting of *kharif* crops. It can be grown on a variety of soils on conserved moisture (Barani), as it is relatively a hardy plant. The oil of taramira is used mostly for non-edible purposes including industrial uses in the manufacturing of grease, soaps, plastics, lubricants etc. Its cake is used as a nutritious feed for animals.

Taramira is mainly grown in drier regions of North-Western India. Because of its efficient root system to extract moisture from deeper layers of soil, it is especially suitable for arid and semi-arid regions of Rajasthan. Rajasthan is the leading state in taramira, occupying more than 65 per cent area and contributes 60 per cent of the nation's production. In Rajasthan, it occupies about 17 thousand ha area with an annual production of 7279 tonnes with the productivity of 433 kg/ha (Anonymous, 2022).

Organic farming aims for human welfare without harming the environment and it follows the principles of ecology, health, fairness and care for all including soil. The modern concept of organic farming involves the science, innovation and tradition. The excessive use of agro-chemicals for last fifty years though helped in achieving remarkable progress earlier, but the least attention given to ecological, agricultural principles resulted in soil degradation, ground water and environmental pollution leading to ecological imbalances. It also adversely affects the human health, by exposing to the chemicals used in agriculture results in serious health risks.

In this situation, a strong awareness has to be created on the acceptance of organic farming as a remedy to manage the ill effects from chemical farming, to achieve sustainable crop production and soil fertility, the role of organic manures and other nutrient management practices such as use of fermented organic manures viz., panchgavya, jeevamrit, vermiwash, beejamrit, sasyamrit etc., are becoming popular among farmers nowadays. The plant can absorb nutrients about 20 times faster through the leaves than applied through the soil, therefore, liquid manures are helpful to overcome temporary nutrient shortages. As taramira is a very important oilseed crop and is valued for its oil, hence organic production of this crop using such fermented organic manures and other input may be a good effort towards sustainable crop production and maintaining quality of produce.

Materials and Methods

Experimental site : The experiment was laid out at Agronomy Farm, Vivekananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5' North latitude and 75° 28' East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48°C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is

contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs/day.

Experimental details : The experiment comprised of 8 treatments involving control, water spray, panchgavya, vermiwash, jeevamrit and their combinations that were laid down in randomized block design and replicated.

S. No.	Treatments	Symbols
1.	Control (No Spray)	T ₁
2.	Water Spray	T ₂
3.	Jeevamrit (10%)	T ₃
4.	Panchgavya (10%)	T ₄
5.	Vermiwash (10%)	T ₅
6.	Jeevamrit (10%) + Panchgavya (10%)	T ₆
7.	Jeevamrit (10%) + Vermiwash (10%)	T ₇
8.	Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%)	T ₈

Pant height : The periodical plant height at 30, 60, 90 DAS and at harvest was measured from the ground level

Table-1 : Effect of liquid formation on plant height at different stages of taramira.

Treatments	Plant height (cm)		
	40 DAS	60 DAS	At harvest
T ₁ - Control	65.81	84.32	104.32
T ₂ - Water spray	65.96	84.39	104.51
T ₃ - Jeevaamrit (10%)	72.92	94.14	114.62
T ₄ - Panchgavya (10%)	73.10	95.32	114.86
T ₅ - Vermiwash (10%)	73.65	95.82	115.36
T ₆ - Jeevamrit (10%) + Panchgavya (10%)	73.92	96.64	116.39
T ₇ - Jeevamrit (10%) + vermiwash (10%)	74.10	98.10	118.62
T ₈ - Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%)	75.15	102.65	122.62
SEm+	2.22	2.87	3.31
CD (P=0.05)	NS	8.71	10.03
CV (%)	5.36	5.30	5.03

Table-2 : Effect of liquid formation on dry matter accumulation at different stages of taramira.

Treatments	Dry matter		
	40 DAS	60 DAS	At harvest
T ₁ - Control	38.12	77.62	153.69
T ₂ - Water spray	38.26	77.86	153.91
T ₃ - Jeevaamrit (10%)	42.61	86.61	169.12
T ₄ - Panchgavya (10%)	43.85	86.94	170.10
T ₅ - Vermiwash (10%)	44.15	87.10	170.65
T ₆ - Jeevamrit (10%) + Panchgavya (10%)	44.26	87.19	171.11
T ₇ - Jeevamrit (10%) + vermiwash (10%)	45.62	87.92	172.52
T ₈ - Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%)	48.62	89.36	175.62
SEm+	1.36	2.75	5.02
CD (P=0.05)	4.12	8.34	15.21
CV (%)	5.44	5.60	5.20

to the top of the main shoot of the selected five plants from each plot.

Dry matter accumulation : To compute the dry matter accumulation/m row length, the plants from 0.5 m row length from the sampling rows were cut from ground level at 30, 60, 90 DAS and at harvest by keeping them in oven at 65° C till their weight became constant. The dried samples were weighed and dry matter accumulation/m row length was worked out at each stage.

Results and Discussion

Plant height : Data revealed that foliar application of liquid organic formulation significantly enhanced the plant height of taramira over control. Foliar application of Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) recorded the maximum plant height at 40, 60 DAS and at harvest.

Dry matter accumulation : It is noticed that foliar application of liquid organic formulation significantly enhanced the dry matter accumulation of taramira over control and water spray. Foliar application of eevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) recorded the maximum dry matter at 60 DAS and at harvest

Foliar application of different liquid formulations

either alone or in combination significantly improved the various growth parameters of taramira viz. plant height, dry matter accumulation. Among various liquid formulations, application of foliar sprays of Jeevamrit (10%) + Panchgavya (10%) + Vermiwash (10%) spray recorded significantly taller plants and highest dry matter. Similar results have been reported by Munji *et al.* (2010), Kumawat *et al.* (2009b) in sesame and Kaur *et al.*, 2015.

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Effect of Foliar Application of Nutrients on Bulb Production of Onion (*Allium cepa* L.)

Pradeep Meel*, P.K. Sharma and Mahipal Dudwal

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : pradeepmeel2571@gmail.com

Abstract

A field experiment entitled Effect of Foliar Application of Nutrients on Bulb Production of Onion (*Allium cepa* L.) was conducted at Vivekananda Global University, Jaipur during Rabi season of 2022-23. The experiment consisting of eight treatment combinations of nutrients viz. control (T_1), water spray (T_2), one spray of NPK (19:19:19) (T_3), two spray of NPK (19:19:19) (T_4), one spray of 0.5% $ZnSO_4$ (T_5), two spray of 0.5% $ZnSO_4$ (T_6), one spray of NPK 19: 19: 19 + 0.5% $ZnSO_4$ (T_7) and two spray of NPK 19: 19: 19 + 0.5% $ZnSO_4$ (T_8) were laid out in randomized block design with three replications. For experimentation, onion variety Bhima super was used. The results of one-year study clearly showed that foliar application of nutrients brought an additive effect in increasing yield attributes of onion as compared to control (no spray) and water spray. Maximum average weight of bulb, marketable yield per plot, yield per plot, total yield was obtained with two spray of NPK 19: 19: 19 + 0.5% $ZnSO_4$ (T_8) which was remained at par with one spray of NPK 19: 19: 19 + 0.5% $ZnSO_4$ (T_7). Therefore, two spray of NPK 19: 19: 19 + 0.5% $ZnSO_4$ (T_8) was found most profitable as it gave highest yield.

Key Words : Onion, Bulb, Yield and NPK

Introduction

Onion (*Allium cepa* L.), the “Queen of the Kitchen” is one of the most commercially valuable vegetables grown in India. Onion belongs to family Amaryllidaceae and native of central Asia. It is considered as a rich source of carbohydrates, proteins and vitamin C, besides minerals like phosphorus and calcium. Onion is known for its flavour, pungency and also as an eco-friendly stored grains protectant. Among fresh vegetables, onion is a pride item of agricultural exports earning valuable foreign exchange to the country and accounts for about 70 % of the total foreign exchange earnings of fresh vegetables.

India consumes, on an average, 40 lakh tonnes of onion a year and the projected imports of around 13,000 tonnes partly meet out from the countries like Iran, Oman, and Dubai. So, to meet the growing demand, concentrated efforts are needed to produce sufficient quantity and of high quality onions. With no scope for expansion in area under vegetable cultivation, future growth has to come from partially increase in output by finding the ways and means to enhance the productivity of onion through suitable agro-technologies that are within the reach of Indian farmers. One of the options is by using balanced nutrition, supply of macro and micronutrients through the combination of both organic and inorganic sources as well as use of plant growth regulators (PGRs) to enhance the yield.

In India, it is grown in 1.27 million hectares area and its production is 21.56 million tonnes of bulb and productivity is 16.97 tonnes/ha, whereas in Rajasthan, it is

grown in 0.11 Million hectares area and production is 2.02 Million tonnes and productivity is 18.36 t/ha (Anonymous, 2021).

Due to inadequacy of land, it is not possible to raise the production of crop horizontally. The high demand of onion can only be met up by increasing its per hectare yield. This can be done by various ways like suitable selection of correct variety, nursery production, planting time and growing method, growth regulation, curing but also the application of macro and micro nutrients play a major role in maintaining the balance of nutrient loss through leaching and run off which is very high due to torrential rains.

Materials and Methods

Experimental site : The experiment was conducted during Rabi 2022-23 at Vivekananda Global University, Jaipur. Geographically, the study area is located at 75°46'77" E longitude and 26°44'25" N latitude and this region falls under agro-climatic zone III A (Semi-arid Eastern Plain Zone) of Rajasthan.

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop

season ranged between 20.1 °C to 33.3 °C and -1.1 °C to 15.6 °C, respectively. A total of 39.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 38.0 to 69.0 per cent, while the average sunshine hours ranged between 4.1 to 9.4 hrs. / day.

Experimental details : The present experiment consisting of 8 treatment combinations was laid out in Randomized Block Design.

S. No.	Treatments	Symbols
1.	Control (No fertilizer)	T ₁
2.	Water spray	T ₂
3.	NPK (19:19:19) spray -one (40 days) (1% - 10 g/litter)	T ₃
4.	NPK (19:19:19) spray - two (40-60 days) (1% -10 g/ litter)	T ₄
5.	ZnSO ₄ at 0.5% spray - one (40 days) (0.5% - 5 g/litter)	T ₅
6.	ZnSO ₄ at 0.5% spray - two (40-60 days) (0.5% - 5g/litter)	T ₆
7.	NPK+ZnSO ₄ spray- one (40 days) (10g/litter+5 g/litter)	T ₇
8.	NPK+ZnSO ₄ spray- two (40-60 days) (10g/litter+5 g/ litter)	T ₈

Average weight of bulb : After harvesting total weights of randomly selected five bulbs were recorded and then mean weight of single bulb was worked out for each replication of all treatments and expressed in grams.

Marketable yield per plot (kg) : Marketable bulb would be calculated by separating rotted, undersized, bolted, double and sprouted bulbs from the plot yield.

Yield per plot (kg) : The yield of bulb (kg) per plot was calculated.

Total yield (q ha⁻¹) : Total yield of bulb (kg) per plot was converted in quintal per hectare multiplying with factor.

Results and Discussion

Average weight of bulb (g) : The average weight of bulb varied in the range of 52.80 g to 76.45 g and the maximum average weight of bulb (76.45 g) was recorded in treatment T₈ (two spray of NPK 19: 19: 19 + 0.5% ZnSO₄). The magnitude of increase in average weight of onion bulb due to two spray of NPK 19: 19: 19 + 0.5% ZnSO₄ was 44.79 and 43.16%, respectively as compared to control and water spray.

Marketable yield per plot (kg) : The numerical values indicated that the treatment T₈ (two spray of NPK 19: 19: 19 + 0.5% ZnSO₄), recorded maximum marketable bulb yield (17.56 kg) which was significantly superior to all the remaining treatments. While, the minimum marketable bulb yield (11.32 kg per plot) was observed in control treatment (T₁). The corresponding enhancement in

marketable bulb yield of onion bulb due to two spray of NPK 19: 19: 19 + 0.5% ZnSO₄ was 42.39 and 39.37%, respectively as compared to control and water spray.

Yield per plot (kg) : The data regarding yield per plot was significantly influenced by different treatments of zinc and NPK as presented in table 4.6 and graphically indicated in fig 4.4. The data indicated that the maximum yield per plot (17.58 kg) was observed in treatment T₈ (two spray of NPK 19: 19: 19 + 0.5% ZnSO₄) which was significantly superior to all the remaining treatments viz., control (T₁), water spray (T₂), one spray of NPK (19:19:19) (T₃), two spray of NPK (19:19:19) (T₄), one spray of 0.5% ZnSO₄ (T₅) and two spray of 0.5% ZnSO₄ (T₆) and remained at par with treatment T₇ (one spray of NPK 19: 19: 19 + 0.5% ZnSO₄). While, the minimum yield per plot (12.23 kg) was observed in control treatment (T₁). The increase in yield per plot of onion due to two spray of NPK 19: 19: 19 + 0.5% ZnSO₄ was 43.73 and 41.24%, respectively as compared to control and water spray.

Total yield (q ha⁻¹) : The numerical values indicated that the treatment T₈ (two spray of NPK 19: 19: 19 + 0.5% ZnSO₄), recorded maximum total yield (296.37 q ha⁻¹) which was significantly superior to all the remaining treatments. While, the minimum total yield of onion was observed in control (T₁). The corresponding enhancement in total yield due to two spray of NPK 19: 19: 19 + 0.5% ZnSO₄ was 46.63 and 43.57%, respectively as compared to control and water spray.

Average weight of bulb and yield (marketable yield per plot, yield per plot and total yield) of onion was recorded with two spray of NPK 19: 19: 19 + 0.5% ZnSO₄ (T₈) which was significantly higher than all the remaining treatments viz., control (T₁), water spray (T₂), one spray of NPK (19:19:19) (T₃), two spray of NPK (19:19:19) (T₄), one spray of 0.5% ZnSO₄ (T₅) and two spray of 0.5% ZnSO₄ (T₆) and remained at par with treatment T₇ (one spray of NPK 19: 19: 19 + 0.5% ZnSO₄). These results are in the line with the findings of Singh *et al.* (2010), Sharma *et al.* (2017), Goyal *et al.* (2017) and Pramanik *et al.* (2018).

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Table-1 : Effect of foliar application of nutrients on average weight of bulb and marketable yield plot¹ of onion.

S. No.	Treatments	Average bulb weight (g)
T ₁ :	Control	52.80
T ₂ :	Water spray	53.40
T ₃ :	NPK (19:19:19) spray - one	64.20
T ₄ :	NPK (19:19:19) spray - two	63.10
T ₅ :	ZnSO ₄ at 0.5% spray - one	64.60
T ₆ :	ZnSO ₄ at 0.5% spray - two	66.10
T ₇ :	NPK + ZnSO ₄ spray - one	75.20
T ₈ :	NPK + ZnSO ₄ spray - two	76.45
SEm+		2.88
Cd (P = 0.05)		8.73

Table-2 : Effect of foliar application of nutrients on number of yield and yield attributed of onion.

S. No.	Treatments	Marketable yield plot ¹ (kg)	Yield per plot (kg)
T ₁ :	Control	11.32	12.23
T ₂ :	Water spray	11.56	12.44
T ₃ :	NPK (19:19:19) spray - one	13.21	14.76
T ₄ :	NPK (19:19:19) spray - two	13.61	15.09
T ₅ :	ZnSO ₄ at 0.5% spray - one	13.01	14.69
T ₆ :	ZnSO ₄ at 0.5% spray - two	13.50	14.95
T ₇ :	NPK + ZnSO ₄ spray - one	15.60	17.28
T ₈ :	NPK + ZnSO ₄ spray - two	16.12	17.58
SEm+		0.62	0.69
Cd (P = 0.05)		1.88	2.09

Table-3 : Effect of foliar application of nutrients on total yield of onion.

S. No.	Treatments	Total yield (q ha ⁻¹)
T ₁ :	Control	202.12
T ₂ :	Water spray	206.43
T ₃ :	NPK (19:19:19) spray - one	248.80
T ₄ :	NPK (19:19:19) spray - two	255.36
T ₅ :	ZnSO ₄ at 0.5% spray - one	243.69
T ₆ :	ZnSO ₄ at 0.5% spray - two	253.45
T ₇ :	NPK + ZnSO ₄ spray - one	293.54
T ₈ :	NPK + ZnSO ₄ spray - two	296.37
SEm+		11.80
Cd (P = 0.05)		35.79

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Effect of Nutrient Management Through Organic Sources on Yield and Harvest Index of Pearl millet (*Pennisetum glaucum* L.)

Rahul Kumar Sharma*, P.K. Sharma and Mahipal Dudwal

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : rahulupadhyay0102@gmail.com

Abstract

A field experimentation was carried out during *Kharif* season of the year 2022-23 at research farm, Vivekananda Global University, Jaipur. The objectives were to study the Effect of Nutrient Management Through Organic Sources on Productivity and Quality of Pearl millet (*Pennisetum glaucum* L.). The experiment consisted of 9 treatment combinations comprising three levels of fertilizer (100% RDF, 100% RDN through FYM, 100% RDN through vermicompost, 75% RDN through FYM, 75% RDN through vermicompost, 100% RDN through FYM + seed inoculation with bio fertilizers, 100% RDN through vermicompost + seed inoculation with bio fertilizers, 75% RDN through FYM + seed inoculation with bio fertilizers, 75%. The experiment was laid out in Randomized Block Design and replicated thrice. Application of 100% RDN through vermicompost + seed inoculation with bio fertilizers increased the yield and harvest index Pearl millet.

Key Words : Pearl millet, FYM, vermicompost, yield and harvest index.

Introduction

Pearlmillet [*Pennisetum glaucum* (L.) R. Br. emend Stuntz] is one of the important millet crop of dry areas of arid and semi-arid climatic condition particularly of Rajasthan. It has been estimated that pearlmillet embodies a tremendous productivity potential particularly in areas having extreme environmental stress condition on account of drought.

Cultivation of pearl millet is mainly confined to semi-arid and arid region of India. In India, pearl millet occupies an area of 6.93 million ha with an average production of 8.61 million tonnes and productivity of 1243 kg/ha (Anonymous, 2020). Rajasthan occupied 42.36 lakh ha area (56.48 % of the national acreage) with the total production of 37.52 lakh tonnes (53 % of the national production) and average productivity of 886 kg/ha (Anonymous, 2019-2020).

Vermicompost is a prime source of macro and micro nutrients in chelated form and fulfills the balanced nutrient requirement of crops for longer period. Besides, it also helps in maintaining soil fertility and practices of precious eco-friendly environment of the soil. Poultry manure is also another important source of nutrients which plays direct role in plant growth. Besides major nutrients, poultry manure also contains traces of micronutrients which are generally not supplied by the commercial fertilizers but essential for plant growth.

Materials and Methods

Experimental site : The experiment was laid out at Agronomy Farm, Vivekananda Global University, Jaipur

during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs/day.

Experimental details : The experiment comprised of 9 treatments involving thiopurea and kinetin used to seed soaking and foliar spray their combinations that were laid down in randomized block design and replicated three times.

S.No.	Treatments	Symbols
1.	100% RDF	T ₁
2.	100% RDN through FYM	T ₂
3.	100% RDN through vermicompost	T ₃
4.	75% RDN through FYM	T ₄
5.	75% RDN through vermicompost	T ₅

6.	100% RDN through FYM + seed inoculation with bio fertilizers	T ₆
7.	100% RDN through vermicompost + seed inoculation with bio fertilizers	T ₇
8.	75% RDN through FYM +seed inoculation with bio fertilizers	T ₈
9.	75% RDN through vermicompost+ seed inoculation with bio fertilizers	T ₉

Grain yield (kg/ha) : Under each experimental plot after discarding border and sampling rows, crop was harvested and produce was bundled. After sun drying these were weighed to record biological yield. The material was threshed manually and winnowed. The clean seed obtained from individual plots was weighed and the weight recorded as grain yield in terms of kg/ha.

Straw yield (kg/ha) : Straw yield was obtained by subtracting the grain yield from biological yield. The grain and straw recorded under each plot were converted into kg/ha.

Biological yield (kg/ha) : After complete sun drying, harvested bundles of each net plot (3.0 m x 1.35 m) were weighed for biological yield and converted in terms of kg/ha.

Harvest index (%) : Harvest index was computed by using the formula outlined by Singh and Stoskopf (1971).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (kg / ha)}}{100}$$

Results and Discussion

Grain yield : Treatment 100% RDN through vermicompost + seed inoculation with bio fertilizers recorded the maximum grain yield (2398 kg /ha).

Stover yield : Treatment 100% RDN through vermicompost + seed inoculation with bio fertilizers recorded the maximum stover yield (6491 kg /ha).

Harvest index : The results reveals that different treatments of nutrition management of organic source of

Table-1 : Effect of foliar nutrition on grain, straw and biological yield of pearl millet.

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
100% RDF	1938.00	5225.00	7163.00
100% RDN through FYM	2137.00	5765.00	7902.00
100% RDN through vermicompost	2094.00	5615.00	7709.00
75% RDN through FYM	2111.00	5711.00	7822.00
75% RDN through vermicompost	2150.00	5801.00	7951.00
100% RDN through FYM + seed inoculation with bio fertilizers	2156.00	5822.00	7978.00
100% RDN through vermicompost + seed inoculation with bio fertilizers	2398.00	6491.00	8889.00
75% RDN through FYM + seed inoculation with bio fertilizers	2387.00	6459.00	8846.00
75% RDN through vermicompost + seed inoculation with bio fertilizers	2342.00	6329.00	8671.00
SEm+	104.38	277.39	380.09
CD (P=0.05)	312.74	831.14	1138.84
CV (%)	8.25	8.13	8.12

Table-2 : Effect of foliar nutrition on harvest index of pearl millet.

Treatments	Harvest index (%)
100% RDF	27.06
100% RDN through FYM	27.04
100% RDN through vermicompost	27.16
75% RDN through FYM	26.99
75% RDN through vermicompost	27.04
100% RDN through FYM + seed inoculation with bio fertilizers	27.02
100% RDN through vermicompost + seed inoculation with bio fertilizers	26.98
75% RDN through FYM +seed inoculation with bio fertilizers	26.98
75% RDN through vermicompost+ seed inoculation with bio fertilizers	27.01
SEm+	1.22
CD (P=0.05)	3.66
CV (%)	7.83

numerically improved the harvest index of pearl millet but could not bring a significant variation.

Application of 100% RDN through vermicompost + seed inoculation with bio fertilizers recorded significantly higher grain yield, stover yield and harvest index. Similar results have been reported by Parmar *et al.* (2020 a) in pearl millet-hybrid napier, Jain and Poonia (2003) in pearl millet and Singh and Singh (2005) in wheat, Lakhana (2002) and Singh and Meena (2020) in pearl millet.

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Influence of Zinc, Iron and Thiourea Spray on growth and yields of Indian Mustard [*Brassica juncea* (L.)]

Shashikant Sharma^{1*}, P.K. Sharma¹, Hoshiyar Singh¹ and R. Suthar¹

¹Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan

²Department of Agronomy, SKN Agriculture University, Jobner, Jaipur, Rajasthan

*Corresponding Author Email : shashikantsharma5635@gmail.com

Abstract

A field experiment was conducted during *rabi* season of 2022-23 at Parluka village in Hanumangarh district of Rajasthan under the supervision of Department of Agriculture, Vivekananda Global University, Jaipur, to study the "Influence of Zinc, Iron and Thiourea Spray on growth and productivity of Indian Mustard [*Brassica juncea* (L.)]". The experiment was laid out according to randomized block design with three replications. There were eight treatments (T₁-Control, T₂-Water spray, T₃-Zinc sulphate at 0.5% spray, T₄-Ferrous sulphate at 0.5% spray, T₅-Thiourea at (500 ppm), T₆-Zinc sulphate at 0.5% spray + Ferrous sulphate at 0.5% spray, T₇ Zinc sulphate at 0.5% spray + Thiourea at (500 ppm), T₈-Ferrous sulphate at 0.5% spray + Thiourea at (500 ppm) were compared. Results showed that the growth parameters, quality parameters, yield attributes and yields, was significantly increased with the application of Zinc sulphate at 0.5% spray + Thiourea at (500 ppm) which was remained at par with Zinc sulphate at 0.5% spray + Ferrous sulphate at 0.5% spray, Ferrous sulphate at 0.5% spray + Thiourea at (500 ppm) and Zinc sulphate at 0.5% spray over control.

Key words : Mustard, zinc, iron, thiourea.

Introduction

Rapeseed and mustard belong to family Cruciferae family, which is grown in northern India comprising traditionally grown indigenous species namely Indian mustard (*Brassica juncea*). It is the most important group of Rabi oilseed crop and contribute a major share to the vegetable fat. Rajasthan is one of the major rapeseed and mustard producing state of India. It ranked first both in terms of area and production of rapeseed and mustard among states in India. In India the area under mustard crop is 6.86 million ha producing about 9.12 million tonnes of seeds with an average productivity of 1331 kg ha⁻¹ and Area under cultivation in Rajasthan was 3.08 million ha, having production of 4.20 million tones and productivity of 1366 kg ha⁻¹ (Anonymous, 2021). The oil content in mustard seeds varies from 37-49 per cent (Bhowmik *et. al.*, 2014), the seeds are highly nutritive containing 38-57 per cent erucic acid, and 27 per cent oleic acid. The oil cake left after extraction is utilized as cattle feed and manure containing 5.1 per cent N, 1.8 per cent P₂O₅ and 1.1 per cent K₂O. Micronutrients hold a dominant and significant role in the growth and metabolic operations of oilseed crops. Zinc and Fe are important micronutrients required in trace amounts by humans, animals, and plants. Zinc and Fe also act as a structural component of several enzymes required for enzyme activation, stimulation of pod setting, seed formation and oil synthesis in the seeds of mustard. Zinc is closely involved in the metabolism of N and protein synthesis, whereas Fe contributes to the

formation of chlorophyll and photosynthesis, thereby altering the yield and quality of oilseed crops.

Materials and Methods

The field experiments were carried out during *rabi* season (2022-23) to study the "Influence of Zinc, Iron and Thiourea Spray on growth and productivity of Indian Mustard [*Brassica juncea* (L.)]" in randomized block design with 8 treatments and 3 replication at Parluka village in Hanumangarh district of Rajasthan under the supervision of Department of Agriculture, Vivekananda Global University, Jaipur. The experimental farm is geographically located at 74° 89' East longitudes, at 29°22' North latitude and at altitude of 197 m above mean sea level (AMSL). The experimental fields were clay loam and the soil fertility status contained available nitrogen (258.5, 253.5 Kg ha⁻¹), available phosphorus (17.3, 16.8 Kg ha⁻¹) and available potassium (278.2, 282.3 Kg ha⁻¹). The organic carbon content was from 0.34-0.38 per cent. The weekly mean maximum and minimum temperatures were of temperature during both summers (40.6° C) and winters (2.7° C). The mean relative humidity fluctuated from 63.50 to 91 per cent during the crop season. The average rainfall is 557 mm per annum, which is mostly received during July to September. The sporadic showers during winters are also common, which are probably observed during this period. The experiments were laid out in randomized block design with three replications and eight treatments. The following treatments were included in the study, T₁- Control, T₂- Water spray, T₃- Zinc

Table-1 : Effect of zinc, iron and thiourea spray on plant population of Indian Mustard.

Treatments	Plant height (cm)	Dry matter accumulation (g m^{-1})	Chlorophyll content (mg g^{-1})
T ₁ -Control	159.50	211.58	156.10
T ₂ -Water spray	38.50	212.58	157.90
T ₃ -Zinc sulphate at 0.5% spray	41.20	231.58	176.30
T ₄ -Ferrous sulphate at 0.5% spray	165.80	220.68	162.60
T ₅ -Thiourea at (500 ppm)	173.60	225.38	170.40
T ₆ -Zinc sulphate at 0.5% spray + Ferrous sulphate at 0.5% spray	177.10	227.58	173.40
T ₇ -Zinc sulphate at 0.5% spray + Thiourea at (500ppm)	181.80	233.88	177.40
T ₈ -Ferrous sulphate at 0.5% spray + Thiourea at (500 ppm)	179.70	232.48	178.50
SEm $\pm$	3.55	3.65	1.95
CD at (p= 0.05)	10.29	10.59	5.65
CV (%)	7.22	6.85	6.25

Table-2 : Effect of zinc, iron and thiourea spray on yield attributes of Indian mustard.

Treatments	Number of Siliquae per plant	Number of seeds per siliqua (cm)	Test weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
T ₁ -Control	290.00	14.20	4.88	1947.00	4471.00	6418.00
T ₂ -Water spray	306.80	14.35	5.27	1963.00	4560.00	6523.00
T ₃ -Zinc sulphate at 0.5% spray	325.60	16.10	4.93	2183.00	4600.00	6783.00
T ₄ -Ferrous sulphate at 0.5% spray	297.20	14.80	5.00	2008.00	4711.00	6719.00
T ₅ -Thiourea at (500 ppm)	327.20	15.45	5.15	2060.00	4971.00	7031.00
T ₆ -Zinc sulphate at 0.5% spray + Ferrous sulphate at 0.5% spray	339.20	15.90	5.21	2181.00	5207.00	7388.00
T ₇ -Zinc sulphate at 0.5% spray + Thiourea at (500 ppm)	347.60	16.05	5.30	2324.00	5381.00	7705.00
T ₈ -Ferrous sulphate at 0.5% spray + Thiourea at (500 ppm)	345.20	16.20	5.27	2271.00	5277.00	7548.00
SEm $\pm$	11.73	0.25	0.18	54.75	179.06	91.89
CD at (p= 0.05)	34.02	0.73	NS	158.86	519.58	266.64
CV (%)	7.01	6.25	6.04	7.01	7.35	6.49

sulphate at 0.5% spray, T₄- Ferrous sulphate at 0.5% spray, T₅- Thiourea at 500 ppm spray, T₆- Zinc sulphate at 0.5% spray + Ferrous sulphate at 0.5% spray, T₇- Zinc sulphate at 0.5% spray + Thiourea at (500 ppm) and T₈- Ferrous sulphate at 0.5% spray + Thiourea at (500 ppm).

Results and Discussion

It is clear from the result of present study that, zinc and iron had significantly affected the growth, yield and quality parameters at harvest. Application of Zinc sulphate at 0.5% spray + Thiourea at (500 ppm) recorded the highest growth attributes like plant height (181.80), dry matter accumulation (233.88 g m^{-2}), and Chlorophyll content (178.50 mg g^{-1}) at harvest which was remained at par with T₇-ferrous sulphate at 0.5% spray + Thiourea at (500 ppm). Plant height and dry matter accumulation increased with the application of T₇ due to increased cell division and cell elongation at higher level of nutrients. The micro nutrients (Zinc sulphate at 0.5% spray + Ferrous sulphate

at 0.5% spray) that the plant needs in small amounts play an important role in the metabolic processes that take place inside the plant. (Malewar (2013), Kumar *et al.* (2014^a) and Sipai *et al.* (2015). Further yield attributes and yields like number of siliquae per plant (347.60), number of seeds per siliquae (16.20) and yield parameters like seed yield ($2324.00 \text{ kg ha}^{-1}$), stover yield ($5381.00 \text{ kg ha}^{-1}$) and biological yield ($7705.00 \text{ kg ha}^{-1}$) recorded with Application of Zinc sulphate at 0.5% spray + Thiourea at (500 ppm) which remained at par with T₇-Zinc sulphate at 0.5% spray + Thiourea at (500 ppm), yield components by enhancing cell division, cell elongation process and photosynthetic activity leading to production and accumulation of more carbohydrates and auxins which favours retention of more flowers ultimately leading to more number of reproductive parts per plant. The similar results were also reported by Kumar *et al.* (2014^a) and Sipai *et al.* (2015).

Conclusions

In light of the results obtained from the present investigation, it may be concluded that foliar application with Zinc sulphate at 0.5% spray + Thiourea at 500 ppm at flowering and siliqueae formation stages produced significantly higher seed yield of 2324.00 kg/ ha, net returns of ₹84721/ha and B: C ratio of 2.01 over control. Hence, foliar application with Zinc sulphate at 0.5% spray + Thiourea at 500 ppm at flowering and siliqueae formation stages for getting higher yield and net returns in loamy sand soils.

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Effect of Nitrogen Levels and Nano-Nitrogen on Quality of Taramira (*Eruca sativa*)

Uday Singh Gurjar*, P.K. Sharma and Dharm Singh Meena

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012.

*Corresponding Author Email : udayveergujjar521@gmail.com

Abstract

A field experimentation was conducted at carried out during *rabi* season of the year 2022-23 at research farm, Vivekananda Global University, Jaipur. The objectives were to study the Effect of nitrogen levels and nano-N on growth and productivity of taramira (*Eruca sativa*) under rainfed condition. The experiment consisted of 9 treatment combinations comprising three levels of nitrogen (control, nitrogen at 15 kg/ha and nitrogen at 30 kg/ha) with three levels of nano-N (water spray, One spray of nano-N at 4 ml/l at 35 DAS and Two sprays of nano- N at 4 ml/l at 35 DAS & 55 DAS). The experiment was laid out in Factorial Randomized Block Design and replicated thrice. The significant improvement in quality viz. protein recorded with the treatment N₂ (nitrogen at 30 kg/ha) over lower levels of nitrogen.

Key Words : Taramira, nitrogen levels, nano-nitrogen, quality and protein content.

Introduction

Taramira (*Eruca sativa*) is a highly drought tolerant crop because of its efficient root system to extract moisture from deeper layers of soil, it is especially suitable for arid and semi-arid regions of Rajasthan. During the periods of severe drought coupled with laterabi rains, taramira is the only alternative left with the farmers on the soils having limited moisture supply. It is generally cultivated on marginal and sub marginal lands of poor fertility without application of organic manures and fertilizers which is one of the most spectacular reasons of its poor productivity. Optimum dose of nutrients and their source play an important role in enhancing the productivity of crops. The increasing use of NPK fertilizers has no doubt remarkably increased the food production but prolonged cultivation of crops using chemical fertilizers alone and simultaneous loss of organic matter due to accelerated oxidation at high temperature in the rainfed ecosystem has resulted great reduction in productivity of soil.

Taramira is mainly grown in drier regions of North-Western India. Because of its efficient root system to extract moisture from deeper layers of soil, it is especially suitable for arid and semi-arid regions of Rajasthan. Rajasthan is the leading state in taramira, occupying more than 65 per cent area and contributes 60 per cent of the nation's production. In Rajasthan, it occupies about 17 thousand ha area with an annual production of 7279 tonnes with the productivity of 433 kg/ha (Anonymous, 2022).

Foliar application of nano nitrogen at critical crop growth stages either alone or in combination with conventional urea increased crop yields and nutrient use efficiency. There is a lack of information on the location

specific performance of nano-nitrogen fertilizer; hereby it is proposed to evaluate the foliar application of nano nitrogen in combination with conventional urea and to compare its effect with that of conventionally applied urea, so that farmers in this region can have an economically viable option for maintaining sustainable crop production with improved nitrogen use efficiency in mustard crop.

Materials and Methods

Experimental site : The experiment was laid out at research Farm, Vivekananda Global University, Jaipur during *rabi* seasons of 2022-23. Jaipur is situated at 26° 5" North latitude and 75° 28" East longitudes at an altitude of 427 meters above mean sea level. In Rajasthan, this region falls under Agro-climatic zone-IIIA (Semi-Arid Eastern Plains).

Climate and weather conditions : The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48 °C, while in winters, it may fall as low as -1.0°C. Frost is not uncommon during winter. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the S-W monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 37.9 °C to 17.3 °C and 21.5 °C to 0.3 °C, respectively. A total of 94.5 mm rainfall was recorded during the cropping season. The relative humidity fluctuated between 34 to 69 per cent, while the average sunshine hours ranged between 4.1 to 9.7 hrs /day.

Experimental details : The presented experiment

consisting of 9 treatment and was carried out in Factorial Randomized Block Design (FRBD).

S. No.	Treatments	Symbols
A. Nitrogen levels		
1.	Control @ 0 kg/ha	N ₀
2.	Nitrogen @ 15 kg/ha	N ₁
3.	Nitrogen @ 30 kg/ha	N ₂
B. Nano-N		
1.	Water spray	U ₀
2.	One spray of nano-N at 4 ml/l at 35DAS	U ₁
3.	Two sprays of nano- N at 4 ml/l at 35DAS & 55DAS	U ₂

Protein content : The per cent crude protein content in grain was calculated by multiplying per cent of nitrogen content in grain with a factor 5.75 (A.O.A.C., 1990).

Protein yield : Protein yield was calculated by using following expression.

Protein yield (kg/ha) =

$$\frac{\text{Protein content in grain (\%)} \times \text{Grain yield (kg / ha)}}{100}$$

Oil content in seed : Oil content in the seed was determined by "Soxhlet's apparatus using petroleum ether (60-80 °C) as an extractant (A.O.A.C., 1960).

Results and Discussion

Protein content in grain

Nitrogen levels : It is noticed that nitrogen levels significantly enhanced the protein content in grain of taramira. Application of 30 kg N/ha recorded the significantly increased protein content of taramira and which were recorded an increase of 10.82 and 4.67 per cent over control and nitrogen at 15 kg/ha, respectively.

Nano-Nitrogen : The increase in protein content in grain of taramira due to nano urea spray *i.e.*, U₂ (Two sprays of nano- N at 4 ml/l at 35 DAS & 55 DAS) was 12.67 and 05.06 per cent in grain, respectively over water spray and One spray of nano- N at 4 ml/l at 35 DAS.

Oil content

Nitrogen levels : Application of N₂ *i.e.*, (nitrogen @ 30 kg/ha) recorded the maximum oil content of taramira

Table-1 : Effect of nitrogen levels and nano-N on protein content and oil content of taramira.

Treatments	Protein content (%)	Oil content (%)
Nitrogen levels		
N ₀ -Control @ 0 kg/ha	13.95	31.31
N ₁ -Nitrogen @ 15 kg/ha	14.77	33.31
N ₂ - Nitrogen @ 30 kg/ha	15.46	35.18
SEm±	0.23	0.60
CD (P=0.05)	0.68	1.73
Nano-Nitrogen		
U ₀ -Water spray	13.81	31.35
U ₁ -One spray of nano-N at 4 ml/l at 35DAS	14.81	33.29
U ₂ -Two sprays of nano-N at 4 ml/l at 35DAS & 55DAS	15.56	35.16
SEm±	0.23	0.60
CD (P=0.05)	0.68	1.73
CV (%)	4.77	5.39

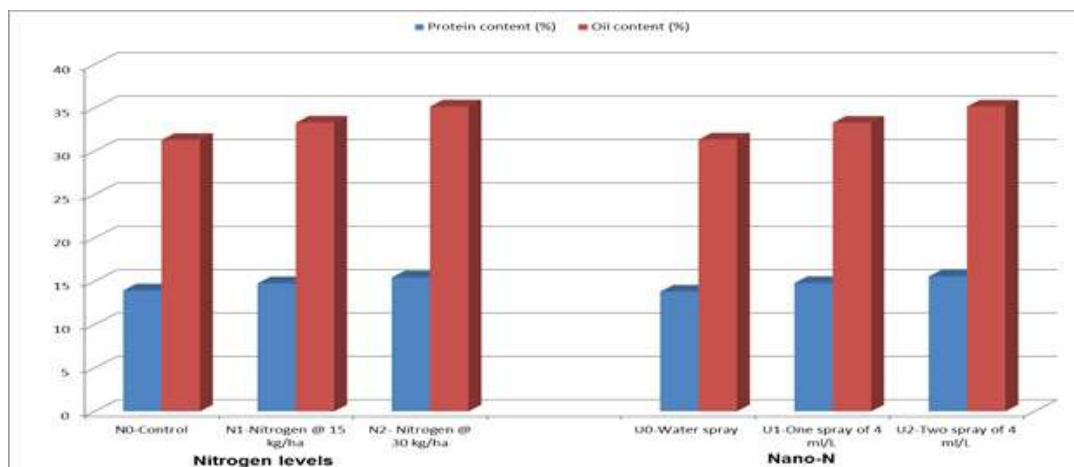


Fig-1 : Effect of nitrogen levels and nano-N on protein content and oil content of taramira.

which were recorded an increase of 12.36 and 5.61 per cent in grain over control (N_0) and nitrogen @ 15 kg/ha (N_1), respectively.

Nano-Nitrogen : The increase in oil content in grain of taramira due to Two sprays of nano- N at 4 ml/l at 35 DAS & 55 DAS (U_2) was 12.15 and 5.62 per cent in grain, respectively over water spray (U_0) and U_1 (One spray of nano-N at 4 ml/l at 35 DAS).

Nitrogen always have a remarkable promoting influence on protein synthesis by way of promoting synthesis of amino acid, which are considered as constituent building blocks of protein thus it is an important constituent of protein. The findings of present investigation are in agreement with those of Ayub *et al.* (2007), Pathan and Bhilare (2010), Jadhav *et al.* (2011), Meena and Jain (2013), Singh *et al.* (2013) and Patil *et al.* (2014).

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Physico-Morphological Seminal Attributes and their Correlation in Pantja Buck

Sunil Kumar^{1*}, H.P. Gupta¹, Rajeev Ranjan Kumar² and Sudhir Kumar³

¹Department of Veterinary Gynaecology and Obstetrics, G.B. Pant University of Agriculture and Technology, Pantnagar-263145 Uttarakhand

²Department of Veterinary Parasitology, G.B. Pant University of Agriculture and Technology, Pantnagar-263145 Uttarakhand

³Department of Veterinary Biochemistry, G. B. Pant University of Agriculture and Technology, Pantnagar-263145 Uttarakhand

*Email : sunilvgo16@gmail.com

Abstract

Present study was undertaken with the objective to study some physico-morphological seminal attributes of Pantja buck and their correlation with each other. Experiment was conducted at Goat unit, Department of Livestock Production Management and Department of Veterinary Gynaecology and Obstetrics, College of Veterinary and Animal Sciences, G. B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India. Four sexually mature Pantja bucks with an age group of 24-30 months and body weight 25-30 kg were selected for the study. A total of 32 ejaculates (8 ejaculates from each buck) were collected twice a week using artificial vagina method and individually examined for physico-morphological seminal attributes like ejaculate volume, pH, sperm mass motility, individual sperm motility, sperm concentration, sperm liveability, sperm morphology, structural and functional sperm plasma membrane integrity and sperm acrosomal integrity. The overall mean values of ejaculate volume (ml), pH, sperm mass motility (0-5 scale), individual sperm motility (%), sperm concentration (billion/ml), sperm liveability (%), sperm head abnormality (%), sperm middle-piece abnormality (%), sperm tail abnormality (%), total sperm abnormality (%), structural and functional sperm plasma membrane integrity (%) and sperm acrosomal integrity (%) were 0.60 ± 0.01 , 6.72 ± 0.02 , 4.15 ± 0.04 , 80.06 ± 0.11 , 3.19 ± 0.03 , 84.25 ± 0.50 , 0.65 ± 0.09 , 0.53 ± 0.05 , 2.03 ± 0.13 , 3.21 ± 0.17 , 77.46 ± 0.43 and 91.62 ± 0.67 , respectively. The mean values of sperm mass motility, sperm concentration and total sperm abnormalities differed significantly ($p < 0.05$) among the experimental bucks. Correlation studies revealed significant ($p < 0.05$) positive correlation between volume and sperm liveability; between sperm mass motility and individual sperm motility. Non significant positive correlation ($p > 0.05$) was observed among all seminal attribute except semen pH and abnormal sperm morphology. Significant ($p < 0.05$) negative correlation was observed between sperm concentration and sperm head abnormalities. Semen pH and morphological abnormalities were negatively correlated with most of the seminal attributes.

Key words : Pantja buck, semen, Plasma membrane structural and functional integrity, morphological abnormality, correlation.

Introduction

In rural areas of developing countries, the contribution of goats is highly significant and has an important role in feeding poor populations. In our country around 35 million families are dependent on goat husbandry for their livelihood as well as protein source (32). According to 20th livestock census India have 148.8 millions of goat population (16). Due to the smaller body size, goat can be raised in very small landholdings. Out of 351 breeds of goats in the world, there are 36 recognized breeds found in India. Recognized breeds of Indian goat population are facing a greater threat due to lack of enforcement of proper breeding policies, inadequate number of breeding bucks, indiscriminate crossbreeding and intermixing among breeds with local animals (19). Variations among breeds in their reproductive performance influence variation in semen characteristics (31; 28; 6). Some factors like age, health status of animal, macro and micro climate, feeding and management, also affect semen quality (20). Beside this some other factors like endocrine balance, soundness of sex organs (25) as well as the

sexual activity of the males at the time of semen collection (5) also found to have a significant effect on reproductive performance in bucks. Pantja is a medium sized, dual purpose *Tarai* goat breed of Uttarakhand. This breed has morphological similarities with deer, commonly found in *Tarai* region of Uttarakhand and adjoining areas of U.P. They contribute about 21% of goat population in Uttarakhand and resistant to many of the diseases compared to other breeds (21). There is lacuna in scientific studies and reports on the seminal attributes of Pantja buck semen cryopreservation of semen in Pantja buck. In the light of above facts, an experiment was undertaken to evaluate the seminal attributes of Pantja buck.

Materials and Methods

Four normal, apparently healthy adult Pantja bucks aged between 24-30 months, weighing 25-30 kg, reared at the Goat unit, Department of Livestock Production and Management, College of Veterinary and Animal Sciences, G.B. Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India were

used as experimental animals with prior permission from ethical committee of the University. The animals were marked as B1, B2, B3 and B4 for identification and recording of data. All the animals were maintained under uniform managemental conditions under semi- intensive system of housing with prior necessary prophylactic immunization.

Semen ejaculates were collected twice a week from each buck during morning hours using artificial vagina method. Immediately after collection the semen samples were rushed to the laboratory and kept within a water bath at 18°C during their initial evaluations following all the standard measures. The pH, mass motility (13) and initial motility (29) of the fresh semen samples were examined soon after collection as per standard protocol. The sperm concentration was evaluated by using standard haemocytometer method (29). Viability of the spermatozoa was evaluated by differential counting method by eosin nigrosin staining method (18). Plasma membrane integrity of the spermatozoa was assessed by hypo osmotic swelling test (HOST) (34). Acrosome integrity of the sperm cells was assessed by Giemsa staining method (30). All the data pertaining to the undergoing experiment were presented as mean $\pm$ SEM analyzed by using mean, standard error and Pearson correlation coefficient to determine difference among the bucks. Significantly affected means were separated by multiple range test (10).

Results and Discussion

The mean values of seminal attributes (Mean $\pm$ SEM) of each Pantja buck along with overall mean value are depicted in Table-1. The overall mean value of ejaculate volume of Pantaja bucks was 0.60 ± 0.01 ml, which was higher than the mean value (0.36 ± 0.06 ml) reported by Dhara *et al.* (9) in Pantja buck. Non significant difference was observed in the mean value of the ejaculate volume among the bucks ($p=0.05$), which primarily believed to be due to individual differences that lead to variation in physiological changes such as an increase in body mass and the simultaneous development of the testis and accessory sex glands after puberty and during sexual maturation consequently leads to variations in semen production (4). The overall mean pH of Pantja buck semen observed in present experiment was 6.72 ± 0.02 , which did not differed significantly between the bucks. The lowest mean pH value (6.66 ± 0.06) was recorded in Buck B3, might be due to presence of a high percentage of actively motile spermatozoa in the semen of this buck, which lower down the pH value because of their higher metabolic activities. This is in accordance with the statement that semen samples with excellent motility of spermatozoa, shows lower pH value because of higher metabolic

activities (2). The overall mean value of sperm mass motility in four bucks was 4.15 ± 0.04 , slightly lower as reported (4.47 ± 0.22 and 4.49 ± 0.07) by other workers (9; 26), respectively in Pantja buck and a significant difference ($p=0.05$) was observed in the mean values of sperm mass motility between four bucks. The lowest mean mass motility value (4.06 ± 0.06) was recorded in Buck B1, while it was the highest in buck B3 (4.25 ± 0.09). This might be because of maximum mean ejaculate volume in buck B3 due to contributory production of more accessory sex glands secretions, which supply the energy source for the sperm motility in the form of ATP (22). The overall mean value of individual sperm motility in four bucks was $80.06 \pm 0.11\%$, again lower than the mean value ($92.28 \pm 1.17\%$) reported (9) and no significant difference was observed among the bucks. However, the observed value was higher than initial motility ($75.05 \pm 8.89\%$) recorded earlier in same breed (24). The overall mean concentration of spermatozoa ($\times 10^9$ /ml) in Pantja buck semen was 3.19 ± 0.03 and varied significantly ($p=0.05$) among bucks might be due to individual differences among bucks especially variation in testicular size as sperm concentration in semen sample is greatly influenced by testicular size (11). Over all mean percentage of sperm liveability in Pantja buck semen was $84.25 \pm 0.50\%$ and did not show significant variation among the bucks. Mean value of sperm liveability in the present study is in accordance with the mean value ($87.28 \pm 0.78\%$ and $82.65 \pm 0.48\%$) reported earlier (9; 24), respectively. However, slightly higher percentage of live spermatozoa ($89.17 \pm 0.51\%$) was reported in Mehsana breed (23). The overall mean values of head, middle-piece, tail and total sperm morphologically abnormal spermatozoa in Pantja buck semen were 0.65 ± 0.09 , 0.53 ± 0.05 , 2.03 ± 0.13 , $3.21 \pm 0.17\%$, respectively slightly lower as reported by other workers (26; 9) in Pantja buck and these values varied significantly among bucks might be due to individual differences among bucks (3). The overall mean value of HOST reacted spermatozoa in Pantja buck semen was $77.46 \pm 0.43\%$ and varied non significantly among bucks. A higher mean value of HOST reacted spermatozoa was reported (9) in the same breed. Similarly a higher mean value ($85.3 \pm 0.92\%$) of HOST positivity compared to the present mean value was noticed in Beetal buck (1). Finding in the present study indicated that buck B3 was more mature buck in the study, produced highest volume of semen with maximum actively motile and healthy spermatozoa, which could result in to more number of HOST positive spermatozoa (healthy plasma membrane containing spermatozoa) in the study. The overall mean value of sperm acrosomal integrity in the semen of Pantja buck was $91.62 \pm 0.67\%$, which did not differed significantly

Table-1 : Physico-morphological seminal attributes of neat semen (32 ejaculates) from 04 Pantja buck (Mean±SE).

	Buck No.	Buck B1	BuckB2	BuckB3	BuckB4	Overall Mean Value
Seminal Attribute						
1.	Volume of ejaculate (ml)	0.57 ±0.05	0.58 ±0.06	0.62 ±0.07	0.61 ±0.06	0.60±0.01
2.	pH of ejaculate	6.76 ±0.04	6.76 ±0.09	6.66 ±0.06	6.71 ±0.06	6.72±0.02
3.	Sperm mass motility (0-5)	4.06 ±0.06 ^a	4.12 ±0.08 ^a	4.25 ±0.09 ^b	4.18 ±0.09 ^{bc}	4.15±0.04
4.	Individual Motility (%)	79.87 ±0.81	79.87 ±1.14	80.37 ±1.33	80.12 ±0.74	80.06±0.11
5.	Sperm concentration (x10 ⁹ /ml)	3.11 ±0.14 ^a	3.17 ±0.07 ^a	3.26 ±0.06 ^b	3.22 ±0.07 ^{bc}	3.19±0.03
6.	Sperm liveability (%)	83.62 ±1.11	83.37 ±0.90	85.62 ±0.77	84.37 ±1.30	84.25±0.50
7.	Sperm head abnormalities (%)	0.87 ±0.22 ^a	0.75 ±0.25 ^a	0.50 ±0.26 ^b	0.50 ±0.18 ^b	0.65±0.09
8.	Sperm middle piece abnormalities (%)	0.5 ±0.26	0.62 ±0.26	0.62 ±0.18	0.37±0.18	0.53±0.05
9.	Sperm tail abnormalities (%)	2.37 ±0.32 ^b	1.75 ±0.36 ^a	1.87 ±0.35 ^a	2.12 ±0.39 ^{ab}	2.03±0.13
10.	Total sperm abnormalities (%)	3.75 ±0.36 ^b	3.12 ±0.35 ^a	3.00 ±0.46 ^a	3.00 ±0.37 ^a	3.21±0.17
11.	Sperm plasma membrane Integrity (%)	76.5 ±1.34	77.37 ±1.46	78.62 ±0.70	77.37 ±1.11	77.46±0.43
12.	Per cent intact acrosome (%)	92.25 ±1.93	93.12 ±1.17	91.12±1.58	90 ±0.70	91.62±0.67

Mean values with at least one common superscript do not differ significantly in row ($P < 0.05$).

among the bucks. (26), while working on Pantja buck semen reported a lower mean per cent intact acrosome (82.63±1.76%). On the other hand, other workers (9) reported a higher mean per cent intact acrosome value (94.31±1.05) than the present study in Pantja buck.

Correlation among physico-morphological seminal attributes : The Pearson correlation coefficients (r) observed among the various physico-morphological seminal attributes in 32 neat Pantja buck ejaculates are tabulated in Table-2. Results revealed that ejaculate volume showed a non significant ($p=0.05$) positive correlation with sperm motility, plasma membrane integrity and acrosomal integrity, while it was significantly ($p=0.05$) positive with sperm liveability. These findings are in agreement with (15) in Osmanabadi buck and (9) in Pantja buck semen. This might be because of contributory production of more accessory sex glands secretions, which supply vital nutrients, membrane stabilizing substances and the energy sources (ATP) for the sperm motility and hence support sperm liveability and membrane integrity (22; 9). On the other hand ejaculate volume showed non significant ($p=0.05$) negative correlation with semen pH and sperm abnormalities. This might be because of availability of sufficient organic substances in seminal plasma for actively motile spermatozoa, which would produce metabolic by products (lactic acid, pyruvic acid etc.) at comparatively more faster rate to lower down semen pH. pH of semen showed non significant ($p=0.05$) negative correlation with all seminal attributes in the present study except sperm concentration and sperm head abnormalities. This finding in the present study is in accordance with the finding of (9), who also reported a non significant ($p=0.05$) negative correlation of seminal pH with sperm motility, liveability, HOST reactivity

and acrosomal integrity. pH of ejaculate is an important semen characteristic that has a profound effect on sperm metabolic activities essential for their survival (energy production). Alteration in semen pH results in decreased sperm movement, capacitation, and cellular and molecular signaling essential for better fertilization of oocyte and this could be one of the causes of infertility in male (33). Sperm concentration showed a significant ($p=0.05$) negative correlation with sperm head abnormalities and non significant negative correlation with sperm middle piece and total sperm abnormalities. On the other hand sperm motility showed a non significant positive correlation ($p=0.05$) with sperm liveability, plasma membrane integrity and acrosomal integrity suggesting that healthy live spermatozoa with intact plasma membrane in the ejaculate maintain higher motility. Our findings corroborate the findings of (23) in Mehsana buck and (9) in Pantja buck, who also documented a positive correlation among sperm motility, sperm liveability and plasma membrane integrity. The sperm liveability, plasma membrane integrity and acrosomal integrity showed a non significant ($p=0.05$) positive correlation with each other and with all the seminal attributes studied, except semen pH and sperm morphological abnormalities. These findings are in agreement with the findings of (15) in Osmanabadi, (27) in Gaddi and (9) in Pantja buck semen, who also reported a positive correlation among sperm motility, liveability, plasma membrane integrity (HOST positivity) and acrosomal integrity and negative correlation of these seminal attributes with semen pH and sperm morphological abnormalities. The negative correlation of sperm liveability, plasma membrane integrity and acrosomal integrity with semen pH and sperm abnormalities might be because of alteration in pH that

Table-2 : Correlation coefficient (r-values) among physico-morphological seminal attributes of neat Pantja buck (n= 32 ejaculates).

Semen Characteristics	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12
Volume of ejaculate (Ch1)	1	-0.572	0.467	0.141	0.618	0.9486*	-0.704	0.38	0.85	0.190	0.482	0.508
Ph of ejaculate (Ch2)	-0.572	1	0.056	-0.674	-0.818	-0.732	0.112	-0.35	-0.058	-0.090	-0.588	-0.393
Sperm concentration (Ch3)	0.467	0.056	1	0.142	0.338	0.181	-0.955	-0.60	0.605	-0.678	0.834	0.733
Sperm mass motility (Ch4)	0.141	-0.674	0.142	1	0.943*	0.225	-0.203	0.237	0.602	0.404	0.407	0.764
Individual sperm motility (Ch5)	0.618	-0.818	0.338	0.943*	1	0.215	-0.311	-0.096	0.522	0.090	0.667	0.818
Sperm liveability (Ch6)	0.9486*	-0.732	0.181	0.225	0.215	1	-0.454	0.599	0.687	0.387	0.316	0.244
Sperm head abnormalities (Ch7)	-0.704	0.112	-0.955*	-0.203	-0.311	-0.454	1	0.342	-0.786	0.460	-0.682	-0.784
Sperm middle piece abnormalities (Ch8)	0.386	-0.352	-0.600	0.237	-0.096	0.599	0.342	1	0.245	0.961*	-0.747	-0.128
Sperm tail abnormalities (Ch9)	0.852	-0.058	0.605	0.602	0.522	0.687	-0.786	0.245	1	0.174	0.375	0.870
Total Sperm Abnormalities (Ch10)	0.190	-0.090	-0.678	0.404	0.090	0.387	0.460	0.961*	0.174	1	-0.667	-0.090
Plasma membrane integrity (Ch11)	0.482	-0.588	0.834	0.407	0.667	0.316	-0.68	-0.747	0.375	-0.667	1	0.745
Per cent intact acrosome (Ch12)	0.508	-0.393	0.733	0.764	0.818	0.244	-0.784	-0.128	0.870	-0.090	0.745	1

causes ionic imbalance, metabolic decoupling, cellular acidosis, activation of unwanted proteases, deprivation of energy, plasma membrane phase transition and its destabilization, which may result in to loss of sperm motility, fertilizing ability and even sperm liveability (14). Sperm morphological abnormalities showed significant to non significant negative correlation with majorities of seminal attributes studied. Similar results have been documented by other workers (8) in West African Dwarf bucks; (27) in Gaddi buck and (9) in Pantja buck. There is a negative correlation between the sperm abnormalities and fertility of semen (7). These findings indicate that presence of more morphologically abnormal, immature sperms with compromised plasma membrane integrity show a low value of motility and subsequently poor fertilizing ability.

Conclusions

The study concluded that the mean values of physico-morphological seminal attributes of Panja buck semen are within the range of other bucks elsewhere in India and world.

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Response of Wheat (*Triticum aestivum* L.) Varieties to Nitrogen Levels

Ashish and U.S. Tiwana

School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, Punjab, India

Email : ashu13409@gmail.com

Abstract

A field experiment was conducted during the Rabi season of session 2022-23 at Agricultural research farm, School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, Punjab to study the “ Response of wheat (*Triticum aestivum* L.) varieties to nitrogen levels”. The experiment comprised of 9 treatment combinations in randomized complete block design with three replications consisted of three wheat varieties viz. DBW 222, PBW 869 and PBW 824 and three nitrogen levels viz. 75, 100 and 125 % of recommended dose. The results revealed that plant height (102 cm), tillers meter⁻¹ (85.4), chlorophyll level (42.3), ear length (8.95 cm), number of grains ear⁻¹ (45.5), grains weight ear⁻¹ (2.27 g), Test weight (45 g), grain yield (55.5 q/ha) and straw yield (66.1 q/ha) were highest in the variety PBW 824. However, the application of 125 kg N/ha of recommended dose was significantly higher plant height (103 cm), tillers meter⁻¹ (86.1), chlorophyll level (43.8), ear length (9.53 cm), number of grains ear⁻¹ (47.2 g), grains weight ear⁻¹ (2.24 g), Test weight (46.1 g), grain yield (56.0 q/ha) and straw yield (65.5 q/ha). Among the varieties, the variety PBW 824 was found to be better as compared to PBW 869 and DBW 222. The variety PBW 824 performed better with recommended dose of 125 Kg N/ha.

Key Words : Varieties, nitrogen levels, growth parameters, yield attributes and yield.

Introduction

Variety plays an important role in producing high yield of wheat because different varieties responded differently for their genotypic characters, input requirement, growth process under the prevailing environment during growing season. It was found that good variety and optimum seedling density simultaneously produced required number of plants per unit area resulting in better yield contributing (Hussain *et al.* 2002). The growth process of wheat plants under a given agro-climatic condition differs with variety. Generally, the modern or improved varieties consume fertilizers in high rates. Therefore, consumption of different fertilizers as well as nitrogen also differs from variety to variety. Nitrogen is one of the major nutrients which reduce the yield of wheat if not applied in proper amount as it is needed for fast growth of plants and to get high production per hectare. Nitrogen plays important role in all the metabolic processes of plants and an essential element for both crop development and biomass (Kaur *et al.* 2015). Nitrogen is the main component and major constituent of plants especially in living tissues formation. Nitrogen is an integral part of proteins, phytochromes, compounds, coenzymes, chlorophyll and nucleic acids. All the biochemical processes occurring in plants are mainly governed by nitrogen and its associated compounds which make it essential for the growth and development of wheat. Therefore, it is necessary to apply nitrogenous fertilizer in the soil to get bumper yields of wheat (Ali *et al.* 2011).

Materials and Methods

The experiment was conducted at the Agriculture Research Farm, School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, Punjab. Geographically, it is situated at 30° 66' N latitude and 76° 29' E longitude at an altitude of 268 meters above the mean sea level. Elongitude at an altitude of 268 meters above mean sea level. The experiment comprised of 9 treatment combinations in randomized complete block design with three replications consisted of three wheat varieties viz. DBW 222, PBW 869 and PBW 824 and three nitrogen levels viz. 75, 100 and 125 % of recommended dose. The treatments used seeds at the rate of 112.5 kg/ha, respectively. The nitrogen in the form of urea (46% N) was applied as per the treatments. The gross plot size was 4.5 m × 3.5 m and net plot size was 4.0 m × 3.0 m. The crop was sown on November 14, 2022 and harvested on April 10, 2023. All the other practices were applied uniformly to the treatments.

Results and Discussion

Growth parameters : The plant height of wheat was significantly influenced by varieties and nitrogen levels (Table-1). The variety PBW 824 recorded significantly higher plant height (102cm) over DBW 222 (98.7cm) but was at par with PBW 869 (100cm). However, difference in PBW 869 and DBW 222 was non- significant. Alam *et al.* (2014) reported the highest plant height (98.4cm) was recorded in Shotabdi over Prodip (93.8cm) and Bijoy (93.3cm). Plant height increases with varieties due to

their genetic character. The application of 125 kg N/ha of recommended dose recorded significantly higher plant height (103cm) over 75 kg N/ha (97.0cm) of recommended dose but was at par with 100 kg N/ha (101cm) of recommended dose. The application of 100 kg N/ha of recommended dose recorded higher plant height over 75 kg N/ha of recommended dose. Islam *et al.* (2014) also reported the plant height increased with the increase of N rate up to 150 kg per ha. However, the tallest plant (90.3cm) was obtained with the treatment 150 kg N/ha over 90 and 120 kg N/ha. The shortest plant (85.5cm) was recorded from the treatment 90 kg N/ha.

Tillers m^{-1} row length of wheat was significantly influenced by varieties and nitrogen levels (Table:1). The significantly higher number of tillers was observed in variety PBW 824 (85.4) over DBW 222 (82.2) but was at par with PBW 869 (83.0). However, difference in variety PBW 869 and DBW 222 was non-significant. Singh *et al.* (2020) also reported that the number of the tiller m^{-1} row length was significantly higher in variety C306 over varieties PBW 613, PBW 644 and PBW 660. The increased tiller m^{-1} row length in wheat plant is genetically governed phenomenon, hormonal balance, nutrient absorption capacity and conversion of radiant energy to chemical energy in presence of chlorophyll. All these processes were reflected in tillers and other yield contributing characteristics. The significantly higher number of tillers was observed in 125 kg N/ha of recommended dose (86.1) over 75 kg N/ha of recommended dose (82.6) but was at par with 100 kg N/ha of recommended dose (84.3). However, the difference in 100 and 75 kg N/ha was non-significant. Yadav *et al.* (2005) also reported that higher nitrogen doses were attributed by increased number of effective tillers $plant^{-1}$, increased number of fertile spikelets $spike^{-1}$, increased spike length, increased number of grain $spike^{-1}$. The interaction between varieties and nitrogen levels was non-significant.

The chlorophyll level of wheat was significantly influenced by varieties and nitrogen levels (Table-1). The variety PBW 824 recorded significantly higher chlorophyll level (42.3) over DBW 222 (40.2) but was at par with PBW 869 (41.1). Bachhaoo *et al.* (2018) also reported Variety Tapowan recorded the significantly higher chlorophyll content over variety Trimbak and Godavari. The increased chlorophyll content in wheat is genetically governed phenomenon, hormonal balance, nutrient absorption capacity and conversion of radiant energy to chemical energy. The application of 125 kg N/ha of recommended dose produced significantly higher chlorophyll level (43.8) over 75 kg N/ha of recommended dose (39.3) and 100kg N/ha of recommended dose (41.2). Khan *et al.* (2018) also reported increase in

chlorophyll content with nitrogen enhanced the protein, amino acid and enzymes, which play a significant role in photosynthetic production, grain formation.

Yield Attributes : The ear length of wheat was significant influenced by varieties and nitrogen levels (Table-2). The variety PBW 824 recorded significantly higher ear length (8.95 cm) over variety DBW 222 cm (7.85 cm) but was at par with PBW 869 (8.30 cm). However, difference in PBW 869 and DBW 222 was non-significant. Ram *et al.* (2017) reported the variety PBW 175 recorded higher ear length over variety WH 1080, and PBW 396. This may due to the better root development and absorption of nutrients from the soil. The significantly higher ear length was recorded in 125 kg N/ha of recommended dose (9.53) over 75 kg N/ha of recommended dose (7.74) but was at par with 100 kg N/ha of recommended dose (8.71%). However, the difference in 100 and 75 kg N/ha was non-significant. Rahman *et al.* (2011) also reported the higher ear length was recorded 120 kg N/ha over 60 and 90 kg N/ha. This is due to the response to N fertilization varies according to location, climate, crops and their varieties, type and characteristics of the soil, rate, time of fertilizer application. The interaction between varieties and nitrogen levels was non-significant.

The number of grain ear $^{-1}$ of wheat was significantly influenced with varieties and nitrogen levels (Table:2). The variety PBW 824 recorded significantly higher grain ear $^{-1}$ (45.5) over DBW 222 (40.6) but was at par with PBW 869 (43.3). Kaur (2017) also reported the variety HD3059 produced highest grains (41.66) per spike and it remained significantly superior over all other varieties (PBW 590, DBW 90, PBW 550, WH 1129, HD 3059 and WH 1021). Variety WH 1021 recorded the lowest number of grains per spike. Differences in number of grains spike among varieties might be due to their genetic variability. The application of 125 kg N/ha of recommended dose produced significantly higher grain per ear (46.2) of wheat over 75 (39.3) and 100 kg N/ha (43.3) of recommended dose. The application of 100 kg N/ha of recommended dose produced significantly higher grain per ear of wheat over 75 kg N/ha. Shende *et al.* (2020) also reported the application of nitrogen at 150 kg ha^{-1} was significantly higher grain per ear (45.0) over 100 (38.8) and 50 kg N/ha (35.7) because nitrogen promotes vegetative growth of plant.

Grain weight ear $^{-1}$ of wheat was significant influenced by varieties and nitrogen levels (Table:2). The variety PBW 824 recorded significantly higher grain weight ear $^{-1}$ (2.27 g) over DBW 222 (2.08 g) but at par with PBW 869 (2.26 g). However, PBW 869 produce significantly higher number of grains weight ear $^{-1}$ over DBW 222. Sultana *et al.* (2022) also reported the significantly higher

Table-1 : Effect of varieties and nitrogen levels on the growth parameters of wheat.

Treatments	Plant Height (cm)	Tiller meter ⁻¹ row length	Chlorophyll levels (SPAD)
Varieties			
DBW 222	98.7	82.2	40.2
PBW 869	100	83.0	41.1
PBW 824	102	85.4	42.3
CD at 5%	2.03	3.20	2.09
Nitrogen level (kg N/ha)			
75	97.0	82.6	39.3
100	101	84.3	41.2
125	103	86.1	43.8
CD at 5%	2.03	3.20	2.09
CD for interaction	NS	NS	NS
CV (%)	4.90	4.21	5.62

Table-2 : Effect of varieties and nitrogen levels on yield attributes, grain yield, Straw yield and harvest index of wheat.

Treatments	Ear length (cm)	Number of Grains per ear	Grains weight/ear (g)	Test weight (g)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
Varieties							
DBW 222	7.85	40.6	2.08	42.1	51.5	64.6	44.3
PBW 869	8.30	43.3	2.26	43.6	55.0	65.4	45.6
PBW 824	8.95	45.5	2.27	45.6	55.5	66.1	45.7
CD at 5%	1.01	2.84	0.18	2.96	3.92	1.42	1.40
Nitrogen levels (kg N/ha)							
75	7.74	39.3	1.97	41.8	51.6	63.1	44.7
100	8.71	43.3	2.34	43.7	54.9	65.2	45.3
125	9.53	46.2	2.42	46.1	56.0	65.5	46.8
CD at 5%	1.01	2.84	0.18	2.96	3.92	1.42	1.40
CD for interaction	NS	NS	NS	NS	NS	NS	NS
CV (%)	6.50	4.80	6.00	5.10	7.15	8.03	4.60

number of grains weight ear⁻¹ (2.42 g) was recorded in PBW 658 followed by HD 308 (2.25 g) and PBW 590 (2.37 g) respectively. This is due to different varieties responded differently for their genotypic characters, input requirement, growth process under the prevailing environment. The application of 125 kg N/ha significantly higher grains weight ear⁻¹ (2.42 g) over 75 kg N/ha (1.97 g) but was at par with 100 kg N/ha (2.34 g). However, the difference in 100 and 75 kg N/ha was non-significant. Sultana *et al.* (2022) also reported the application of 180 kg N/ha produced significantly higher number of grains per ear (2.48 g) followed by 0, 60 and 120 kg N/ha. The minimum number of grains per ear (2.00 g) was obtained in control. This could be due to increased photosynthates with increasing nitrogen levels.

Test weight of wheat was influenced significantly with varieties and nitrogen levels (Table-2). The significantly higher test weight recorded in variety PBW 824 (45.6 g) over variety DBW 222 (42.1 g) but at par with PBW 869 (43.6 g). However, the difference in PBW 869

and DBW 222 was non-significant. Shafi *et al.* (2016) was reported the variety Siran 2010 recorded significantly higher test weight (43 g) over Atta habib (39.0 g) but was at par with Janbaz (39.2 g). This is due to nutrients use efficiency of varieties. The application of 125 kg N/ha recommended dose recorded significantly higher test weight (46.1 g) over 75 kg N/ha (41.8 g) but was at par with 100 kg N/ha of recommended dose (43.7 g). Chaudhary *et al.* (2016) was reported that the high value of test weight (46.9 g) were achieved with application of 150 kg N/ha. The nitrogen levels significantly improved the test weight over control treatment. This could be due to increased photosynthates with increasing nitrogen levels. The interaction between varieties and nitrogen levels was non-significant.

Yield Parameters : The grain yield of wheat was influenced significantly with varieties and nitrogen levels (Table-2). The variety PBW 824 recorded significantly higher grain yield (55.5 q/ha) over DBW 222 (51.5 q/ha) but was at par with PBW 869 (55.0 q/ha). However, the

difference in PBW 869 and DBW 222 was non-significant. Singh *et al.* (2016) reported that the higher grain yield of PBW 824 was due to its superiority in yield attributes over all other varieties which ultimately resulted in higher grain yield in this variety. The application of 125 kg N/ha of recommended dose produced significantly higher grain yield (56.7 q/ha) of wheat over 75 kg N/ha of recommended dose (51.7 q/ha) but was at par with 100 kg N/ha of recommended dose (54.0 q/ha). However, the difference in the grain yield between 125 and 100 % of the recommended dose was non-significant. Rawat and Kuligod (2014) also reported that nitrogen content in grain increased with increase of nitrogen level up to 150 kg N/ha. This may due to the better root development and absorption of nutrients from the soil. The interaction between varieties and nitrogen level was non-significant.

The straw yield of wheat was influenced significantly with varieties and nitrogen levels (Table-2). The variety PBW 824 recorded significantly higher yield (66.1 q/ha) over variety DBW222 (64.6q/ha) but was at par with PBW 869 (65.4 q/ha). However, the difference in PBW869 and PBW 824 was non-significant. Gupta *et al.* (2022) also reported that the higher straw yield due to the characteristics which contributed to the yields are specific and depend upon the genetic potential of genotypes. The application of 125 kg N/ha of recommended dose produced significantly higher straw yield (65.5 q/ha) of wheat over 75 kg N/ha of recommended dose (63.1 q/ha) but was at par with 100 kg N/ha of recommended dose (65.2 q/ha). However, the 100 Kg N/ha of the recommended dose was significant higher over 75 Kg N/ha of recommended dose. Singh *et al.* (2008) reported the application of 145 kg N/ha of recommended dose produced significantly higher straw yield over 116 and 87 kg N/ha. This is due to increment in nitrogen take up was probably due to improvement in soil conditions, which promoted the proliferation of roots and plants demand, was in turn drew more nutrients for the larger area and greater depth. High increase in nitrogen levels increase all yield contributing which in term increase in grain and straw yield. The interaction between varieties and nitrogen levels was non-significant.

Harvest Index (%) : Harvest index of wheat was influenced significantly with the varieties and nitrogen levels (Table-2). The variety PBW 824 recorded significantly higher harvest index (45.7%) over variety DBW 222 (44.3%) but was at par with PBW 869 (45.6%). However, the difference in PBW 869 and PBW 824 was non-significant. Chaudhari *et al.* (2018) reported the maximum harvest index (41.2%) was recorded with DBW 17 variety followed by PBW 373 (40.39%) and PBW 550 (40.8%). The application of 125 kg N/ha of recommended dose produced significantly higher harvest index (46.8%)

of wheat over 75 kg N/ha (45.0%) but was at par with 100 kg N/ha of recommended dose ((45.7%). However, the difference in 100 and 75 kg N/ha was non-significant. Rahman *et al.* (2011) reported the higher N levels value (41.9%) of harvest index was recorded significantly with application of 150 kg N/ha over 100 (38.0%) and 125 kg N/ha (38.9%). The interaction between varieties and nitrogen levels was non-significant.

Conclusions

Based on experiment, it was concluded that the variety PBW 824 produced significantly higher grain yield with 125 Kg N/ha.

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Effect of Seed Rates and Row Spacing on the Growth, Yield Attributes and Grain Yield of Wheat (*Triticum aestivum* L.)

Lakshit Saini and U.S. Tiwana

School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, Punjab, India

Email : lakshitsaini009@gmail.com

Abstract

A field experiment was conducted during the *rabi* season of 2022-23 at Agricultural Research Farm of School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, Punjab to study the effect of seed rates and row spacing on the growth, yield attributes and grain yield of Wheat (*Triticum aestivum* L.). The experiment was laid out in a randomized complete block design (RCBD) with three replications. The treatments comprised of three seed rates viz. 75, 100 and 125% of recommended seed rates and three row spacings i.e. 15, 20 and 25 cm. The result revealed that highest plant height (99.5 cm) and number of tillers/m row length (84.8) observed in 125% of recommended seed rate. The yield attributing characters significantly increased in 75% of recommended seed rate. 75% of recommended seed rate recorded highest ear length (8.03 cm), number of grains/ear (41.0), grain weight/ear (2.88 g) and higher test weight (54 g). The grain yield was significantly higher in 125% of recommended seed rate (54.5 q/ha). Straw yield also followed the same trend (63.7q/ha). Row spacing significantly influenced the growth, yield attributes and yield of the wheat. 20 cm row spacing recorded higher plant height (100 cm) and higher number of tillers/m row length (84.9). The 20 cm row spacing recorded higher ear length (8.05 cm), number of grains/ear (40.8), grain weight/ear (2.69 g) and higher test weight (56.5 g). The 20 cm row spacing recorded higher grain yield (54.4 q/ha) and straw yield (64.0 q/ha).

Key Words : Seed rates, row spacing, growth parameters, yield attributes and yield.

Introduction

Wheat (*Triticum aestivum* L.) is one of the prominent cereal crops grown for the grain purpose worldwide. Wheat is most widely consumed source of food, is processed into products such as bread, pasta crackers, biscuits, breakfast cereals, noodles, cakes, alcoholic beverages and a great number of minor products (Rehman *et al.* 2017). Seed rate plays a vital role for optimum plant densities which is a pre-requisite for increased seed yield. It influences the yield attributes and yield of wheat. Seed rate determines the planting density which in turn influences the crop growth, nutrient uptake, tillering capacity, number and weight of grains, and ultimately grain yield due to inter-plant competition. Row spacing plays a significant role on growth, development, and yield of wheat at its optimum level beside it provides scope to the plants for efficient utilization of solar radiation and nutrients (Mali and Choudhary, 2013). Narrow row spacing may cause leaf overlapping while with wider row spacing, a major part of solar radiation goes unutilized by the crop. The inter-row competition in the crop with narrow spacing also poses pest and disease threats as well as makes it difficult to manage. Wider rows result in an uncovered ground surface which attracts weed growth and unutilized resources which are again taken up by weed and pose crop weed competition (Balasubramaniyan and Palaniappan, 2011).

Materials and Methods

The experiment was carried out during the *rabi* season 2022-23 at the Agricultural Research Farm, RIMT University, Mandi Gobindgarh, Punjab. The experimental field it is situated in Punjab at 30° 66' N latitude and 76° 29' E longitude at an altitude of 268 meters above the mean sea level. The total rainfall during the crop season was 106.3 mm. The recommended doses of 120 kg N ha⁻¹, 60 kg P₂O₅ ha⁻¹, and 60 kg K₂O ha⁻¹ were incorporated at sowing time in the form of urea, single super phosphate, and muriate of potassium. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The treatments comprised of three seed rates viz. 75, 100 and 125% of recommended seed rates and three row spacing i.e. 15, 20 and 25 cm. The gross plot size was 4.5 × 3.5 m² and net plot size was 4.0 × 3.0 m². The crop was sown on November 14, 2022 and harvested on April 10, 2023.

Results and Discussion

Growth Parameter : The plant height of wheat was influenced significantly by seed rates and row spacing (Table-1). Among different seed rates, the significantly higher plant height was observed in 125% of recommended seed rate (99.5 cm) over 75% of recommended seed rate (95.6 cm) but was par with 100% of recommended seed rate (97.0 cm). Pandey *et al.*

(2004) also reported higher plant height under 125% seed rate might be due to a greater number of plants which would have struggled for sunlight and grew in upward direction resulting increase in plant height. The 20 cm row spacing recorded significantly higher plant height (100 cm) over 15 cm row spacing (94.8 cm) but was par with 25 cm row spacing (97.3 cm). Tufa *et al.* (2020) reported that 20 cm row spacing resulted higher plant height (99.48 cm) than 25 cm row spacing (97.04 cm) Plant height increases with optimal row spacing because it improves light interception and increases light utilization efficiency in crop plants. The interaction between seed rates and row spacing was found non-significant.

Number of tillers/m row length was influenced significantly by seed rates and row spacing (Table-1). The significantly higher number of tillers was observed in 125% of recommended seed rate (84.8) over 75% of recommended seed rate (81.8) but was par with 100% of recommended seed rate (83.5). Ram *et al.* (2013) also recorded the highest Number of tillers/m row length at seed rate of 125 kg/ha. The number of effective tillers per meter of row length increased as seed rate increased because more plant populations produced more tillers. The 20 cm row spacing was recorded significantly higher number of tillers (84.9) over 25 cm row spacing (81.4) but was par with 15 cm row spacing (83.0). Singh *et al.* (1989) from Pusa (Bihar) observed that the higher number of effective tillers m^{-1} row length in 20 cm row spacing over 25 cm row spacing and 30 cm row spacing. The interaction between seed rates and row spacing was found non-significant.

Chlorophyll level of wheat was influenced by seed rates and row spacing (Table 1). The highest Chlorophyll level (44.3) was observed with 75% of recommended seed rate over 125% of recommended seed rate (41.5) but was par with 100% of recommended seed rate (42.9). Jamaati *et al.* (2009) also reported that with the increase in plant density chlorophyll content decreased. Chlorophyll level of wheat was influenced by row spacing. The highest Chlorophyll level (45.3) was observed with 25 cm row spacing over 20cm row spacing (42.6) and 15 cm row spacing (41.0). Altundag and Karademir (2021) observed that the lowest value of chlorophyll content was obtained at 15 cm row spacing. The interaction between seed rates and row spacing was found non-significant.

Yield Attributes : The ear length of wheat was influenced significantly by seed rates and row spacing (Table-2). The 75% of recommended seed rate recorded significantly higher ear length (8.03 cm) over 125% of recommended seed rate (7.53 cm) but was par with 100% of recommended seed rate (7.64 cm). Chand *et al.* (2011) also reported that maximum ear length was obtain with

lower seed rate (9.30 cm). The 20 cm row spacing recorded significantly higher ear length (8.04 cm) over 25 cm row spacing (7.65 cm) but was par with 15 cm row spacing (7.50 cm). Singh *et al.* (2020) also observed a significant improvement in ear length under different row-spacing conditions. In comparison to 15 cm spacing, a row spacing of 22.5 cm had longest ear length (10.42cm). Non-significant interaction effect was noticed between seed rates and row spacing.

Number of grains per ear was influenced significantly by seed rates and row spacing (Table-2). The 75% of recommended seed rate produced significantly higher number of grains per ear (41.0) over 125% of recommended seed rate (38.0) but was par with 100% of recommended seed rate (40.0). Prasad *et al.* (1991) observed higher value of effective number of grains/ear under lower seed rate than normal seed rate. The 20 cm row spacing recorded significantly higher number of grains per ear (40.8) over 15 cm row spacing (38.4) but was par with 25 cm row spacing (39.8). Mali and Choudhary (2013) recorded that 20 cm row spacing give higher number of grains per ear (57.8) over 15 cm row spacing (55.50) The interaction between row spacing and seed rates was found non-significant.

Grain weight per ear was influenced significantly by seed rates and row spacing (Table-2). The 75% of recommended seed rate recorded significantly higher grain weight per ear (2.88 g) over 125% of recommended seed rate (2.04 g) and 100% of recommended seed rate (2.45). Singh and Singh (1996) also reported that grain weight is higher in lower seed rate as compared to higher seed rate. Grain weight per ear of wheat was influenced significantly 20 cm row spacing recorded significantly higher grain weight per ear (2.69 g) over 25 cm row spacing (2.42 g) but was par with 15 cm row spacing (2.26). Singh *et al.* (1994) also reported that 20 cm row spacing produce higher grain weight per ear due to better utilization of moisture and nutrients as well as solar radiation. The interaction between seed rates and row spacing was found non-significant.

Test weight was influenced significantly with seed rates and row spacing (Table-2). 75% of recommended seed rate recorded significantly higher test weight (54.0 g) over 125% of recommended seed rate (50.1 g) but was par with 100% of recommended seed rate (51.9 g). Chand *et al.* (2011) also recorded highest 1000 grains weight at lower seed rate (55.7g) as compare to 100 kg/ha seed rate. The 20 cm row spacing recorded significantly higher test weight (56.5 g) over 25 cm row spacing (51.8 g) and 15 cm row spacing (49.7g). Jain *et al.* (1991) also reported that maximum test weight under 20 cm was probably due to better growth and development of crop

Table-1 : Effect of seed rates and row spacing on the growth of wheat.

Treatments	Plant height (cm)	Number of tillers/m row length	Chlorophyll level (SPAD)
Seed rates (%)			
75%	95.6	81.1	44.3
100 %	97.0	83.5	42.9
125 %	99.5	84.8	41.5
CD at 5 %	3.70	2.61	2.60
Row spacing (cm)			
15	94.8	83.0	41.0
20	100	84.9	42.6
25	97.3	81.4	45.3
CD at 5 %	3.70	2.61	2.60
CD interaction	NS	NS	NS
CV %	6.2	5.7	6.2

Table-2 : Effect of seed rates and row spacing on yield attributes and grain yield of wheat.

Treatments	Ear length (cm)	Number of grains per ear	Grain weight/ear (g)	Test weight (g)	Grain yield (q/ha)	Straw yield (q/ha)	Harvest index (%)
Seed rates (%)							
75	8.03	41.0	2.88	54.0	49.5	61.8	44.4
100	7.64	40.0	2.45	51.9	52.3	62.4	45.5
125	7.53	38.1	2.04	50.1	54.5	63.3	46.2
CD at 5%	0.40	2.32	0.24	2.32	2.90	1.40	1.80
Row spacing (cm)							
15	7.50	38.4	2.26	49.7	49.0	61.4	43.7
20	8.05	40.8	2.69	56.5	54.4	63.6	46.2
25	7.55	39.8	2.42	51.8	52.8	62.6	45.6
CD at 5%	0.40	2.32	0.24	2.32	2.90	1.40	1.80
CD interaction	NS	NS	NS	NS	NS	NS	NS
CV%	5.0	4.6	10	4.4	5.0	6.0	4.7

which increased uptake of nutrient and better nourishment of grains resulting in bold size of grain, ultimately increase in test weight. The interaction between seed rates and row spacing was found non-significant.

Yield parameter : The grain yield of wheat was significantly influenced by seed rates and row spacing (Table-2). Seed rate influenced the grain yield of wheat significantly. The 125% of recommended seed rate recorded significantly higher grain yield (54.5 q/ha) over 75% of recommended seed rate (49.5 q/ha) but was par with 100% of recommended seed rate (52.3 q/ha). Sandhu *et al.* (2010) also reported that increasing trend in grain yield of wheat with increasing in seed rates. The 20 cm row spacing was recorded significantly higher grain yield (54.4 q/ha) over 15 cm row spacing (49.0q/ha) but was par with 25 cm row spacing (52.8q/ha). Ghafari *et al.* (2017) also reported significantly higher grain yield of wheat with 20 cm row spacing. The higher grain yield of wheat at 20 cm row spacing was due to more ear length, a greater number of grains per ear and higher test weight.

Straw yield of wheat was influenced significantly by seed rates and row spacing (Table-2). The 125% seed rate was recorded higher straw yield (63.3 q/ha) over 75% of recommended seed rate (61.8 q/ha) but was par with 100% of recommended seed rate (62.3 q/ha). Pandey *et al.* (1999) also reported that increased straw yield with increased seed rates kg/ha. The 20 cm row spacing was recorded significantly higher straw yield (63.6) over 15cm row spacing (61.4 q/ha) but was par with 25 cm row spacing (62.6 q/ha). Godora and Kumar (2022) also reported that crop sown with row spacing 20 cm showed significantly higher grain yield (49.13 q/ha) and straw yield (72.70 q/ha).

Harvest index (%) : Seed rate influenced the harvest index of wheat significantly (Table-2). The higher harvest index (46.2) was observed with 125% of recommended seed rate over 75% of recommended seed rate (44.4) but was par with 100% of recommended seed rate (44.4). Sarker *et al.* (2007) reported that higher harvest index was recorded in 125kg/ha seed rate (40.1) as compare to 100

kg/ha seed rate (38.4). The 20 cm row spacing recorded significantly higher harvest index (46.2) over 15 cm row spacing (43.7) but was par with 25 cm row spacing (45.6). Dass and Mangal (2017) reported that higher harvest index was recorded with 20 cm row spacing (38.3) as compared to 30 cm row spacing.

Conclusions

Based on research experiment, Higher grain yield, straw yield and biological yield recorded in 125% of recommended seed rate and 20 cm row spacing.

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Constraints Faced by the Onion Growers in Utilization Behavior of Integrated Pest Management Practices in Jodhpur District of Rajasthan

Kamlesh Gurjar¹, Banwari Lal¹, Surbhi Jangir², Shubham Mishra³ and Saurabh Pandey⁴

¹Department of Extension Education, Agriculture University, Jodhpur, Rajasthan

²Department of Extension Education, MPUAT, Udaipur, Rajasthan

³Division of Extension Education, NDRI, Karnal, Haryana

⁴Department of Extension Education and communication, AAU, Anand, Gujarat

*Email : jangirsurbhi95@gmail.com

Abstract

Onion play a very important role in meeting the nutritional requirements of human beings. The study was conducted in purposely selected Jodhpur district of Rajasthan. The Jodhpur district had sixteen panchayat samitis, out of 16 panchayat samitis namely Tinwari and Osian were selected based on highest area production of Onion cultivation. A complete list of villages with area and production of Onion cultivation were collected from Department of Agriculture Jodhpur, Rajasthan from the identified panchayat samitis. Out of ten villages i.e. six from Tiwari and four from Osian were selected. The sample size of 120 respondent's selected through proportionate random sampling. The findings data that among all the studied constraints four categories of constraints, technological (70.00 MPS) were perceived with the highest intensity by respondents in the first rank, followed by Miscellaneous constraints (69.72 MPS) in second place, Economical Constraints (68.06 MPS) was ranked third and Marketing constraints (65.09 MPS) fifth by all respondents, respectively.

Key words : Constraints, utilization behaviour, independent variables IPM practices.

Introduction

IPM is an ecologically based approach that focuses on long-term pest control using a variety of strategies, including biological control, habitat alteration, altered agronomic practises, and the adoption of resistant cultivars. Even though a particular practise is a crucial component of an IPM system, using it to control a single organism does not constitute IPM. The best chance of maintaining long-term crop protection is through the integration of several different insect control approaches. Pesticides may be used to eradicate or prevent the target organism, but only when monitoring and scouting data suggest they are necessary to avert financial loss. Pesticides are typically used by farmers to manage insect pests in onion crops that are bad for both soil fertility and human health. IPM practise must be adopted in order to preserve soil fertility and productivity. Onions are one of India's most important vegetable and spice crops due to their extensive use. Like with other vegetable crops, there are a variety of limitations that prevent onions from producing their full potential. Pests and diseases seriously hinder the production of onions. Many of pests, including (mites, thrips, armyworms, cutworms, leaf miners, and diseases including damping off, purple blotch, leaf blight, and colletotrichum blight), are a major pest that cause 35-45 percent yield loss annually. Onion thrips (*Thrips tabaci*) are one such pest. This functions as a vector for a number of viral infections. In order to limit yield loss and

create high-quality marketable bulbs, an integrated strategy is required. Putting IPM into action has proven to be far more difficult, despite the fact that its ideas and philosophy are now broadly accepted in both the political and scientific arenas. Attempts to create and spread IPM technologies in poor nations over the past 20 years have had varying degrees of success (Yudelma et al., 1998; Kiss and Meerman, 1991). The IPM's guiding principles and concepts are not being embraced by Indian farmers. The many academics came up with a number of explanations for this uneven success. Early studies found certain fundamental causes, such as a lack of extension resources to meet the demands of farmers who want to use IPM (Brader, 1979), the need for more emphasis on farmer training to spread the word about IPM (Kenmore, 1987), and others. Varied communication routes and sources elicit varied responses from farmers. Farmers' decisions are largely influenced by their exposure to the sources and media of agricultural knowledge. Previous studies found that factors such as age, education, family background, and agricultural experience are accounted for by the farmers' diversity of knowledge obtained from various sources and channels. IPM may be perceived by farmers as being ineffective for their farming system and being overly complicated, expensive, and unsafe. According to numerous academics and reports, there are many nations where the excessive and careless use of pesticides has negative consequences on people, other living things, non-living things, and the environment.

Therefore, it is imperative for the scientific community to identify and assess the field-level barriers to the use of IPM technologies, particularly in the growing of vegetables. Various researchers like Rashid et al. (2003); IPM DANIDA Project (2004); Kim and Park (2005); Baral et al. (2006) etc.

Research Methodology

The present study was undertaken in purposely selected Jodhpur district of Rajasthan. The district had sixteen panchayat samities, out of 16 panchayat samities namely Tinwari and Osian were selected based on highest area production of Onion crop. Out of ten villages i.e. six from Tiwari and Four from Osian and 120 farmer for study were selected.

The respondents were prompted to describe their perceptions of the various predicted limits in order to gauge the perceived severity of the constraints. The perceived intensity of constraints was quantified by assigning the score using the three-point continuum scale viz., most serious, serious and less serious with a score of 3, 2 and 1, respectively.

Mean Score : Mean score was obtained by total scores of each statement divided by total number of respondents.

$$\text{Mean score} = \frac{\text{Total obtained score of a practice}}{\text{Total no. of respondents}}$$

Correlation Coefficient (r) : The correlation coefficient ("r" value) was used to measure the relationship between dependent and independent variables. The correlation coefficient between two groups was calculated by using the following formula.

$$r = \frac{\frac{\sum XY}{n}}{\sqrt{\frac{\sum X^2}{n} \cdot \frac{\sum Y^2}{n}}}$$

Where r = Correlation Coefficient

X = Independent variable

Y = Dependent variable

n = Total number of respondents

Results and Discussion

In this section, it was tried to find out the constraints in utilization of integrated pest management practices as perceived by the respondents in the study area. Constraints in utilization of IPM practices by the onion growers was measured by getting responses of the onion growers on three-point continuum namely "Most serious?", "Serious" and "Less serious" with weightage of 3, 2 and 1, score, respectively

All the possible constraints faced by the respondents were grouped into four major categories viz., technological, economical, marketing and miscellaneous constraints.

It found that majority of onion growers (65.83%) were having medium level of perception of the constraints followed by low problem in utilization of integrated pest management practices (19.17%). Whereas, 15.00 percent of onion growers having high constraints in utilization of integrated pest management practices.

It is evident from the table that 65.83 percent integrated pest management practices were moderately utilized by the onion growers, whereas 19.17 percent IPM practices were high information utilized practices by the onion growers. Only 15.00 per cent were under low utilized category by the onion growers.

As far as the technological constraints are concerned it was found "Lack of knowledge about the life cycle of pests and their infection on vegetables" (74.44 MPS) was perceived with high intensity faced by Onion growers indicated by first rank. This was followed by Lack of knowledge about weed management practices in IPM (74.17 MPS, II Rank), Lack of knowledge about the use of natural enemies (67.50 MPS, III Rank), Lack of knowledge about insect/pest Control in IPM techniques (65.83 MPS, IV Rank) and Lack of proper guidance regarding preparation of biopesticide / plant vitalisers (63.61 MPS, V Rank).

In case of economical constraints reveals that "Non-availability of Neem cake at the local level / High cost of Neem cake" (72.78 MPS) was perceived as overall severe economic constraint as it was accorded the first rank through Onion growers. The other constraints like "High cost of chemical pesticide", "High cost of labour charges" and "Lack of finance to purchase biopesticide and plant vitalisers" were also reported as important constraints with MPS 68.06, 67.78 and 63.89 and Rank II, III, and IV respectively.

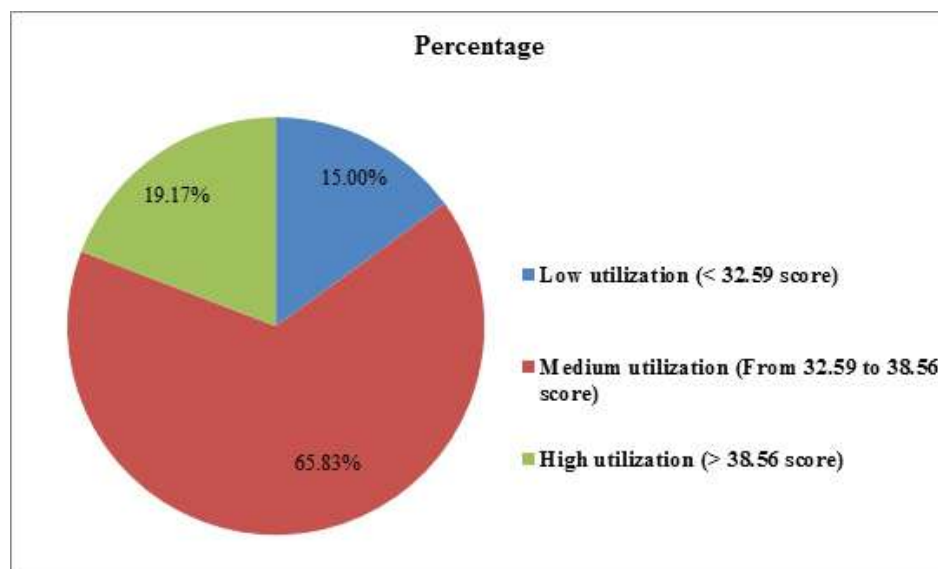
In case of marketing constraints, it was reported indicates that mainly "Lack of market facilities in the local areas" (76.94 MPS), was faced by Onion growers. This was followed by the other constraints like "Non-availability of Bio- control agents" (66.94 MPS), "High labour charges for weed controlling during peak season" (65.00 MPS), were assigned II and III, Rank, respectively. Whereas, "Inadequate availability of Bio- pesticides in the market" and (64.17 MPS) was faced with lowest intensity which was ranked IV.

In case of miscellaneous constraints, it was revealed that "Lack of coordination between various services? supply of marketing agencies" (77.78 MPS) was

Table-1 : Distribution of onion growers according to their level of constraints in utilization of IPM practices. n=120

S. No.	Levels of Utilization	Frequency	Percentage
1.	Low utilization (< 32.59 score)	18	15.00
2.	Medium utilization (From 32.59 to 38.56 score)	79	65.83
3.	High utilization (> 38.56 score)	23	19.17
	Total	120	100.00

Mean =35.58 S.D. = 2.98

**Fig.-1 : Distribution of onion growers according to their level of constraints in utilization of IPM practices.****Table-2 : Distribution of respondents according to their type of constraints in utilization of IPM practices. n=120**

1.	Technological constraints	Mean per cent Score	Rank
a.	Lack of knowledge about insect/pest Control in IPM techniques	65.83	IV
b.	Lack of knowledge about weed management practices in IPM	74.17	II
c.	Lack of proper guidance regarding preparation of biopesticide / plant vitalisers	63.61	V
d.	Lack of knowledge about the use of natural enemies	67.50	III
e.	Lack of knowledge about the life cycle of pests and their infection on vegetables	74.44	I
	Overall MPS	70.00	
2.	Economical constraints		
a.	Lack of finance to purchase biopesticide and plant vitalisers	63.89	IV
b.	High cost of labour charges	67.78	III
c.	High cost of chemical pesticides	68.06	II
d.	Non-availability of Neem cake at the local level / High cost of Neem cake	72.78	I
	Overall MPS	68.06	
3.	Marketing constraints		
a.	Non availability of Bio-control agents	66.94	II
b.	High labour charges for weed control during peak season	65.00	III
c.	Inadequate availability of Bio-pesticides in the market	64.17	IV
d.	Lack of market facilities in the local areas	76.94	I
4.	Miscellaneous constraints		
a.	Lack of timely and appropriate transfer of technology measures by Agri. Deptt. / private agencies	67.22	III
b.	Lack of dedicated and competent extension personnel	63.61	IV
c.	Lack of supply of published information regarding various practices of IPM	68.33	II
d.	Lack of co-ordination between various services and supply of marketing agencies	77.78	I
	Overall MPS	69.72	

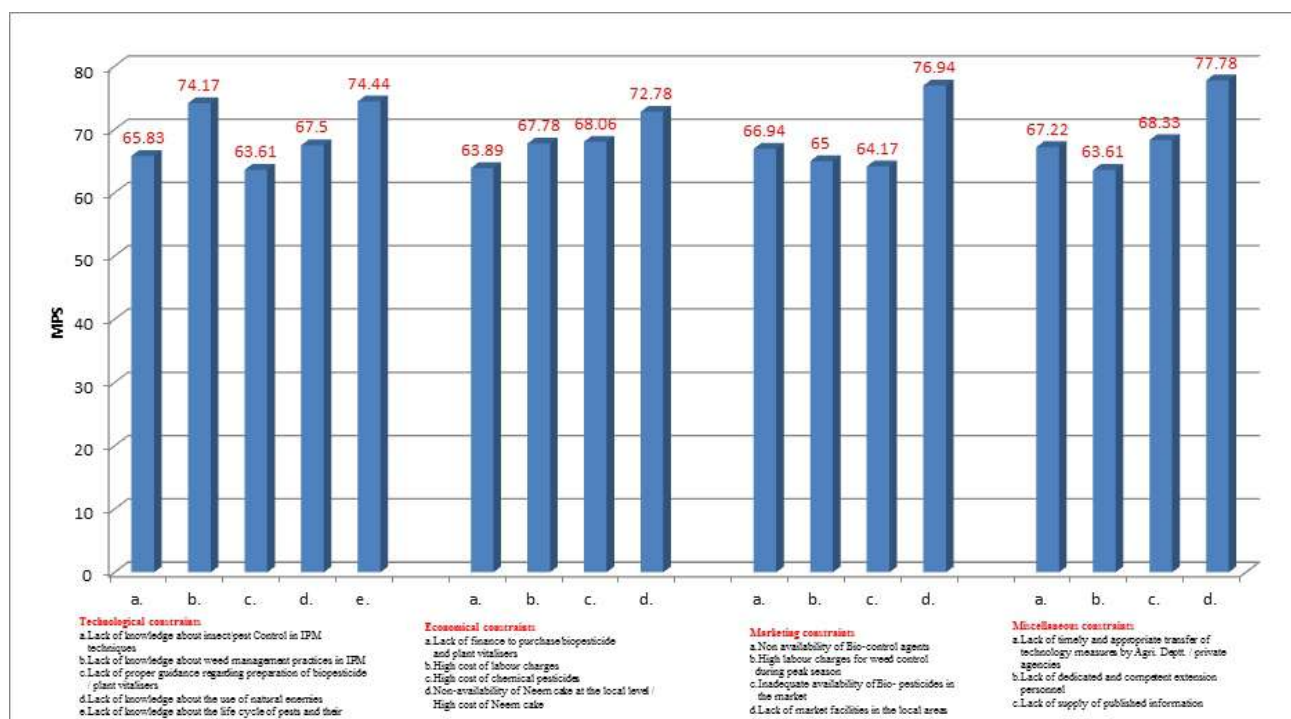


Fig-2 : Distribution of respondents according to their type of constraints in utilization of IPM practices.

perceived at top priority among all Miscellaneous constraints and accorded first rank 64 by the respondents followed by “Lack of supply of published information regarding various practices of IPM” (68.33 MPS) and “Lack of timely and appropriate transfer of technology measures by Agri. Deptt. /private agencies” (67.22 MPS) which were considered critical constraint with II, and III Rank, respectively and “Lack of dedicated and competent extension personnel” (63.61MPS) with IV Rank.

Conclusions

Constraints four categories of constraints, technological (70.00 MPS) were perceived with the highest intensity by respondents in the first rank, followed by Miscellaneous constraints (69.72 MPS) in second place, Economical Constraints (68.06 MPS) was ranked third and Marketing constraints (65.09 MPS) fifth by all respondents, respectively.

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Constraints Perceived by Tribal Farmers of Rajasthan in Adoption of Improved Production Technology of Ajwain

Surbhi Jangir^{1*}, B.S. Badhala², Kamlesh Gurjar³, Saurabh Pandey⁴ and Shubham Mishra⁵

¹Department of Extension Education, MPUAT, Udaipur, Rajasthan

²Department of Extension Education, SKNAU, Jobner, Rajasthan

³Department of Extension Education, AU, Jodhpur, Rajasthan

⁴Department of Extension Education and communication, AAU, Anand, Gujarat

⁵Division of Extension Education, NDRI, Karnal, Haryana

*Email : Jangirsurbhi95@gmail.com

Abstract

The present study was conducted in Pratapgarh district of Rajasthan to find out the constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain. 5 tribal villages from Choti sadari tehsil of Pratapgarh was selected randomly. Data were collected from randomly selected 65 Tribal farmers. The data from these tribal farmers was collected using a well structured interview schedule and face to face interview method during year 2022. The findings showed that the overall constraints perceived by Tribal farmers were financial constraints (58.85 MPS) as most important Constraint followed by Input Constraint (57.61 MPS) and Marketing Constraint (51.11 MPS). Further, Technical Constraint (50.19 MPS) was perceived as least important constraint in adoption of improved production technology of Ajwain. Further, it concluded that “Unavailability of fertilizer at the peak seasons”, “Lack of knowledge about seed treatment”, “Minimum support price is not fixed by Govt.” and “High cost of HYV seeds” was major constraints perceived by the Tribal farmers. There is a need to provide trainings and organizing demonstrations to raise the knowledge and awareness among the tribal farmers. Hence, there is a need to provide trainings and organizing demonstrations to raise the knowledge and awareness among the tribal farmers.

Introduction

Ajwain (*Trachyspermum ammi*) is an annual herbaceous plant belonging to Apiaceae family. Mediterranean region in Egypt is the origin place of Ajwain. Ajwain falls under minor seed spices and is widely cultivated in arid and semi-arid regions. It is cultivated in India, Iran, Egypt and Afghanistan.

India is one of the leading countries in the world with respect to area, production and export of different seed spices. Rajasthan and Gujarat have emerged as “Seed Spices Bowl” and together they contribute 80% of the total seed spices production in the country. Madhya Pradesh, Uttar Pradesh, Punjab, Haryana, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu are also contributing to the total seed spices production of the country (Anonymous2020).

Ajwain is mainly cultivated for its seed and volatile oil (Thymol). Ajwain seed generally contains 2.5 to 5% essential oil and 26% fatty oils (Raghavan, 2007). The greyish brown seeds of Ajwain are usually considered for medical and nutritional purposes.

Rajasthan is a leading state in cultivation of spices. It has most suitable Agro-climatic conditions for the cultivation of different spice crops. India, Rajasthan has secured an unique place as it produces about 8-9 lakh t

seed from about 8 lakh hectares area (Anonymous 2020). Therefore, it is high time to assess the constraints hindering the adoption of improved production technology of Ajwain by the Tribal farmers in Pratapgarh districts Rajasthan.

Research Methodology

The present study was conducted in Pratapgarh districts of Rajasthan. Pratapgarh district was selected purposively due to the reason that Pratapgarh district has the highest area (222 ha) and production (333 t) of Ajwain crop among all tribal districts of Rajasthan (Anonymous 2019-20). Pratapgarh district comprises of 5 tehsils. Out of which Choti Sadari was tehsil selected as it has highest area and production under Ajwain crop among all tehsils of Pratapgarh.

From the selected tehsils, 5 Ajwain growing villages; namely; Karzu, Manpura Jagir, Rawatpura, Bambori and Raghunathpura were selected. From each of the selected villages, 13 tribal farmers were selected randomly. In this way a total sample of 65 tribal farmers was selected. A separate interview schedule was prepared to find out the constraints that hinders the adoption of improved production technology of Ajwain. Appropriate statistical tools were applied to interpret the results. The responses obtained from respondents were recorded on a three-point continuum namely high, medium and low extent.

Mean Percent Score (MPS) for each of the constraints was calculated to find out the priority area of constraints in various aspects.

Mean Percent Score was obtained by dividing the total score of each practice statement by maximum score obtained under each practice and multiplying it by hundred. The formula for calculation MPS is given below :

$$\text{MPS} = \frac{\text{Total score obtained by respondents}}{\text{Maximum score obtained}} \times 100$$

Results and Discussion

In this study the term constraint was used to denote the problems and obstacles which the tribal farmers perceived in adoption of improved production technology of Ajwain.

1. Category wise constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain : For the analysis of constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain, 31 major constraints were categorized into four different categories as technical, input, financial and marketing constraints. Each statement was assigned a rank according to the MPS obtained.

1.1 Input constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain : The data presented in Table-1 revealed that “Unavailability of fertilizer at the peak seasons” was the major input constraint perceived by the Tribal farmers with 68.72 MPS. Followed by “Unavailability of good quality seeds at the time of sowing” (63.08 MPS) and “Unavailability of short duration varieties” (58.97 MPS).

The constraints which were faced to lesser extent were “lack of irrigation facility” and “supply of inferior quality seeds” with 55.38 and 54.36 MPS, respectively.

The least perceived constraints faced by them was “unavailability of recommended chemical for plant protection measures” with 45.13 MPS.

The reason for facing these constraints was lack of knowledge, socio-economic factors and poor availability of quality seeds and plant protection measures in the tribal areas.

Similar findings are reported by Meena (2010) and Yadav (2021).

1.2 Technical constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain : The data in Table-2 indicated that “Lack of knowledge about seed treatment” with 59.49 MPS was the major constraints about technical aspect perceived by Tribal farmers.

Followed by “Lack of knowledge about plant protection chemicals”, “Poor knowledge about dose of chemical fertilizer” and “Lack of knowledge about cultivation of HYV” with 53.33, 52.82 and 51.79 MPS, respectively.

The constraints which were perceived at relatively lesser extend were “Lack of knowledge about recommended seed rate”, “Lack of knowledge about grading and standardization”, and “Lack of knowledge about chemical weed control” with 50.77, 48.72 and 42.56 MPS.

The least perceived constraint faced by them was “poor knowledge about irrigation management” with 42.05 MPS.

The analysis of table clearly indicated that poor technical knowledge lead to various technical constraints hindering the adoption of improved production technology of Ajwain.

Similar findings are reported by Meena (2010) and Yadav (2021).

1.3 Marketing constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain : The data in Table-3 revealed that Tribal farmers reported “Minimum support price is not fixed by Govt.” as major marketing constraint with 74.87 MPS.

Followed by “Lack of latest market information”, “Lack of storage facilities” and “Transportation facilities are very costly” were perceived major constraints related to marketing with 61.03, 55.38, and 53.85.

They perceived moderate constraints about “Lack of knowledge about market rate”, “Low price of good quality produce in market”, “Very high fluctuation in price” and “Lack of market for the commodity” with 45.13, 44.10, 43.59 and 42.56.

The least perceived constraints faced by them was “Mal practices by local businessman” with 39.49 MPS.

Similar findings are reported by Meena (2010) and Yadav (2021).

1.4 Financial constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain : The analysis of Table-4 revealed that Tribal farmers reported “High cost of HYV seeds” was perceived as major financial constraint with 69.74 MPS.

Followed by “Lack of credit facilities” and “High cost of plant protection chemicals” with 67.69 and 60.51 MPS, respectively. The constraints which faced relatively lesser extend were “High cost of weedicides”, “High cost of

Table-1 : Input constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain.

S. No.	Input Constraints	MPS	Rank
1.	Unavailability of good quality seeds at the time of sowing	63.08	2
2.	Supply of inferior quality seeds	54.36	5
3.	Unavailability of fertilizer at the peak seasons	68.72	1
4.	Unavailability of recommended chemical for plant protection measures	45.13	6
5.	Lack of irrigation facility	55.38	4
6.	Unavailability of short duration varieties	58.97	3
	Overall	57.61	

Table-2 : Technical constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain.

S. No.	Technical Constraints	MPS	Rank
1.	Lack of knowledge about seed treatment	59.49	1
2.	Lack of knowledge about cultivation of HYV	51.79	4
3.	Lack of knowledge about grading and standardization	48.72	6
4.	Lack of knowledge about recommended seed rate	50.77	5
5.	Poor knowledge about dose of chemical fertilizer	52.82	3
6.	Lack of knowledge about plant protection chemicals	53.33	2
7.	Poor knowledge about irrigation management	42.05	8
8.	Lack of knowledge about chemical weed control	42.56	7
	Overall	50.19	

Table-3 : Marketing constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain.

S. No.	Marketing Constraints	MPS	Rank
1.	Lack of storage facilities	55.38	3
2.	Transportation facilities are very costly	53.85	2
3.	Lack of knowledge about market rate	45.13	6
4.	Low price of good quality produce in market	44.10	7
5.	Mal practices by local businessman	39.49	9
6.	Minimum support price is not fixed by Govt.	74.87	1
7.	Very high fluctuation in price	43.59	8
8.	Lack of latest market information	61.03	4
9.	Lack of market for the commodity	42.56	5
	Overall	51.11	

labour” and “high cost of fertilizers” with 57.44, 56.92 and 54.87 MPS.

The least perceived constraint faced by them were “high cost of inputs” and “high cost of equipments” with 52.82 and 50.77 MPS.

The reason might be the poor economic profile of the tribal farmers and lack of credit facilities/ sources etc.

Similar finding are reported by Yadav (2021).

2. Overall constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain : The data in Table-5 reveals the overall constraints which could be responsible for lower adoption of improved production technology of Ajwain. The data depicted that the constraints like “Financial constraints” was most perceived by the Tribal farmers with 58.85 MPS. “Input constraints” was second most important constraint which was having 57.61 MPS “Marketing constraints (51.11 MPS)” and “Technical constraints (50.19 MPS)” was found to be comparatively less important constraints

and was ranked third and fourth. Similar finding are reported by Yadav (2021) and Jaitawat (2007).

Conclusions

It can be concluded that financial constraints (58.85 MPS) was perceived as the most important Constraint followed by Input Constraint (57.61 MPS) and Marketing Constraint (51.11 MPS). Further, Technical Constraint (50.19 MPS) was perceived as least important constraint in adoption of improved production technology of Ajwain by Tribal farmers of Pratapgarh district of Rajasthan.

In case of aspect wise constraints it was found that “Unavailability of fertilizer at the peak seasons”, “Lack of knowledge about seed treatment”, “Minimum support price is not fixed by Govt.” and “High cost of HYV seeds” was major constraints perceived by the tribal farmers. There is a need to provide trainings and organizing demonstrations to raise the knowledge and awareness among the tribal farmers.

Table-4 : Financial constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain.

S. No.	Financial Constraints	MPS	Rank
1.	Lack of credit facilities	67.69	2
2.	High cost of labour	56.92	5
3.	High cost of inputs	52.82	7
4.	High cost of equipments	50.77	8
5.	High cost of HYV seeds	69.74	1
6.	High cost of weedicides	57.44	4
7.	High cost of plant protection chemicals	60.51	3
8.	High cost of fertilizers	54.87	6
	Overall	58.85	

Table-5 : Overall constraints perceived by the Tribal farmers in adoption of improved production technology of Ajwain.

S. No.	Constraints	MPS	Rank
1.	Input Constraints	57.61	2
2.	Technical Constraints	50.19	4
3.	Marketing Constraints	51.11	3
4.	Financial Constraints	58.85	1
	Overall	55.44	

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Integrated Nutrient Management in Wheat (*Triticum aestivum* L.) using Cow Dung Manure with Natural Resources in Soybean-Wheat Cropping System in Vindhyan Plateau of Madhya Pradesh

Anshul Raghuwanshi^{1*}, O.P.S. Raghuwanshi², M.S. Raghuwanshi¹, Lekhraj Yadav¹ and K.S. Bangar¹

¹RVSKVV, College of Agriculture, Indore-452001, M.P.

²JNKVV, ABV, College of Agriculture, Khurai (M.P.),

*Email : anshulraghuwanshi003@gmail.com

Abstract

An experiment was conducted at research farm, College of Agriculture, Ganj Basoda (M.P.) at fixed site for consecutive three years (2013-14, 2014-15 and 2015-16) on Vertisols of Vindhyan Plateau of Madhya Pradesh to evaluate the effect of cow dung manure with variable levels of natural carriers, namely rock phosphate and feldspar on growth, grain and straw yields, test weight, harvest index, nutrient content and economics of wheat in soybean-wheat cropping system. The experiment was laid out in randomized block design with four replications. Yield attributes like plant height, length of ear-head, number of effective tillers per m², number of grains per spike and harvest index were maximum and differed significantly from recommended dose of nutrient through natural nutrient carriers (control) on application of recommended dose of natural carriers coupled with incorporation of cow dung manure @ 5 t per ha. In general, the value of these attributes increased with integration of cow dung manure in different proportions with recommended dose of natural resources. The enhanced yield attributes by application of recommended dose of natural carriers coupled with incorporation of cow dung manure @ 5 t per ha was reflected in increase of grain and straw yield by 27.64 and 27.50 per cent, respectively over control.

Key words : Cow dung, natural sources, growth, soybean-wheat system.

Introduction

Wheat (*Triticum aestivum* L.) has been described as “Staff of life or king of cereals” and one of the most important staple food crop. Wheat has its own outstanding importance as a human food, it is rich in carbohydrates and protein. Wheat is cultivated in at least 43 countries of the world. The leading countries in wheat cultivation are China, India, Thailand, Indonesia and U.S.A. and total production of wheat was 647 million tonnes under area of 218 million hectares with a productivity of 2960 kg/ha (FAO, 2012). Wheat is a dominant *rabi* cereal crop of central zone of India. It is producing about 93.50 million tonnes of wheat from an area of 30.23 million hectare with an average productivity of 3093 kg ha⁻¹ in 2015-16 (<http://eands.dacnet.nic.in>). Madhya Pradesh, which is one of the major wheat growing states, produces 1455 thousand tonnes of wheat from 5261 thousand hectares area with an average productivity of 2765 kg ha⁻¹ in 2015-16 (<http://eands.dacnet.nic.in>). Due to intensive cropping, where food grain production and fertilizer use run parallel, soil is degrading day by day with respect to soil fertility and productivity. This may be attributed to the minimum and extra removal of nutrient resources from the soil strata than they are replenished, so soil is becoming deficient in available nutrients. Since, agriculture becomes more intensive and chemical dependent, therefore soil toxicities and nutrient imbalance threaten sustainable

production. So, we have to think about the cheap and easily available alternate source of nutrients, which not only supply the nutrients to the soil but also improve the physico-chemical properties of the soil. Thus, demand for fertilizers can be lowered by supplementing the nutrients through organic manures. In recent years due to unsuitable effect of chemical fertilizers on the soil, using of organic materials serves as a good and suitable source to supply soil food elements. In addition to supply nutrients, organic manures may improve the soil health, physico-chemical properties and biological conditions of the soil. Judicious use of FYM with chemical fertilizers improves soil physical, chemical and biological properties and improves the crop productivity (Sharma *et al.* 2007). Application of organic manures may also improve availability of native nutrients in soil as well as the efficiency of applied fertilizers (Sawrup, 2010).

Materials and Methods

An experiment was conducted during the *kharif* and *rabi* seasons of 2013-14, 2014-15 and 2015-16 at research farm, College of Agriculture, Ganj Basoda, Vidisha of Vindhyan Plateau of Madhya Pradesh. The soil of the experimental site belonged to Vertisols with clayey texture, pH 7.60, organic carbon 0.48 % and EC 0.38 dS per m. The available N, P₂O₅, K₂O and S contents were 190, 12.4, 290 and 9.2 kg per ha, respectively. The experiment was laid out in a randomized block design with

Table-1 : Effect of integrated nutrient management in wheat using cow dung manure with natural resources on plant height, length of ear head, number of effective tillers, number of grains per spike, test weight, grain yield and straw yield. (Data pooled for three years).

Treatments	Plant height (cm)	Length of ear-head (cm)	No of effective tillers/mrl	No of grains spike ⁻¹	Test weight (g)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
T ₁ RDN	72.57	8.53	84.57	47.20	46.30	4201.70	6536.70
T ₂ RDN +1t ha ⁻¹ Cow dung	73.77	8.63	86.77	48.20	47.20	4881.70	6696.70
T ₃ RDN+2t ha ⁻¹ Cow dung	74.57	9.17	90.97	48.40	49.40	4991.70	7386.70
T ₄ RDN+3t ha ⁻¹ Cow dung	75.13	9.67	91.87	49.40	50.20	5045.00	7816.70
T ₅ RDN+4t ha ⁻¹ Cow dung	76.13	10.27	93.97	49.60	51.30	5601.70	8116.70
T ₆ RDN+5t ha ⁻¹ Cow dung	76.57	10.47	94.77	50.20	52.20	5806.70	9016.70
CD 5%	0.98	0.79	2.09	1.65	1.43	179.77	231.56

RDN-Recommended dose through natural carriers, nitrogen through urea

Table-2 : Effect of integrated nutrient management in wheat using cow dung manure with natural resources on nutrient content and economic viability. (Data pooled for three years).

Treatments	Nutrient content (%)			Net returns (Rs/ha)	B:C ratio
	N	P	K		
T ₁ RDN	2.026	0.243	0.381	73769.30	3.69
T ₂ RDN +1t ha ⁻¹ Cow dung	2.086	0.303	0.415	84432.70	4.12
T ₃ RDN+2t ha ⁻¹ Cow dung	2.106	0.323	0.481	87199.30	4.16
T ₄ RDN+3t ha ⁻¹ Cow dung	2.126	0.343	0.531	90471.70	4.21
T ₅ RDN+4t ha ⁻¹ Cow dung	2.186	0.363	0.581	99774.70	4.54
T ₆ RDN+5t ha ⁻¹ Cow dung	2.246	0.373	0.625	106040.00	4.72
CD 5%	0.11	0.032	0.11	2881.33	0.943

RDN- Recommended dose through natural carriers, nitrogen through urea

four replications and six treatments encompassing recommended doses of nutrients through natural carriers (RDN) and its combination with five graded quantities of cow dung manure. The RDN was taken as control for comparison. The cow dung manure used in the experiment analysed: N-25, P₂O₅-41.2, K₂O-10.9 kg/ha. All the agronomic operations were carried out as per recommendations for raising the crop. Wheat var. GW-366 was sown on 19th to 23rd November-13, 28th to 30th November-14 and 24th to 28th November-15 and harvested on 05th to 12th April-14 (*rabi* 2013-14), 26th to 31st March-15 (*rabi* 2014-15) and 25th to 29th March-16 (*rabi* 2015-16) during the experimentations. Necessary plant protection and intercultural operations were done as per package of practices of the wheat GW-366. Sowing was done at on station with recommended seed rate of wheat @ 100 kg ha⁻¹ and nutrients were used as per treatments. The recommended dose of nutrients for wheat (120:80:40 kg N: P₂O₅:K₂O/ha) was applied as basal through rock phosphate and feldspar and N was with urea. Cow dung manure as per treatment was incorporated 15 days prior to sowing of wheat. The data on plant height, length of ear-head, number of effective tillers per mrl and number of grains per spike grain and harvest index were recorded on five randomly selected plants and yield (grain and straw) from each plot was recorded at harvest. The

recorded data was pooled for three years and statistically analysed as described by Panse and Sukhatme (1978) The economic analysis was carried out using prevailing cost of inputs and produce and reported as net returns and benefit cost ratio.

Results and Discussion

Different yield parameters were appreciably affected with the different treatment of integrated nutrient management. The plant height, length of ear-head, number of effective tillers per mrl and number of grains per spike were significantly higher in RDN integrated with cow dung manure @ 5 t per ha as compared to RDN. Plant height showed significant difference with RDN (76.13 cm) on integration of cow dung manure @ 4 t per ha and (76.57 cm) @ 5 t per ha with RDN. The integration of cow dung manure with RDN @ 2t per ha on wards significantly increased length of ear head (9.17 to 10.47) as compared to RDN (Table-1). The harvest index did not differ significantly. The improvement in the number of effective tillers per mrl and number of grains per spike were reflected in grain and straw yield. The integration of RDN with cow dung manure @ 2 t per ha and beyond increased grain and straw yield significantly over RDN. Maximum grain (5806.70 kg/ha) and straw (9016.70 kg/ha) was recorded in incorporation of cow dung manure @ 5 t per

ha with RDN (Table-1). These findings are in line with those reported by Singh, *et al.*, 2008, Mubarak and Singh, 2011 and Desai, *et al.*, 2015.

The integration of RDN with graded levels of cow dung manure, in general, led to significant increase in N, P and K contents in grain and there was progressive increase with graded levels of cow dung manure. The highest contents of nitrogen (2.246 %), phosphorus (0.373 %) and potassium (0.625 %) were recorded when RDN was integrated with cow dung manure @ 5 t per ha (Table-2).

Economic analysis revealed that the net returns increased progressively with integration graded levels of cow dung manure with RDN (Rs 84432.70-106040.00) as compared to RDN (Rs 73769.30). Similar was the trend in case of B: C ratio. The maximum net returns (Rs 106040.00) and B: C ratio (4.72) was recorded in incorporation of cow dung manure @ 5 t per ha and lowest was with RDN (Rs 73769.30 and 3.69, respectively) (Table-2). Similar trends were also observed by Singh, *et al.*, 2008, Sepat, *et al.*, 2010 and Desai, *et al.*, 2015.

Conclusions

The outcome of three years study established that integration of cow dung manure with RDN even @ 1 t per ha leads to enhancement in productivity and profitability of wheat and nutrient management schedule provides optional use of natural carriers. To harness better advantage, these natural carriers of nutrients may be integrated with incorporation of cow dung manure @ 5 t per ha.

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Integrated Nutrient Management in Chickpea (*Cicer arietinum*) using Cow dung Manure with Natural Resources in Vindhyan Plateau of Madhya Pradesh

Anshul Raghuwanshi^{1*}, O.P.S. Raghuwanshi², Lekhraj Yadav¹, M.S. Raghuwanshi¹ and K.S. Bangar¹

¹RVSKVV, College of Agriculture, Indore-452001, M.P.

²JNKVV, ABV, College of Agriculture, Khurai (M.P.),

*Email : anshulraghuwanshi003@gmail.com

Abstract

An experiment was conducted at research farm, College of Agriculture, Ganj Basoda (M.P.) at fixed site for consecutive three years (2013-14, 2014-15 and 2015-16) on Vertisols of Vindhyan Plateau of Madhya Pradesh to evaluate the effect of cow dung manure with variable levels of natural carriers, namely rock phosphate and feldspar on growth, grain and straw yields, test weight, harvest index, nutrient content and economics of chickpea in soybean-chickpea cropping system. The experiment was laid out in randomized block design with four replications. Yield attributes like plant height, pods per plant, grain and harvest index were maximum and differed significantly from recommended dose of nutrient through natural nutrient carriers (control) on application of recommended dose of natural carriers coupled with incorporation of cow dung manure @ 5 t per ha. In general, the value of these attributes increased with integration of cow dung manure in different proportions with recommended dose of natural resources. The enhanced yield attributes by application of recommended dose of natural carriers coupled with incorporation of cow dung manure @ 5 t per ha was reflected in increase of grain and straw yield by 18.66 and 25.07 per cent, respectively over control.

Key words : Cow dung, natural sources, growth, soybean-chickpea system

Introduction

Chickpea (*Cicer arietinum* L.) is an important grain legume crop in the world which was globally, total production is approximately 14.2 million tons from an area of 14.8 million ha and a productivity of 0.96 t ha⁻¹ FAOSTAT, (2014). South East Asia, led by India is leading producers, while in East Africa, Ethiopia, Tanzania, Malawi, and Kenya are leading chickpea producers. Worldwide chickpea is largely grown as a rain fed crop (> 90%) in the arid and semiarid environments in Asia and Africa. Chickpea, almost in all regions, is grown on marginal soils and the good soils are used for growing other more favored crops. For obtaining high grain yields proper management of the crop is must and proper nutrient management is one of the important factors contributing towards high productivity. Though chickpea, being a grain legume, is capable of fixing atmospheric nitrogen, a starter dose of nitrogen is essential for proper growth and development of the plant. Chickpea grain yields are known to improve with the application of nitrogen Namvar *et al.*, (2011), Yagmur and Kaydan, (2011). Phosphorus plays an important role in nodulation, nitrogen fixation, growth and yield of chickpea Singh *et al.*, (2010). Higher chemical fertilizers price coupled with the low affordability by small farmers is the biggest obstacle for fertilizer use in the marginal lands. Furthermore, global warming is the major threat for the depletion of the soil organic carbon *i.e.* the main skeleton of soil fertility and productivity. However,

sole application of farmyard manure is constrained by access to sufficient organic inputs, low nutrient content of manures, high labor demand for preparation and transportation. These constraints can be solved by the substitution of organic sources containing higher amounts of plant nutrients, which can improve and sustain crop yields while improving soil fertility status. Though chickpea meets 80% of its nitrogen requirement from symbiotic nitrogen fixation, application of fertilizer is important as starter until the nodulation operates synchronously to fix the atmospheric N (Gaur *et al.*, 2010). The crop also requires balanced and optimum amounts of other nutrient elements such as phosphorus, potassium, sulfur and micro nutrients (Dhakal *et al.*, 2016). So, it is necessary to apply balanced nutrients from easily available sources of organic to sustainably improve the productivity of chickpea. Chickpea plays a significant role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea meets 80% of its nitrogen requirement from symbiotic nitrogen fixation and can up to 140 kg N /ha from air. Sub-optimal and skewed nutrition management in practice in chickpea is considered to be one of the limiting factors in productivity from soybean- chickpea cropping system. The present study was undertaken to investigate the effect of different doses of cow dung manure with combinations of natural carriers on growth, yield, nutrient content and economics of chickpea.

Materials and Methods

Table-1 : Effect of integrated nutrient management in chickpea using cow dung manure with natural resources on plant height, number of branches, number of pods, test weight, harvest index, grain and straw yields. (Data pooled for three years).

Treatments	Plant height (cm)	No of Branches/plant	No of Pods/plant	Test weight (g)	Harvest Index (%)	Grain Yield (kg/ha)	Straw Yield (kg/ha)
T ₁ RDN	31.67	8.53	47.50	123.36	33.46	1961.67	3885.00
T ₂ RDN + 1t ha ⁻¹ Cow dung	39.27	12.77	52.70	132.46	33.38	2156.67	4285.00
T ₃ RDN + 2t ha ⁻¹ Cow dung	40.07	13.23	54.30	133.26	33.54	2225.00	4390.00
T ₄ RDN + 3t ha ⁻¹ Cow dung	40.92	13.67	55.10	133.83	33.09	2281.67	4595.00
T ₅ RDN + 4t ha ⁻¹ Cow dung	41.17	13.83	55.77	134.16	32.59	2348.33	4835.00
T ₆ RDN + 5t ha ⁻¹ Cow dung	42.27	14.07	57.70	134.66	31.63	2411.67	5185.00
CD 5%	0.63	0.54	0.47	0.71	NS	121.75	234.59

RDN-Recommended dose through natural carriers, nitrogen through urea

Table-2 : Effect of integrated nutrient management in chickpea using cow dung manure with natural resources on nutrient content and economics. (Data pooled for three years).

Treatments	Nutrient content (%)			Net returns (Rs/ha)	B:C ratio
	N	P	K		
T ₁ RDN	3.07	0.26	1.90	55043	2.92
T ₂ RDN + 1t ha ⁻¹ Cow dung	3.13	0.39	2.00	61958	3.20
T ₃ RDN + 2t ha ⁻¹ Cow dung	3.21	0.41	2.10	63873	3.21
T ₄ RDN + 3t ha ⁻¹ Cow dung	3.27	0.47	2.15	65515	3.22
T ₅ RDN + 4t ha ⁻¹ Cow dung	3.36	0.50	2.19	68015	3.26
T ₆ RDN + 5t ha ⁻¹ Cow dung	3.43	0.52	2.24	70735	3.31
CD 5%	0.18	0.036	0.14	2799	NS

RDN- Recommended dose through natural carriers, nitrogen through urea

An experiment was conducted during the *kharif* and *rabi* seasons of 2013-14, 2014-15 and 2015-16 at research farm, College of Agriculture, Ganj Basoda, Vidisha of Vindhyan Plateau of Madhya Pradesh. The soil of the experimental site belonged to Vertisols with clayey texture, pH 7.60, organic carbon 0.48 % and EC 0.38 dS per m. The available N, P₂O₅, K₂O and S contents were 190, 12.4, 290 and 9.2 kg per ha, respectively. The experiment was laid out in a randomized block design with four replications and six treatments encompassing recommended doses of nutrients through natural carriers (RDN) and its combination with five graded quantities of cow dung manure. The RDN was taken as control for comparison. The cow dung manure used in the experiment analysed: N-25, P₂O₅-41.2, K₂O-10.9 kg/ha. All the agronomic operations were carried out as per recommendations for raising the crop. Chickpea var. JG-63 was sown on 19th to 23rd November-13, 28th to 30th November-14 and 24th to 28th November-15 and harvested on 05th to 12th April-14 (*rabi* 2013-14), 26th to 31st March-15 (*rabi* 2014-15) and 25th to 29th March-16 (*rabi* 2015-16) during the experimentations. Necessary plant protection and intercultural operations were done as per package of practices of the chickpea JG-63. Sowing was done at on station with recommended seed rate of chickpea @ 80 kg ha⁻¹ and nutrients were used as per

treatments. The recommended dose of nutrients for chickpea (20:60:20 kg N: P₂O₅:K₂O /ha) was applied as basal through rock phosphate and feldspar and N was with urea. Cow dung manure as per treatment was incorporated 15 days prior to sowing of chickpea. The data on plant height, number of branches per plant, number of pods per plant, test weight and harvest index were recorded on five randomly selected plants and yield (grain and straw) from each plot was recorded at harvest. The recorded data was pooled for three years and statistically analysed as described by Panse and Sukhatme (1978) The economic analysis was carried out using prevailing cost of inputs and produce and reported as net returns and benefit cost ratio.

Results and Discussion

The plant height, number of branches per plant and number of pods per plant were significantly higher in RDN integrated with cow dung manure @ 5 t per ha as compared to RDN. Plant height showed significant difference with RDN (41.17 cm) on integration of cow dung manure @ 4 t per ha and (42.27 cm) @ 5 t per ha with RDN. The integration of cow dung manure with RDN @ 2 t per ha on wards significantly increased number of pods per plant (47.5 to 57.7) as compared to RDN (Table-1). The harvest index did not differ significantly. The improvement in pod number per plant was reflected in

grain and straw yield. The integration of RDN with cow dung manure @ 2 t per ha and beyond increased grain and straw yield significantly over RDN. Maximum grain (2411.67 kg/ha) and straw (5185.00 kg/ha) was recorded in incorporation of cow dung manure @ 5 t per ha with RDN (Table-1). The results are also corroborated the findings of Amiri *et al.*, (2017). The integration of RDN with graded levels of cow dung manure, in general, led to significant increase in N, P and K contents in grain and there was progressive increase with graded levels of cow dung manure. The highest contents of nitrogen (3.43 %), phosphorus (0.52%) and potassium (2.24%) were recorded when RDN was integrated with cow dung manure @ 5 t per ha (Table-2). The results of similar kind were also reported by Quddus *et al.*, (2018). Economic analysis revealed that the net returns increased progressively with integration graded levels of cow dung manure with RDN (Rs 61958-70735) as compared to RDN (Rs 55043). Similar was the trend in case of B: C ratio. The maximum net returns (Rs 70735) and B: C ratio (3.31) was recorded in incorporation of cow dung manure @ 5 t per ha and lowest was with RDN (Rs 55043 and 2.92, respectively) (Table-2). The results are also in support of the findings of Nagarajaiah *et al.*, (2005).

Conclusions

The outcome of three years study established that integration of cow dung manure with RDN even @ 1 t per ha leads to enhancement in productivity, profitability and quality parameters of chickpea and nutrient management schedule provides optional use of natural carriers. To harness better advantage, these natural carriers of nutrients may be integrated with incorporation of cow dung manure @ 5 t per ha.

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Evaluation of Major Quantitative Parameters with Reference to Grain Yield in Finger Millet *Eleusine coracana* (L.) Gaertn Accessions

Karishma*, Vikky Kumar, Bharti Singh and Prafull Kumar

S.G. College of Agriculture and Research Station, Jagdalpur-494001, IGKV, Raipur, Chhattisgarh, India

*Corresponding Author Email : karishma123markam@gmail.com

Abstract

The research was carried out in Kharif 2019 at the Research Cum Instruction Farm S.G. College of Agriculture and Research Station, Kumhrawand, Jagdalpur, Bastar, IGKV Raipur (C.G.) to evaluate 85 accessions of finger millet for qualitative parameters. The 12 major quantitative characters' visual observations based on DUS descriptors viz. Days to 50% flowering, days to maturity, peduncle length, ear head length, no. of finger per panicle, no. of productive tillers per plant, plant height, finger length, finger width, no. of seed per panicle, grain yield, test weight. crop duration as utmost criteria; the early flowering genotypes were IC0476495, GEC415, GEC517 (55 DAS), while the medium duration genotypes were C.G. Ragi-2, (68 DAS), GPU-67 (65 DAS), GEC 106 (65 DAS), GEC363 (65 DAS), GEC 67 (68 DAS). The late duration genotypes were GEC 79 (79 DAS) followed by IC0476541, GEC 241, GEC 51, GEC 378 (86), GEC 440 (98 DAS). The experimental mean grain yield per plant was 6.23g, with a range of 2.46 to 10.012g per plant. For grain yield per plant, the genotypes were divided into three categories: low (4 g), medium (4.0–6.0 g), and high (> 6 g). 5 (6%) of the test accessions had low grain yields, 34 (40%) medium yields, and 46 (54%) high grain yields. The research found that the collected Germplasm contained significant variations between the finger millet accessions. The targeted improvement program for finger millet may be implemented in the future, and the conservation and further improvement of this Germplasm is urgently required.

Key words : Quantitative traits, morphological markers, DUS, germplasm.

Introduction

Eleusine coracana is known by a number of indigenous names throughout the world, including ragi in India. It is referred to as finger millet in English. It is a significant crop among small millets and ranks third in terms of production and area among millets in the nation, behind sorghum and pearl millet. It is primarily grown in India as a rainfed crop because of the valuable food grains it produces in addition to its adaptability to various kinds of agroecological constraints. It has $x = 9$ chromosomes. *E. coracana* subs. *coracana* is a tetraploid subspecies of this genus that developed as a result of productivity (Shukla *et al.*, 2015). It has primarily been grown as an irrigated crop in states like Tamil Nadu and Gujarat. Whereas the total production of high yielding varieties was estimated to be 1614.53 thousand tons, or 70.73%, (Directorate of Millets Development, 2014). Finger millet is grown on 1169 ha in India, producing 1873 tons and 1601 kilograms per hectare annually, and on 6.9 ha in Chhattisgarh, producing 1.3 tons and 188 kilograms per hectare annually (Anon.2018). Finger millet highly nutritional grain. If finger millet is compared with world's major cereal; wheat and rice, it is considerably rich in micronutrients such as vitamins and minerals. Especially, it is a richest source of calcium among all major cereals with up to 10 times more calcium content than brown rice,

wheat or maize and 3 times more than milk. Table 1 shows a comparative nutrient content of finger millets. If we look at the macronutrient content of finger millet, it contains 72.6 % carbohydrates, 7.3 % protein, 1.3% fat, 3.6 % crude fiber, 19.1 % dietary fiber and 3 % minerals (Prajapati *et al.*, 2019).

Materials and Methods

The study was carried out in Kharif 2019 at Kumhrawand Research Cum Instruction Farm S. G. College of Agriculture and Research Station, Jagdalpur, Bastar IGKV Raipur (C.G.). It was planted on July 17, 2019. Direct line sowing of the seeds. 10 cm between plants and 23 cm between rows was the recommended spacing. During the sowing process, a base dose of 20 kg N/ha and 25 kg DAP/ha was applied. To raise a quality crop in one season, all advised cultural practices were followed. Throughout the crop growth period, the advised set of practices was used. The visual observations taken on Major 12 Quantitative Characters based on DUS descriptors Viz .-flowering stage (Days to 50% flowering, peduncle length), dough stage (earhead length, finger length, fingers per ear, number of productive tillers per plant), maturity stage (days to maturity) and after harvesting (grain yield per plant, fodder yield per plant, test weight). Yield were recorded according to morphological descriptor DUS guideline provided by Protection of Plant Variety and Farmers Right Authority.

Results and Discussion

Days to 50 percent flowering (DAS) : Days to 50% flowering ranged from 55 to 98 DAS, with a mean of 78.32 DAS, according to the findings of the current study. Many crop improvement programs prefer early genotypes because they are less likely to experience high pest and disease incidence and unusual weather. In the current experiment, 3 early (55 DAS) genotypes contributed about 20%, 7 medium duration (56-70 DAS) genotypes contributed about 33%, and 75 late (>70 DAS) genotypes contributed about 48%. The early flowering genotypes were IC0476495, GEC415, GEC517 (55 DAS), while the medium duration genotypes were C.G. Ragi-2, (68 DAS), GPU-67 (65 DAS), GEC 106 (65 DAS), GEC363 (65 DAS), GEC 67 (68 DAS). The late duration genotypes were GEC 79(79 DAS) followed by IC0476541, GEC 241, GEC 51, GEC 378 (86), GEC 440 (98 DAS). Days to flowering were estimated to be between 45 and 92 days by Malambane and Jaisil (2015). High levels of variation and selection for maturity classes that work well with cropping systems were seen in these traits.

Days to maturity (DAS) : A mean of 113.18 DAS was found, with a range of 103 to 124 days to maturity. The genotypes were divided into three categories: early (105 DAS), medium (105–120 DAS), and late (>120 DAS). 24 test accessions matured early (20%), 51 matured moderately (33%) and 10 matured late (47%), according to the test accessions. The genotype GEC 342 was early maturing (103 DAS) followed by GEC 321, IC0477569, GEC 25, GEC 187, The genotypes showing medium maturity were IC0476541 (107 DAS), followed by GEC 440, GEC 296, Indira Ragi-1, IC0477787 (106 DAS), GEC 51(114 DAS). The genotype showing late maturity were IC0477507 (124 DAS), IC04776032 (129DAS), IC0477503 (126 DAS) and IC077161-X (129 DAS), GEC 197, (126 DAS). Similar result in agreement with the present study was also observed by Malambane and Jaisil (2015), they suggested that Days to maturity were in the ranges of 65-139 days. These traits showed high variations and selection for maturity classes that are suitable for cropping systems is possible. Hardari *et al.*, (2012) reported the mean days to maturity in different entries was 109.20 days with a range from 84 (GE 5943) to 128 (GE 5006) days. Days to maturity is very important from the view of harvesting of the produce since finger millet has dual advantage of grain as well as fodder.

Peduncle length (cm) : Peduncle length ranged from 7.6 to 20 cm and the mean was recorded to be 13.25 cm. Peduncle length was divided into five categories i.e. very short (<10 cm), short (10-20cm), Medium (20.1-30 cm), long (30.1-40 cm) and very long (>40 cm). Among genotypes taken under consideration 8 (10%) had very

short peduncle length and 74 (90%) had short type peduncle length. Medium, long and very long type of peduncle length was not found. The genotype GEC 440 (7.6 cm) GEC 511(9.6 cm), IC0477328 (9.2cm) showed peduncle length in very short category, while the genotype GEC 425 (16.2 cm), IC0476541 (16.6 cm), GEC 223(15 cm), had short peduncle length. G. Malambane & P. Jaisil (2015) Hardari *et al.* (2012).

Ear head length (cm) : Ear head length recorded an appreciable amount of variation and ranged from 3.54 to 3.54cm with a mean of 6.13 cm. Ear head length can be grouped into very short (< 4.0 cm), short(4.0-6.0 cm), short to medium (6.1 to 8.0 cm), medium (8.1-10 cm), long (10.1-12 cm) and very long (>12 cm). Based on the categories, 1 genotypes had very short ear head length (1%), 47 genotypes had short ear head length (56%), 29 genotypes had short to medium (34%), 5 genotypes had medium (6%), 1 genotype had long (1%) and 2 genotype showed very long ear head length (3%). The genotype with very short ear head length was GEC 241(3.54 cm), and 47 genotypes with short ear head length GEC 425 (4.7 cm), followed by IC0476541 (4.9 cm), IC0477507(4.8cm), GEC 259 (4.5 cm), IC0477503 (4.42 cm), IC0471951 (4.82cm), GEC 280 (4.9 cm) , 29 genotypes with short to medium ear head length IC0477152 (6.82cm) followed by IC04776032 (6.2 cm) , IC0477161-X (6.88 cm), IC0477604 (6.72 cm), GEC 58 (6.4 cm), GPU- 67(6.3 cm) , GEC 122 (7.7 cm). 5 genotypes with medium ear head length IC0477325 (8.5cm), followed by IC0477787 (8.8 cm), GEC 270 (8.8cm), GEC 79 (8.6 cm) GPU 28 (8.36 cm), 1 genotype with long ear head length GEC 440 (10.6 cm), 2 genotypes with very long ear head length IC0477913 (13.3cm), INDIRA RAGI -1 (13.2 cm). Madhavi Latha and Subba Rao, 2016. A crucial characteristic that directly affects grain yield is the quantity of productive tillers in a plant. The tested entries' ear heads ranged in length from 7.9 cm (VR 989 and VR 990) to 11 cm (PPR 1012).

Finger length (cm) : The average finger length was 6.45 cm, but the range from 4 to 10.2 cm was also observed. Short (5 cm), medium (5-7 cm), and long (>7 cm) finger lengths are separated into three groups. In the current study, 43 genotypes and 16 genotypes with medium finger lengths, respectively, made up 50% and 19% of the total sample. No genotypes have short fingers, while 26 genotypes, or 31% of the test materials, have long fingers. The genotype GEC 51 (4.4 cm) had the short finger length, followed by IC0477507(4.8cm), GEC 421 (4.4 cm) , GEC 425 (5 cm) , the genotypes GEC 181 (5.6 cm), had the medium finger length , followed by GEC 259 (5.2 cm), GEC319 (5.6 cm), IC0476753 (6 cm), GE 453 (6.2 cm) and the genotypes GEC 241 (10.2 cm), had long finger length followed by IC0477152 (7.2 cm), GEC 440 (9.6

Table-1 : Analysis of variance (ANOVA) for different yield related traits.

Source of variation	DF	DM	PL(cm)	EHL (cm)	FL (cm)	FW (cm)	NFPP	PTPP	PH (cm)	NSPP	TW(g)	GYPP (g)
Block	91.87	200.62	10.72	2.54	4.75	0.024	2.259	0.993	387.95	15829.26	0.186	3.70
Treatment	52.66**	68.04*	5.49**	2.68**	1.69*	0.014*	0.954*	0.283**	91.19*	5743638**	0.236**	2.19**
Check	232.94	142.38	3.41	2.43	4.46	0.003	0.698	0.469	564.55	259097.61	0.728	3.95
Error	11.38	17.81	0.67	0.31	0.63	0.63	0.183	0.167	14.61	32392.14	0.100	0.100

cm), GEC 517 (10.2 cm), GEC 415 (9 cm). Haradari *et al.*, 2012 the mean finger length recorded was 6.00 cm with a range of 3.50 (GE 6288) and 13.80 cm (GE 4715). The accessions GE 4715 (13.8), GE 4743 (12.6), and GE 6399 (12.4) demonstrated the highest finger length can be used in breeding programs to increase the finger size, ultimately resulting in an increase in grain yield.

Fingers per ear : There was a noticeable amount of variation in the average number of fingers per panicle. Three classes of fingers per panicle are distinguished: low (5), medium (5-8), and high (>8). The range of fingers per panicle in our experiment was 2.6 to 7.4, with a mean performance of 5.11. In our experiment, 42% of the total accessions, or 36 genotypes, were categorized as medium. and the remaining 58 % were constituted by 4 genotypes which had a low number of fingers per head. No genotype had high value for fingers per panicles. The genotype GEC 23, GEC 425, IC0476541, GEC 181, IC0477152 recorded minimum number of fingers per panicle and the genotypes GEC 241, IC0476921, IC047669-X, GEC 296, INDIRA RAGI-1, GEC 432, showed the maximum number (5) of fingers per panicles. In the present study, productive tillers per plant ranged from 1- 3.2 with a mean performance of 1.82. Similar results were found in the Singam setti *et al.*, (2018) experiment, where the number of fingers per ear (57.69 and 15.97) demonstrated high heritability with moderate genetic advance as a percent of the mean.

Productive tillers per plant : The number of productive tillers per plant is divided into three categories: low (1-3), medium (4-6), and high (>6). Based on this classification, each genotype had a small number of productive tillers per plant; however, in the current study, 15 genotypes had no tillers and 69 genotypes had tillers (2–3) per plant. The genotype GEC 257, IC0477787, GPU-67, and GEC 396 demonstrated the greatest number of productive tillers per plant (three tillers). These genotypes can be used in future breeding programs for improvement in tiller number per plant. The genotype IC0477405 (1) and IC047569 (1) showed the least number of productive tillers per plant. Plant height ranged from 53.8 to 102.8 cm with the mean performance of 80.38 cm. Haradari *et al.* (2012). It ranged from 1.10 (GE 5983) to 13.40 (GE 6240) with a mean value of 5.70 the accessions GE 6240 (13.4), GE

4687 (13.2) and GE 4910 (11.4) showed the highest number of productive tillers. As many the productive tillers, so high will be the yield of the crop.

Plant height (cm) : Among the genotypes studied, 35 were short in plant height (41%) followed by GEC 23 (53.8 cm), GEC 425 (65%), IC0476541 (65.6 cm), GEC 104 (74.4cm) and, 50 were of medium plant height (59 %) followed by GEC 122 (102.8 cm), IC0476464 (98.8 cm), INDIRA RAGI-1 (90cm), IC0477787 (90.2 cm). The genotypes very short (40 cm), tall (120.1-160.0), and very tall (>160 cm) were not discovered. According to Baradari *et al.* (2018), plant heights varied from 45.60 cm (GE 6058) to 157.20 cm (GE 4735), with a mean plant height of 95.60 cm being recorded. Short-statured plants are preferred if grains are the end product; on the other hand, tall-statured plants are preferred if fodder is the end product.

Finger width (cm) : Finger width ranged from 0.54 to 1.12cm with mean of 0.85 cm. The genotypes were grouped three categories for finger width namely Narrow (<0.7), medium (0.7-1.0) and wide (>1.0). Among accessions 11(13%) were narrow, 66 (78%), were medium, 8(9%), were wide finger length. The genotype in the category narrow width were IC0477325(0.54 cm), followed by IC0477651(0.58 cm), IC0477913 (0.62cm), IC04776032 (0.64 cm), GEC 58 (0.66 cm). The genotypes possessing medium finger width were GEC241 (0.72cm) followed by IC0477161X (0.74 cm), GEC 122(0.76 cm), GEC 51(0.76), GEC 223(0.78 cm) and wide genotypes were GPU-28(1.02 cm) followed by GEC244 (1.02cm), IC0476378 (1.04 cm), GEC 67(1.08 cm), GEC197(1.1 cm).

Number of seed per plant : Number of seed per panicle ranged from 454 to 1865 with mean of 931.05. Genotypes showing minimum mean value GEC- 440 (454), IC04776032 (480), GEC 104 (511) and genotypes showing maximum value GEC 67 (1865), C.G. Ragi-2 (1801), IC0477673 (1676), IC0476378 (1520).

Grain yield per plant (g) : The experimental mean grain yield per plant was 6.23 g, with a range of 2.46 to 10.012 g, indicating sufficient variation. For grain yield per plant, the genotypes were divided into three categories: low (4 g), medium (4.0–6.0 g), and high (>6 g). Among the test

accessions, 5 (6%) were low, 34 (40%) were medium and 46 (54%) were high grain yielding genotypes. The genotype in the category of low yield was GEC 51 (2.46 g) followed by IC0477325 (2.554 g), GEC 62 (2.684 g) and IC0477045 (3.846 g). The genotypes possessing medium grain yield per plant were GEC 425 (4.318), GEC 241 (4.69 g), IC0477507 (4.016 g), GEC 296 (5.826), IC0476404 (5.7 g), while the genotype GEC 181 (6.304g), followed by GEC 440 (6.694 g), GEC 104 (6.018 g), GEC 259 (8.284 g), IC0587982 (6.814 g) and IC0077654 (7.1 g) were grouped into High grain yield category. In present experiment the treatments (genotype) and error component were estimated for 12 characters (Table 1). Similar to the current finding, Dasanayaka (2016) also noted significant variation in the number of seeds produced per plant.

Test weight (g) : The mean test weight was 3.24 g, with a range of 2.11 to 4.28 g. Test weights were divided into low (2.0 g), medium (2.0 - 3.0 g), and high (>3.0 g) categories. In the present study 25 (29%) genotypes showed medium test weight and 60 showed high values for test weight contributing 71% of the test accessions. No genotype had low value for test weight GEC 51 (2.78 g) showed medium test weight, followed by IC04477152 (2.89 g), IC047735 (2.38 g), GEC 249 (2.46 g), GEC 321 (2.52 g) and genotypes having high test weight were IC0476541 (3.12 g) followed by, GEC 223 (3.41 g) and IC0477507 (3.63 g) GEC 425 (4.15 g), IC0477787 (4.11 g). In terms of straw yield, Kandel (2019) found similar results for Farmer's (local) variety (7.94)-GE-0480 (10.78) tons per hectare and thousand grain weight (test weight). Every breeding program should pay close attention to how different finger millet genotypes differ in agronomic and yield-attributing traits.

Conclusions

The research identified important variations among the finger millet accessions and assessed their presence in the gathered genetic material. On the basis of DUS descriptors, the main qualitative characters viz. Days to 50% flowering, day to maturity, Peduncle length, Ear head length, Finger length, fingers per ear, productive tillers per plant, plant height, Finger width, Grain yield per plant (g), and Test weight (g) were discovered to be dominant among the investigated accession are significant influencing characters accountable for diversity. The preservation and further development of these Germplasm are urgently required, and a targeted improvement program for finger millet may be implemented in the future.

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Genetic Variability Studies in Indian Mustard (*Brassica juncea* L. Czern and Coss)

Masoom Ali* and G.M. Lal

Department of Genetics and Plant Breeding, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh

*Email : masoomalisugauli786@gmail.com

Abstract

Indian Mustard, scientifically known as *Brassica juncea*, is a plant species belonging to the Brassicaceae family. It is cultivated extensively for its edible leaves, seeds, and oil. In a recent study, twenty genotypes of mustard were evaluated for genetic variability. The experiment was conducted during the *Rabi* season of 2022 at central research farm Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology, and Sciences in Prayagraj, following a Randomized Block Design with three replications. A set of 20 genotypes of Indian mustard were evaluated. The plants were spaced 10 cm apart within rows, and rows were set 45 cm apart. Data were collected from five randomly selected plants of each genotype across all replications, focusing on fourteen different traits. From the present investigation it is concluded that analysis of variance showed significant variation among different genotypes for all characters studied. High estimate of heritability coupled with high GCV and high genetic advance as percent of mean was recorded for number of secondary branches. High estimate of heritability coupled with moderate GCV and high genetic advance as percent of mean was recorded for harvest index, number of siliquae per plant, seed yield per plant and number of primary branches. This indicates closeness of respective σ_p^2 and σ_g^2 value thereby low environmental effect on expression of these characters. Such values may be attributed to the additive gene effects and direct selection for these traits would be fruitful.

Key words : GCV, PCV, heritability, genetic advance, genotype.

Introduction

Vegetable oil consumption in India is predicted to reach at least 20 kg per person annually by 2030, making the oilseeds industry crucial to meeting this demand. With 1.276 billion people expected, the nation will need 204 lakh tonnes of vegetable oils, which is equal to 680 lakh tonnes of oilseeds if the ratio of different oilseeds stays the same. By the end of the XII plan, the nation must produce roughly 544 lakh tonnes of oilseeds to achieve near self-sufficiency in vegetable oils. After the USA, China, and Brazil, India has the fourth-largest vegetable oil economy in the world. About 260 lakh hectares of the country are used to grow oil seeds, mostly on marginal lands that depend on monsoon rains and have limited water resources. Oilseeds represent 13% of the gross cropped area, 3% of the Gross National Product (GNP), and 10% of the value of all agricultural commodities. Furthermore, 72% of the total oilseeds area is confined to rainfed farming, which is mostly cultivated by marginal and small farmers [Source: Directorate of Oilseed Development, Ministry of Agriculture and Farmers Welfare, Government of India, 2020-21]. Most oilseed crops grown in India include groundnut, rapeseed, mustard, soybean, sesame, sunflower, safflower, and Niger. Linseed and castor are non-edible. Due to rising levels of population, standard of living, rapid industrialization, and the synthesis of biofuels from oil seed crops, there is a greater need for vegetable oil.

Imports in large quantities are being used to close the supply and demand gap.

The most significant variety of cruciferous oilseeds is Indian mustard, also known as rai, which takes up nearly 70% of the total area planted in rapeseed mustard. With a contribution of 27.5% of the total hectareage and 20% of the production, India is the world's largest producer of rapeseed-mustard. However, the global average of 1408 kg/ha was far above the plateaued average productivity of 900 kg/ha that persisted in India (Lavanya *et al.*, 2022). Major states producing Rapeseed-Mustard are Rajasthan, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat, and West Bengal. Mustard is second important oilseed crop in India after Groundnut contributing to about 25 per cent of countries total oilseed production. In India the area under mustard crop is 6.86 million ha producing about 9.12 million tonnes of seeds with an average productivity of 1331 kg/ha and Area under cultivation in Rajasthan was 3.08 million ha, having production of 4.20 million tonnes and productivity of 1366 kg/ha (Anonymous, 2021). The percentage of oil varies from 36% to 48%. The seed and oil are used as a garnish when making pickles and to season curries, vegetables, and other foods. They also serve as a food preservative. All over northern India, the oil is used to prepare food for human consumption, particularly for frying. It is used in the lubrication, lubricant, and biofuel industries. The oil seed cake is used for manuring and as cattle feed. Young plants' leaves and stems are used as green vegetables

because they provide enough sulphur and minerals for the diet, and its green stems and leaves make a superior source of green fodder for livestock. Botanically Indian Mustard, known as *Brassica juncea* (L. Czern and Coss) belongs to cruciferous family or Brassicaceae and is an annual herb (Roy *et al.*, 2012). It is an amphidiploid self-pollinated species with chromosome number $2n=4x=36$ (Nagaharu, 1935). Mustard has been cultivated in many parts of Eurasia for centuries and is suitable for subtropical and temperate climate cultivars. Its main origin is Central Asia (north-western India), followed by eastern India, central and western China, Myanmar, and Iran and its Near East (Jeromela *et al.*, 2008). The area under mustard production in India accounts to 6.82 million hectares with production of 10.95 million tonnes in year 2020-21. (Source: DES, Ministry of Agriculture & Farmers Welfare, Government of India, 2021-22). In terms of area and mustard production, Rajasthan comes in first place in 2020–21, followed by Haryana and Madhya Pradesh. As of 2020–21, 2.23 million tonnes of mustard will be produced in Uttar Pradesh on an area of 0.91 lakh hectares, with a productivity of 1605 kg/ha.

Genetic resources from plants, animals, and microorganisms are known as “germplasm,” and they are used in breeding and research programmes to create new varieties that are adapted to shifting environmental conditions and satisfy consumer demand for food. Plant breeders can create new varieties that are more resistant to stress factors by evaluating germplasm to identify desirable traits for environments and production systems. Additionally, it protects crop genetic diversity, which is essential for food security and sustainable agriculture. CIMMYT and IRRI are two organisations that use germplasm evaluation for breeding programmes to create new strains with increased yield potential, drought tolerance, and disease resistance. A plant breeder needs germplasm, which is the basic material needed to start a breeding programme and contains genetic diversity for both quantitative and qualitative traits. Plant breeders must be aware of how mustard germplasm is categorised for these traits in order to choose and improve the crop. Any crop improvement programme requires the quantification of genetic variability for economically significant qualitative and quantitative traits. Breeders can start a successful breeding programme by choosing superior parents with the help of their understanding of genetic progress and heritability. Therefore, a key component of any yield improvement programme is the identification of superior parents with better heritability and genetic advance for various traits (Khan *et al.*, 2005).

Materials and Methods

To comprehend the genetic variability, heritability, of

Indian mustard genotypes, the current study, was conducted. The present investigation was done to understand the genetic variability, heritability present among Indian mustard genotypes. The investigation was carried out at Central Research Farm (CRF), Department of Genetics and Plant breeding, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj during the *Rabi* season of 2022. The experiment was set up using a Randomized Block Design (RBD). The Fisher and Yates, 1936 method was used to statistically analyse the data. Johanson *et al.*, formulae was used to calculate GCV and PCV (1955). Heritability (in the broad sense) was eliminated by the formula Burton and Devane deduced (1953). The details of genotype used in experiment has been enlisted below in table-1.

Results and Discussion

Analysis of Variance : For the purposes of the experimental design, analysis of variance was performed on the mean sum squares data for 14 characters. Table-2 displays the variance analysis for the various characters that was calculated. For all the studied characters, the analysis of variance revealed highly significant differences ($=0.01$ & 0.05) among 20 genotypes, indicating that there is a sizable amount of genetic variation among the Indian mustard germplasms. Additionally, it demonstrated the range of mustard genetic improvement through selection. The data on the values of different characters and the analysis of variance showed significant differences among genotypes for all 14 characters indicating that the material has adequate genetic variability to support the breeding programme for improving the pod yield of Indian mustard. These results agreed with the studies conducted by Roy *et al.* (2011), Iqbal *et al.* (2019), Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022).

Genetic parameters : From table-3, Wide range of differences for GCV were observed which varied from 1.33% (Oil content) to 21.53% (Number of secondary branches) indicating considerable amount of variability present among the genotypes. PCV varied from 1.98% (oil content) to 22.85% (number of secondary branches). Comparison of coefficient of variance indicated that the phenotypic coefficient of variance (PCV) was higher than their corresponding genotypic coefficient of variance (GCV) for all the characters which indicated effect of environment on the characters expression. Similar results were concluded earlier by Roy *et al.* (2011), Iqbal *et al.* (2019), Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022).

High GCV and PCV was recorded for number of

Table-1 : Genotypes Details.

Sl.No.	Genotypes	Sl.N.	Genotypes	Sl. No.	Genotypes	Sl.No.	Genotypes
1.	RH-1	6.	JM-2 (Jawahar mustard)	11.	GM-1 (Gujrat mustard)	16.	DRMR-1165-40
2.	RH-781	7.	Brijraj	12.	Pusa Jai Kisan	17.	Nav gold
3.	RLM-619	8.	RH-189	13.	JM-1 (Jawahar mustard)	18.	PM-21 (Patan mustard)
4.	PBR-297	9.	RH-406	14.	JDM-5	19.	NRCDR-02 (check 1)
5.	CS-60	10.	Pusa Mahak	15.	Jagannath	20.	NRCHB-101 (check 2)

Table-2 : Analysis of Variance (ANOVA) for 14 characters in Mustard.

Sl. No.	Source	Mean Sum of Squares (MSS)		
		Replication	Treatment	Error
	Degrees of freedom	n=2	n=19	n=38
1.	Days to 50% flowering	0.60	9.719**	2.74
2.	Days to maturity	26.60	23.308*	9.86
3.	Number of Primary Branches	0.010	1.014**	0.02
4.	Number of secondary branches	0.3670	23.496**	0.96
5.	Siliqua length (cm)	0.2920	0.28**	0.10
6.	Number of siliquae per plant	546.7370	4040.128*	188.35
7.	Plant height (cm)	457.97	537.515**	128.85
8.	Test weight (g)	0.0160	0.238**	0.06
9.	Number of seeds per siliqua	0.0530	3.41*	0.91
10.	Main Raceme length (cm)	34.5330	28.888**	11.53
11.	Seed yield per plant (g)	0.0760	6.13*	0.30
12.	Biological yield (g)	6.1850	9.877**	3.49
13.	Harvest Index (%)	2.3560	134.463**	10.00
14.	Oil content (%)	0.5820	1.025**	0.29

**, * Significant at 1% and 5% level of significance respectively.

Table-3 : Genetic Parameters for 14 characters of 20 Mustard genotype.

Sl. No.	Characters	Range	GCV	PCV	h ² (Broad Sense)	Genetic Advancement 5%	Genetic Advancement as % of Mean 5%
1.	Days to 50% flowering	63.67-70.33	2.28	3.36	45.91	2.13	3.18
2.	Days to maturity	121.33-129.67	1.69	3.02	31.24	2.44	1.94
3.	Number of Primary Branches	4.33-6.67	10.27	10.61	93.67	1.15	20.48
4.	Number of secondary branches	7.93-17.53	21.53	22.85	88.73	5.32	41.77
5.	Siliqua length (cm)	5.31-6.37	4.25	6.86	38.37	0.31	5.42
6.	Number of siliquae per plant	154.33-267.93	17.69	18.95	87.21	68.93	34.04
7.	Plant height (cm)	137.47-181.27	7.05	9.83	51.39	17.24	10.41
8.	Test weight (g)	3.37-4.23	6.56	9.19	50.92	0.36	9.64
9.	Number of seeds per siliqua	10.33-14.40	7.43	10.73	47.97	1.30	10.61
10.	Main Raceme length (cm)	51.20-62.80	4.17	7.21	33.42	2.86	4.96
11.	Seed yield per plant (g)	8.53-13.35	13.45	14.44	86.85	2.68	25.82
12.	Biological yield (g)	20.17-27.45	6.51	10.58	37.89	1.85	8.26
13.	Harvest Index (%)	37.06-61.16	13.81	15.38	80.59	11.91	25.54
14.	Oil content (%)	36.20-38.10	1.33	1.98	45.32	0.68	1.84

secondary branches only. Moderate GCV was recorded for harvest index, number of siliquae per plant, number of primary branches and seed yield per plant. Low GCV was recorded for biological yield, test weight, number of seeds per siliquae, main raceme length, siliquae length, plant height, days to 50% flowering, days to maturity and oil content.

High GCV and PCV was recorded for number of secondary branches only. Moderate PCV and GCV was

recorded for number of siliquae per plant, seed yield per plant and harvest index in mustard was earlier reported by Roy *et al.* (2011), Iqbal *et al.* (2019), Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022). Low PCV and GCV were recorded for Plant height, number of primary branches, days to 50% flowering, days to maturity, siliquae length, number of seeds per siliquae, main raceme length and oil content was earlier concluded

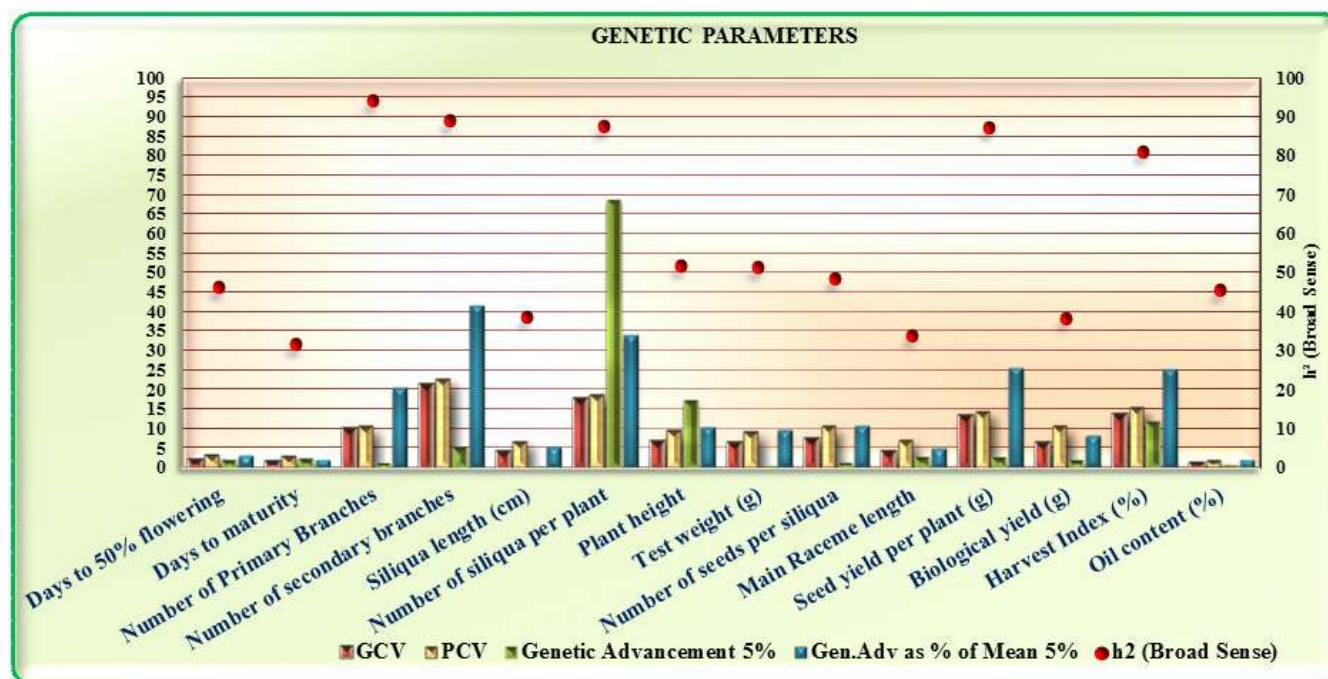


Figure-1 : Histogram of Genetic variability parameters for 14 characters of 20 Indian mustard genotype.

by Roy *et al.* (2011), Iqbal *et al.* (2019), Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022). Moderate PCV was recorded for secondary branches, test weight, biological yield was earlier reported by Roy *et al.* (2011), Iqbal *et al.* (2019), Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022) Chauhan *et al.*, (2023). The results obtained for PCV and GCV showed that there is considerable possibility of further improvement through hybridization followed by appropriate selection for these characters.

Genetic variability : In the present investigation, high heritability estimates have been observed for number of primary branches, number of siliquae per plant, harvest index, number of secondary branches and seed yield per plant in mustard germplasm. According to Panse and Sukhatme (1957) such characters are pre-dominantly governed by additive gene action and could be improved through individual plant selection owing to their high heritability values. Similar results for high heritability for number of primary branches was reported earlier by Roy *et al.* (2011), Iqbal *et al.* (2019), Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022). Similar conclusion for high heritability for number of siliquae per plant and harvest index was given by Akabari and Niranjana (2015) and Yadav and Pandey (2018).

The genetic advance as percentage of mean

provides an idea of the amount of progress that can be achieved by selection for the concerned trait. High genetic advance as percentage of mean was estimated for number of siliquae per plant only. However, moderate values were observed for plant height and harvest index. Rest character had low estimates of genetic advance as percentage of mean. Similar results were concluded by Roy *et al.* (2011), Iqbal *et al.* (2019), Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022).

Heritability estimates are typically affected by the type of genetic material, sample size, sampling technique, execution of the experiment, calculation method, and effect of linkage, among other factors. Heritability estimates combined with genetic progress were found to be more accurate at predicting the response to selection than heritability estimates alone, according to Johanson *et al.*, (1995).

In the present study, high estimate of heritability coupled with high GCV and high genetic advance as percent of mean was recorded for number of secondary branches. High estimate of heritability coupled with moderate GCV and high genetic advance as percent of mean was recorded for harvest index, number of siliquae per plant, seed yield per plant and number of primary branches. These traits are governed by additive gene effects and therefore, may be improved through direct selection. Similar findings were concluded by Roy *et al.* (2011), Yadav and Pandey (2018), Iqbal *et al.* (2019),

Mahanta *et al.* (2019), Saiyad *et al.* (2020), Yadav *et al.* (2020), Chakroborty *et al.* (2021), Nishad *et al.* (2022), Chauhan *et al.*, (2023).

Conclusions

Analysis of variance showed significant variation among different genotypes for all characters studied. High estimate of heritability coupled with high GCV and high genetic advance as percent of mean was recorded for number of secondary branches. High estimate of heritability coupled with moderate GCV and high genetic advance as percent of mean was recorded for harvest index, number of siliquae per plant, seed yield per plant and number of primary branches. This indicates closeness of respective σ^2_p and σ^2_g value thereby low environmental effect on expression of these characters. Such values may be attributed to the additive gene effects and direct selection for these traits would be fruitful.

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Effect of Bio-Fortification in Pearl Millet (*Pennisetum glaucum* L.) through Micronutrients

Ankit Kasania, P.K. Sharma, Mahaveer Prasad Ola*, Babu Lal Choudhary and Abhinav

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan-303012

*Corresponding Author Email : mahaveerprasadola37@gmail.com

Abstract

The field investigation was conducted during the *kharif* season of 2022-2023 at Agricultural Research Farm, Vivekananda Global University, Jaipur. The experiment consisting of nine treatments was laid out in Randomized Block Design with three replications. All most all the characters show significant difference among treatments except plant population at 20 DAS, plant height at 20 DAS and dry matter accumulation at 20 DAS. In pearl millet, plant height (cm), dry matter accumulation (g m⁻²), chlorophyll content (mg g⁻¹) and yield attributing character- number of effective tillers plant⁻¹, length of ear head (cm), girth of ear head (mm), grain weight earhead⁻¹ (g) were found superior in soil application of ZnSO₄ @ 25kg/ha + 0.5% FeSO₄ Foliar spray at tillering stage; 20-25 DAS (T7). Maximum grain yield (2578.53 kg ha⁻¹), stover yield (4519.93 kg ha⁻¹) and biological yield (7098.46 kg ha⁻¹) were also obtained in treatment of soil application of ZnSO₄ @ 25kg/ha + 0.5% FeSO₄ Foliar spray at tillering stage; 20-25 DAS (T7).

Key words : Growth, treatment and yield.

Introduction

The importance of micronutrients has been recognized during the past four decades when wide spread micronutrient deficiencies particularly that of zinc were observed in major part of the country, where intensive agriculture is adopted. Micronutrients are not only important for more crop productivity, but also important for sustaining human and animal health. It is well known fact that zinc is now considered as fourth most important yield limiting nutrient after nitrogen, phosphorus and potassium. Increasing zinc concentration in food crops, resulting better crop production and improved human health is an important global challenge. Iron plays a vital role in the formation of plant chlorophyll. Iron containing plant haemoglobins are another promising target for altering iron content in plant-based foods. Plant haemoglobin is similar to the human haemoglobin, with iron binding capacity and is most commonly found in nodulating legumes (nitrogen fixing plants) (Kundu *et al.*, 2003).

Bio fortification refers to the genetic improvement of key food crops with more nutrient content. It differs from fortification (addition of exogenous nutrients as in iodized salt) by improving the nutrient status of crops at source through agricultural interventions viz. Agronomy, Breeding and Biotechnology. Now a day in pearl millet, some of the hybrids and varieties with high iron and zinc content are released. Bio fortified hybrids or varieties of pearl millet contain higher amount of iron (73.0 ppm) and zinc (41.0 ppm) as compared to 45-50 ppm iron and 30-35 ppm zinc in popular hybrids or varieties grown by the

farmers. Iron is the second most abundant metal in nature and fourth most abundant element in the earth crust. Because of their iron absorption efficiency, cereals provide an important entry point for iron into the food chain, however, the concentration of iron in the grain are quite low compared to meat-iron sources.

Soil application of fertilizer is the easiest way to overcome micronutrient deficiency; however, it is not always successful and sustainable due to agronomic and economic factors such as reduced availability of micronutrient element due to topsoil drying, subsoil constraints, disease interactions and cost of fertilizer in developing countries. Micronutrient deficiency status in north India in early eighties was different than now after four decades. Zinc deficiency remained a major problem all over country. Zinc deficiency has increased from 44 per cent to 48 per cent and expected to further increase up to 63 per cent by 2025 as most of the marginal soils are showing higher response to added zinc (Singh 2006). Micronutrient deficiencies are gaining much importance in the World, not only for their role in sustaining higher crop yields but such increased nutritional deficiency in soil, seed and feed, is more affecting animal and human health.

Agronomic fortification with foliar application of micronutrients particularly zinc and iron not only increase the yield but also nutrient quality of pearl millet for obtaining good economic return and also nutritional security. So, enrichment of pearl millet with zinc and iron fortification is one of the options to improve the quality.

Materials and Methods

The experiment was conducted during *kharif* season of 2022-23 at Agricultural Research Farm, Vivekananda Global University, Jaipur. The present experiment consisting of 9 treatments was carried out in randomized block design replicated three times. The seeds were line sown in furrows opened with the help of a wooden marker at a row spacing of 45 cm $\times$ 15 cm, using 4 kg seeds ha⁻¹ and furrow were covered immediately after sowing. The recommended rate of nutrients (N, P, K 60, 30 and 30 kg ha⁻¹) were applied in the form of urea, di ammonium phosphate and muriate of potash. The treatments along with their symbols are given in Table 1 and other details are given below.

Statistical analyses : In order to test the significance of variation in experimental data obtained for various treatment effects, data were statistically analyzed as described by Cochran and Cox (1963). The critical difference was calculated to assess the significance of treatment mean wherever the 'F' test was found significant at 5 per cent level. To estimate various characters was computed. Further, in order to establish cause and effect and relationship were calculated.

Results and Discussion

Effect on growth attributes : Plant growth depends upon availability of nutrients which help in enlargement of cells. Growth of pearl millet at various stages in terms of plant height, dry matter accumulation plant⁻¹, differ significantly (Table 2). Plant population (m⁻¹ row length) did not vary significantly at 20 DAS and at harvest but numerically better population was observed in the Soil application FeSO₄ @ 20 kg/ha + 0.5% FeSO₄ spray at tillering stage; 20-25 DAS (T9) treatments. The increase in plant height from sowing to 20 DAS was 19.67 to 31.47 cm among different treatments and during 21-40 DAS the range was 33.33 to 34.5 cm and during 41-60 DAS the range was 108.17 – 113.5 cm, thereafter the increase was slow from 61 DAS -harvest stage. At harvest, the plant height in treatment T3, T4, T5, T2, T9, T8, T6 and T7 was 2.0, 4.03, 7.07, 8.10, 10.10, 12.10, 18.20 and 19.17 cm more as compared to the control (T1). The rate of dry matter accumulation g m⁻² was maximum between 21-40 DAS and 41- 60 DAS compared to sowing to 20 DAS and 61 DAS - harvest among all the treatments. At harvest, dry matter accumulation was 875.50 g m⁻² (T7), 865.20 g m⁻² (T6), 860.05 g m⁻² (T8), 854.90 g m⁻²(T9), 839.45 g m⁻² (T5), 827.09 g m⁻² (T2), 815.76 g m⁻² (T4), 800.31 g m⁻² (T3) and values were 115.36, 105.06, 99.91, 94.76, 79.31, 66.95, 55.62, 40.17 g m⁻² higher than control (760.14 g m⁻²), respectively. The enhancement in chlorophyll content due to Soil application of ZnSO₄ @ 25kg/ha +

0.5% FeSO₄ Foliar spray at tillering stage; 20-25 DAS (T7) was 18.38 per cent as compared to control. At 60 DAS, chlorophyll content was 2.77 mg g⁻¹ (T7), 2.74 mg g⁻¹ (T6), 2.72 mg g⁻¹ (T8), 2.69 mg g⁻¹ (T9), 2.58 mg g⁻¹ (T5), 2.54 mg g⁻¹ (T2), 2.48 mg g⁻¹ (T4), 2.42 mg g⁻¹ (T3) compared to 2.34 mg g⁻¹ control. This might be due to the adequate supply of micronutrient (Zn & Fe) to the plants. Similar results have been found by Jain *et al.* (2001) in Pennisetum glaucum, Dadhich and Gupta (2005) on pearl millet, Anonymous (2016) in pearl millet, Yadav *et al.* (2014) in wheat, Tiwari *et al.* (1982) in potato crop, Detroja *et al.* (1995) in fenugreek, Baque *et al.* (2006) in wheat, Thalooth *et al.* (2006) in mungbean, Jakhar *et al.* (2006) in pearl millet and Dhaliwal *et al.* (2013) in maize.

Effect on yield and yield attributes : In the present study, number of effective tillers plant⁻¹, length of ear head (cm), girth of ear head (mm), grain weight earhead⁻¹ (g), test weight (g), grain, stover and biological yield (kg ha⁻¹) were significantly higher in T7 treatment (Soil application of ZnSO₄ @ 25kg/ha + 0.5% FeSO₄ Foliar spray at tillering stage; 20-25 DAS) than the control therefore, resulting in higher grain yield (Table 3 and Fig 1). Similarly, grain yield was 669.63 kg ha⁻¹ (T7), 515.10 kg ha⁻¹ (T6), 363.60 kg ha⁻¹ (T8), 272.70 kg ha⁻¹ (T9), 212.10 kg ha⁻¹ (T5), 121.20 kg ha⁻¹ (T2), 80.80 kg ha⁻¹ (T4), 60.60 kg ha⁻¹ (T3) higher than control (Table-3). Such enhancement effect might be attributed to the favorable influence of these micro nutrients (Zn and Fe) on metabolism and biological activity and its stimulatory effect on photosynthetic pigments and enzyme activity which in turn encourage vegetative growth of plants and finally yield (Michail *et al.* 2004). Balanced nutrition due to combined use of application time of micronutrient throughout the crop period probably resulted in better growth, enhanced yield attributes and finally yield (Raghuwanshi *et al.* 1997). The stover yield was highest in Soil application of ZnSO₄ @ 25 kg/ha + 0.5% FeSO₄ Foliar spray at tillering stage; 20-25 DAS (T7) treatment (4519.93 kg ha⁻¹) and lowest in the control (3211.27 kg ha⁻¹). The treatment T6, T8, T9, T5, T2, T4 and T3 showed 1127.47 kg ha⁻¹, 1031.83 kg ha⁻¹, 916.07 kg ha⁻¹, 619.10 kg ha⁻¹, 473.13 kg ha⁻¹, 322.13 kg ha⁻¹ and 261.73 kg ha⁻¹ more stover yield than the control, respectively. This increase in the stover yield might be attributed to the increase in plant height, leaf area and dry matter production plant⁻¹. The biological yield varied from 5120.17 kg ha⁻¹ to 7098.46 kg ha⁻¹ among different treatments and T7 treatment showed maximum biological yield with a value of 7098.46 kg ha⁻¹. The treatment T6, T8, T9, T5, T2, T4 and T3 showed 1642.57 kg ha⁻¹, 1395.43kg ha⁻¹, 1188.77kg ha⁻¹, 831.20kg ha⁻¹, 594.33kg ha⁻¹, 402.93kg ha⁻¹ and 322.33 kg ha⁻¹ more biological yield than the control, respectively. The remarkable improvement in yield attributes owing to different

Table-1 : Treatments along with their symbols.

S. No.	Treatments	Symbols
1.	Control	T ₁
2.	Soil application ZnSO ₄ @ 25kg/ha	T ₂
3.	Soil application FeSO ₄ @ 20kg/ha	T ₃
4.	0.5% ZnSO ₄ Foliar sprat at tillering stage 20-25 DAS	T ₄
5.	0.5% FeSO ₄ Foliar spray at tillering stage (20-25 DAS)	T ₅
6.	T ₂ + 0.5% ZnSO ₄ Foliar spray at tillering stage DAS	T ₆
7.	T ₂ + 0.5% FeSO ₄ Foliar spray at tillering stage (20-25 DAS)	T ₇
8.	T ₃ + 0.5% ZnSO ₄ Foliar sprat at tillering stage 20-25 DAS	T ₈
9.	T ₃ + 0.5% FeSO ₄ spray at tillering stage (20-25 DAS)	T ₉

Table-2 : Effect of bio-fortification through micronutrients on plant population m⁻¹ row length, plant height and dry matter accumulation (g/m²) of pearl millet.

Treatment	Plant population (m ⁻¹ row length)		Plant height (cm)				Dry matter accumulation (g m ⁻²)			
	At 20 DAS	At harvest	At 20 DAS	At 40 DAS	At 60 DAS	At harvest	At 20 DAS	At 40 DAS	At 60 DAS	At harvest
T1	8.67	8.10	19.67	53.00	161.17	171.70	22.25	164.80	607.70	760.14
T2	9.15	8.10	23.60	58.00	168.30	178.77	23.49	173.04	636.54	827.09
T3	9.33	8.76	25.57	55.00	163.20	173.70	22.97	169.95	630.36	800.31
T4	8.33	8.00	26.57	57.00	163.20	175.73	23.38	172.01	619.03	815.76
T5	9.00	8.67	27.53	58.00	169.30	179.80	23.69	175.10	643.75	839.45
T6	9.55	9.07	27.53	63.00	176.47	189.90	25.24	188.49	679.80	865.20
T7	9.33	9.00	30.50	65.00	178.50	190.87	25.75	190.55	684.95	875.50
T8	9.55	9.00	31.47	61.00	173.40	183.80	24.72	183.34	673.62	860.05
T9	9.71	9.03	28.53	60.00	171.37	181.80	24.21	180.25	667.44	854.90
SEm ±	0.35	0.26	0.16	0.13	0.05	0.17	0.02	0.17	0.57	0.66
CD (P=0.05)	1.06	0.97	0.49	0.40	0.15	0.51	0.07	0.50	1.73	1.99

Table-3 : Effect of bio-fortification through micronutrients on chlorophyll content, yield and yield attributes of pearl millet.

Treatment	Chlorophyll content (mg g ⁻¹) at 60 DAS	Yield attributes					Yield (kg ha ⁻¹)			
		Number of effective tillers plant ⁻¹	Length of ear head (cm)	Girth of ear head (mm)	Grain weight ear head ⁻¹ (g)	Test weight (g)	Grain yield	Stover yield	Biological yield	Harvest index
T1	2.34	1.00	13.95	57.57	6.97	8.13	1,908.90	3,211.27	5,120.17	37.28
T2	2.54	1.50	15.05	63.63	7.58	9.25	2,030.10	3,684.40	5,714.50	35.53
T3	2.42	1.30	14.05	59.59	7.17	8.54	1,969.50	3,473.00	5,442.50	36.19
T4	2.48	1.30	14.55	60.60	7.37	8.85	1,989.70	3,533.40	5,523.10	36.03
T5	2.58	1.70	16.05	65.65	7.68	9.66	2,121.00	3,830.37	5,951.37	35.64
T6	2.74	1.91	17.66	74.74	8.38	10.47	2,424.00	4,338.73	6,762.73	35.85
T7	2.77	1.97	18.06	76.76	8.59	10.78	2,578.53	4,519.93	7,098.46	36.33
T8	2.72	1.94	17.36	70.70	8.18	10.17	2,272.50	4,243.10	6,515.60	34.88
T9	2.69	1.90	16.76	68.68	7.98	9.86	2,181.60	4,127.33	6,308.93	34.58
SEm ±	0.01	0.02	0.06	0.22	0.02	0.03	7.18	15.35	22.37	0.06
CD (P=0.05)	0.01	0.04	0.18	0.65	0.05	0.09	21.71	46.43	67.64	0.95

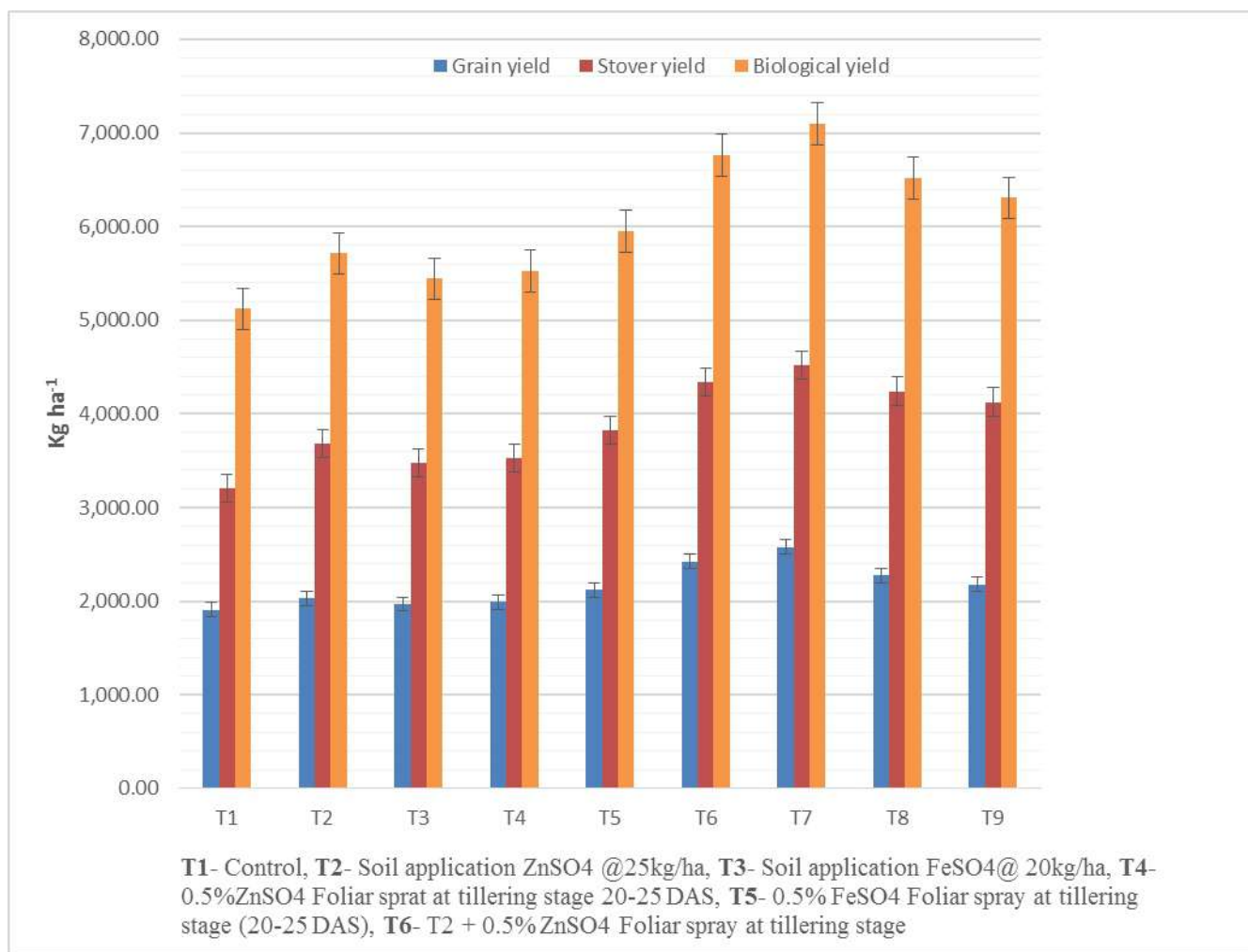


Fig.-1 : Effect of bio-fortification through micronutrients on yields of pearl millet.

combinations of micro nutrients has resulted in increased grain yield, stover yield and biological yield over the control. These findings corroborate the results of Patil *et al.* (2006) in maize, Pervaiz *et al.* (2003) in wheat, Thavaprakash and Velayudham (2009), Khambalkar *et al.* (2012).

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Seasonal Incidence of Girdle Beetle, *Obereopsis brevis* in Soybean [*Glycine max* (L.) Merrill]

Devesh Parmar^{1*}, H.R. Chaudhary², B.K. Patidar², H.P. Meghwal² and Laxman Singh Saini³

¹Department of Entomology, RCA, MPUAT, Udaipur, Rajasthan

²Professor, Department of Entomology, AU, Kota, Rajasthan

³Department of Entomology, SKNAU, Jobner, Rajasthan

*Corresponding Author Email : 0909deveshparmar@gmail.com

Abstract

The present investigation on "Seasonal Incidence of girdle beetle in Soybean [*Glycine max* (L.) Merrill]" was conducted during *kharif*, 2019 at Agricultural Research Station, Ummedganj, Agriculture University, Kota. The results revealed that the occurrence of girdle beetle was initiated during second week of August. The girdle beetle infestation found in increasing trend during periodical observations and reached its peak in first week of October. The correlation study reveals that the girdle beetle infestation was significantly negative correlated with rainfall. Girdle beetle has been observed predominant insect pest and its infestation increases as the crop stages up to 26.20 per cent.

Key words : seasonal, incidence, girdle beetle, correlation, peak, infestation, per cent, predominant.

Introduction

Soybean [*Glycine max* (L.) Merrill] is one of the most important oilseed commercial crop of India. It is world's most useful and cheapest sources of protein (Akinyele and Harshbarger, 1983), vitamins, minerals, carbohydrate and other ingredients. Soybean is a legume crop mainly but seeds widely used as oilseed. It contains 40% protein, well balanced in essential amino acids; 20% oil, rich in poly unsaturated fats specially Omega 6 and Omega 5 fatty acids; 6-7% total minerals; 5-6% crude fiber and 17-19% carbohydrates (Chauhan and Joshi, 2005). Madhya Pradesh, Maharashtra and Rajasthan covers an area 52.4, 39.3, and 9.3 lakh ha, respectively. The Rajasthan state stands third occupying the soybean area and second in productivity (1244 kg/ha). The crop covers 92 to 93 per cent area and production by these three states Madhya Pradesh, Maharashtra and Rajasthan (Anonymous, 2018).

There are many problems in cultivation of soybean in India as well as Rajasthan, as all stages of this crop are prone to heavy infestation by insect-pest complex. The crop is infested by more than 275 insect pests throughout its growth stage from germination to maturity (Babu *et al.*, 2017). In India, 20 insect species have been recorded major pests infesting soybean crop (Singh and Singh, 1990). Among borers, girdle beetle (*Obereopsis brevis* Swed.) is predominant, among defoliators, tobacco caterpillar (*Spodoptera litura* Fabricius) and green semiloopers (*Chrysodeixis acuta* Walker) are predominant. Immature stages (larva or caterpillar) of both tobacco caterpillar and green semilooper damage

the crop mostly at vegetative stage and in severe case, it completely defoliates the crop resulting drastic yield loss. *Spodoptera litura* larvae even damage to soybean pods also (Chaturvedi *et al.*, 1998 and Singh *et al.*, 2000). Therefore, the present study of the insects-pests and their relative occurrence with reference to different crop stages was conducted, to determine the management strategy pertaining to their nature of damage at most vulnerable or susceptible crop stage so that feasible and economic control measure can be determined for their effective and economic management in the crop.

Materials and Methods

The field experiment to investigate the Seasonal Incidence of girdle beetle in Soybean [*Glycine max* (L.) Merrill]" was conducted during *kharif*, 2019 at Agricultural Research Station, Ummedganj, Kota. The experiment was laid out in plots measuring 4.2 m x 5 m (21 m²) replicated thrice. Soybean variety JS-335 was sown in the second week of July, *kharif* 2019 after onset of monsoon which is a general practice of sowing in the region adopting all agronomical practices required for raising the crop. Observation of girdle beetle, *obereopsis brevis* was recorded from "earmarked one meter row length area" at five places plot wise weekly started at 7 days of germination. The total as well as infested plants were counted and per cent infestation was worked out :

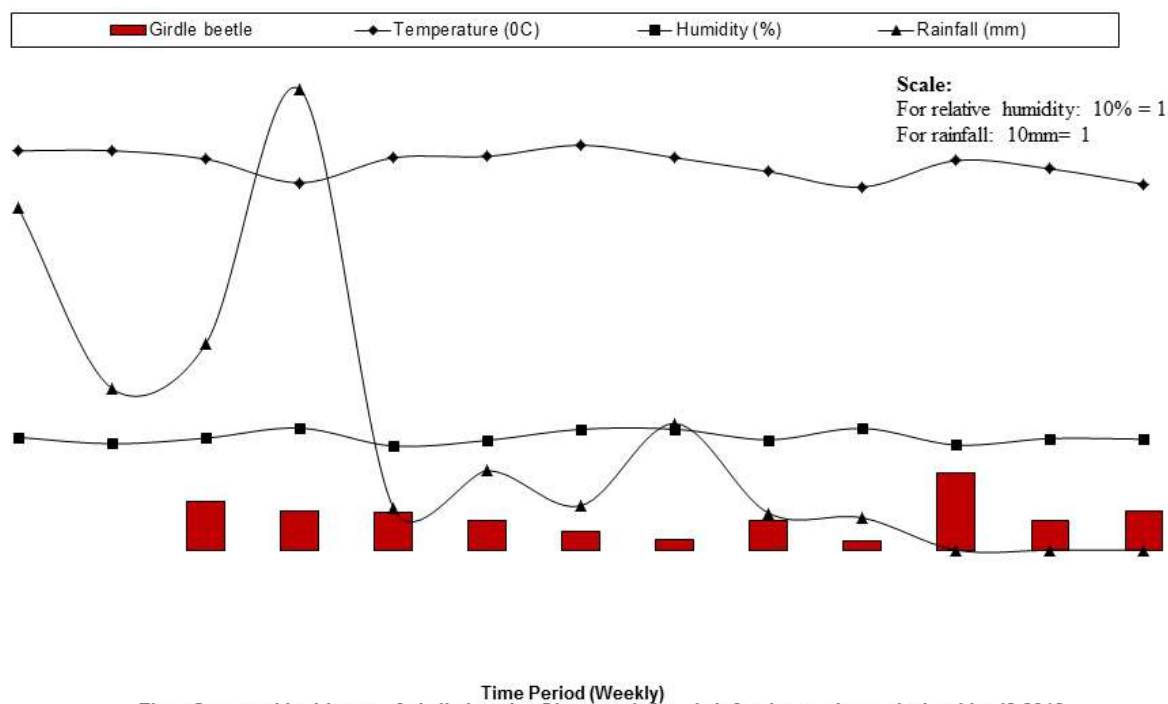
$$\text{Per cent infestation} = \frac{\text{Number of plants infested}}{\text{Total number of plants}} \times 100$$

Simple correlation was worked out between the population of insect pests and abiotic factors by the Karl

Table-1 : Seasonal incidence of girdle beetle, *Obereopsis brevis* infesting soybean during kharif, 2019.

SMW No.	Period From - To	Mean temp. (°C)	Mean relative humidity (%)	Rainfall (mm)	Girdle beetle, <i>Obereopsis brevis</i> (% infested plant)	Girdle beetle, <i>Obereopsis brevis</i> (% infested plant in particular week)
30	23 July – 29 July	28.7	81.0	246.0	0.00	0.00
31	30 July – 05 Aug	28.7	76.4	116.0	0.00	0.00
32	06 Aug - 12 Aug	28.1	80.5	148.5	3.44	3.44
33	13 Aug - 19 Aug	26.4	87.7	331.0	6.21	2.77
34	20 Aug - 26 Aug	28.2	74.8	30.0	8.96	2.75
35	27 Aug – 2 Sep	28.3	78.9	57.0	11.04	2.08
36	03 Sep – 09 Sep	29.1	86.9	32.0	12.41	1.37
37	10 Sep – 16 Sep	28.2	86.9	91.0	13.11	0.70
38	17 Sep – 23 Sep	27.2	79.3	26.5	15.18	2.07
39	24 Sep – 30 Sep	26.1	87.5	23.2	15.87	0.69
40	1 Oct. - 7 Oct.	28.0	75.5	0.0	21.37	5.50
41	8 Oct – 14 Oct	27.4	80.2	0.0	23.44	2.07
42	15 Oct – 21 Oct	26.3	79.7	0.0	26.20	2.76
Coefficient of correlation (r) for population and mean atm. temp.					-0.496	-
Coefficient of correlation (r) for population and mean RH					-0.020	-
Coefficient of correlation (r) for population and total rainfall					-0.721*	-

* Significant at 5% level of significance

Fig. : Seasonal incidence of girdle beetle, *Obereopsis brevis* infesting soybean during kharif, 2019

Pearson's coefficient of correlation formula (Steel and Torry, 1980):

Where,

$$r_{xy} = \frac{\frac{\sum XY}{n} - \frac{\sum X}{n} \frac{\sum Y}{n}}{\sqrt{\left(\frac{\sum X^2}{n} - \frac{(\sum X)^2}{n} \right) \left(\frac{\sum Y^2}{n} - \frac{(\sum Y)^2}{n} \right)}}$$

r_{xy} = Simple correlation coefficient

X = Variable i.e. abiotic component.

(Average temperature, relative humidity and total rainfall)

Y = Variable i.e. mean number of insect pests per plant

n = Number of observations.

The correlation coefficient (r) values were subjected to the test of significance using t-test :

$$t = \frac{r}{\sqrt{\frac{1-r^2}{n}}} \sim t_{n-2} \text{ d.f.}$$

The calculated t-value obtained was compared with tabulated t-value at 5% level of significance.

Result and Discussion

The incidence of girdle beetle commenced in the second week of August with 3.44 per cent infested plants. The maximum infestation of girdle beetle was observed (5.5%) during first week of October. The overall girdle infestation in soybean crop was recorded as 26.20 per cent. The per cent girdle beetle infestation exhibited negatively significant correlation with mean rainfall ($r = -0.721$), while, negatively non significant correlation with temperature ($r = -0.496$) and mean relative humidity ($r = -0.020$). The results corroborate the findings of Shrivastava *et al.* (1972) girdle beetle damaged the soybean plants to the extent of 13.7 to 42.2 per cent from August to October. Kumar *et al.* (2019), who reported that the infestation of girdle beetle started in 2nd week of August, when crop was 35 days old with 3.08 per cent plant infestation. However, number of infested plants were slowly increased and reached to 9.20 and 15 per cent in 4th week of August and last week of September.

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Effect of Molybdenum and Boron on Growth and Yield of Chickpea (*Cicer arietinum* L.)

Jitendra Samota, P.K. Sharma, Babu Lal Choudhary and Mahaveer Prasad Ola*

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan-303012

*Corresponding Author Email : mahaveerprasadola37@gmail.com

Abstract

A field study on “Effect of Molybdenum and Boron on Growth and Yield of Chickpea (*Cicer arietinum* L.)” was conducted at Vivekananda Global University, Jaipur during *Rabi* season of 2022-23. The experimental results showed that the growth and yield of chickpea were significantly increased due to application of molybdenum and boron. The maximum plant height, dry matter accumulation, number of branches plant⁻¹, number of pods plant⁻¹, number of seeds pod⁻¹, seed yield, straw yield and biological yield (2346, 3652 and 5998 kg ha⁻¹, respectively) of chickpea was obtained with the application of molybdenum @ 2.0 kg ha⁻¹ which was significantly superior as compared to control and application of molybdenum @ 1.0 kg ha⁻¹. Results further showed that application of boron @ 3.0 kg ha⁻¹ recorded highest plant height, dry matter accumulation, number of branches plant⁻¹, number of pods plant⁻¹, number of seeds pod⁻¹, seed yield, straw yield and biological yield (2320, 3678 and 5997 kg ha⁻¹, respectively) of chickpea.

Key words : Boron, chickpea, growth, molybdenum and yield.

Introduction

India has become self-sufficient with respect to the production of cereals but still lags behind with respect to the production of pulses. Pulses are important source of dietary protein and have unique ability of maintaining and restoring soil fertility through biological nitrogen fixation as well as addition of ample amount of residues to the soil. Chickpea (*Cicer arietinum* L.) is considered to be the third most important pulse crop of the world after French bean and field peas. India is the largest producer, importer and consumer of the pulses in the world. In India, it is cultivated in an area about 28.83 m ha with the production of 25.72 m tones and yield of 892 kg ha⁻¹. In Rajasthan, it is

cultivated in 6.15 m ha with the production of 4.31 m tones with the productivity of 701 kg ha⁻¹ (Anonymous, 2022). Average yield of crop in Rajasthan is below the potential yield and low yield of crop is mainly due to cultivation of traditional varieties without or with little fertilization and lack of other improved agronomic practices in marginal lands. The low productivity of chickpea is a matter of great concern to the agriculture planners. In addition to the application of major nutrients, legume crops also require adequate amount of micro nutrients for better growth development and adequate bacterial activity for nodule development. Therefore, an optimum supply of micronutrient under balanced condition is very important for achieving higher productivity.

Molybdenum is an important micronutrient leading to poor seed yield of pulses in molybdenum deficient soils. It is an essential component of the enzyme nitrate reductase, which catalyzes the conversion of NO₃⁻ to NO₂⁻.

Molybdenum is a structural component of enzyme nitrogenase which is actively involved in atmospheric nitrogen fixation by root nodule bacteria in leguminous crops. Molybdenum concentrations in legume nodules can be ten times higher than in leaves. It also acts in enzymes, which bring about oxidation reduction reaction, especially the reduction of nitrate to ammonia prior to amino acids and protein synthesis in the cells of plant. Similarly, Boron content in legumes is higher than the other crops. In general, the requirement of B is higher in dicots (20-70 mg kg⁻¹) than monocots (5-10 mg kg⁻¹). Boron Toxicity in crop plants is likely to occur when the level of hot water soluble boron in the soil exceeds the 5 mg kg⁻¹

level in soil, whereas boron levels of less than 0.5 mg kg⁻¹ are generally not high enough for optimum plant growth. Boron is absorbed as boric acid (H₃BO₃) and borate (H₂BO₃⁻) by plants roots and is transported within the plant by the transpiration stream through xylem and accumulates near the leaf tips and the margins of older leaves. Therefore an experiment on effect of molybdenum and boron on growth and yield of chickpea (*Cicer arietinum* L.) has been undertaken.

Materials and Methods

The field experiment was conducted at Research Farm of Vivekananda Global University, Jaipur during *Rabi* season of 2022-23. This region falls under agro-climatic zone III A of Rajasthan (Semi-arid Eastern Plain Zone). The experiment was laid out in factorial randomized block design with three replications and consisting three treatments of molybdenum (0, 1.0 and 2.0 kg ha⁻¹) and

three treatments of boron (0, 1.5 and 3.0 kg ha⁻¹). The seeds of chickpea variety CSJ-515 were sown on 18th

November, 2022. The sowing was done at row spacing of 30 cm using a seed rate of 80 kg ha⁻¹ by “Kera” method with the help of *desi* plough. The seeds were dropped manually in furrow opened by plough at a depth of 4-5 cm. The soil samples were collected from 0-15 cm depth of soil profile with the help of screw auger before sowing coriander. It was air dried in shade, grinded and analyzed for determination of physical and chemical properties of soil. Soils are loamy sand with 0.21% organic carbon,

132.73 kg ha⁻¹ N, 19.92 kg ha⁻¹ P₂O₅ and 231.76 kg ha⁻¹ K₂O. The total rainfall received during the crop season was 39.5 mm. On the basis of gross plot size the quantity of fertilizer required as per treatment was calculated and weighed for different plots. The recommended dose of N, P₂O₅ and K₂O was applied in the form of DAP, urea and MOP to all plots as basal. The required micronutrients were weighted and dissolved in water @ 500 liters ha⁻¹. The solution was neutralized with 0.5% calcium oxide. Molybdenum was applied in the form of sodium molybdate containing 39% Mo and boron was applied through borax containing 11% boron prior to sowing in the soil as per treatments and applied in furrows before sowing. One hoeing and weeding was done manually at 30 DAS to facilitate aeration and removing the weeds. Three post sowing irrigation were applied through sprinkler. All the plant protection measures were adopted to take healthy crop at maturity stage, after leaving two rows on each side as well as 60 cm along the width of each side, a net plot area was harvested separately for recording the yield. Growth, yield and yield attributes of chickpea were statistically analyzed as guidelines of Panse and Sukhatme (1985).

Results and Discussion

Effect of molybdenum : The growth attributes of chickpea was affected significantly by application of molybdenum. Results revealed that application of molybdenum at 2.0 kg/ha significantly increased plant height and dry matter accumulation at 60, 90 DAS and at harvest and number of branches plant⁻¹ of chickpea. The significant improvement in these characters might also be due to the fact that molybdenum is a component of the enzyme nitrogenase which is essential for the process of symbiotic nitrogen fixation. It is also present in nitrate reductase which is responsible for the reduction of nitrates to ammonia prior to amino acid and protein synthesis in the plant cells causing better growth in terms of plant height and dry matter production. These results corroborate the findings of Yadav *et al.* (2017), Sahare *et al.* (2019) and Kathyayani *et al.* (2021).

The application of molybdenum at 2.0 kg ha⁻¹ produced significantly higher number of pods plant⁻¹, number of seeds pod⁻¹, seed yield, straw yield and biological yield of chickpea which was proved significantly higher as compared to control and application of molybdenum at 1.0 kg ha⁻¹. The increase in yield and yield characters could be attributed to increased size of source and consequently enhanced translocation of photosynthates towards newly formed sinks (pods and seeds). The results on seed and straw yields thus confirmed the trend observed in growth and yield attributing characters with application of molybdenum. The yield of a crop is the cumulative effect of yield attributing characters such as pods per plant, seeds per pod and test weight. Significant improvement in the present study is in close agreement with the findings of Alam *et al.* (2020), Hossain *et al.* (2020), Hoque *et al.* (2021) and Kathyayani *et al.* (2021).

Effect of boron : Application of boron @ 3.0 kg ha⁻¹ recorded significantly higher plant height, dry matter accumulation and number of branches of chickpea as compared to control and application of boron @ 1.5 kg ha⁻¹. This might be due to quick availability of boron to crop during the entire growing season. Boron plays an important role in tissue differentiation and carbohydrate metabolism. It is also a constituent of cell membrane and essential for cell division, maintenance of conducting tissue with regulatory effect on other element. It is also necessary for sugar translocation in plant and development of new cell in meristematic tissue. Such beneficial effect of boron with better edaphic environment available to the crop, might have improved all the growth attributes. Similar finding have also been reported by Praveena *et al.* (2018), Hoque *et al.* (2021) and Kumar *et al.* (2022).

Significantly greater number of pods plant⁻¹, seeds pod⁻¹, seed, straw and biological yields of chickpea was observed with the application of boron @ 3.0 kg ha⁻¹ which was superior to control and application of boron @ 1.5 kg ha⁻¹. Enhanced vegetative growth in terms of number of branches per plant and leaf area provided more site for translocation of photosynthates and ultimately resulted in increment in yield attributes. The beneficial effect of boron on yield attributes may be due to flower development, pollen grain formation, pollen viability, pollen tube growth for proper pollination and seed development. The increase in yield due to application of boron may be attributed to cumulative effect of increase in number of pods and seeds pod⁻¹. The favourable effect of boron on sink component could be attributed to better development of the plants in terms of plant height and dry biomass production leading to

Table-1 : Effect of molybdenum and boron on growth attributes of chickpea.

Treatments	Plant height (cm)				Dry matter accumulation (g plant ⁻¹)				Number of branches plant ⁻¹
	At 30 DAS	At 60 DAS	At 90 DAS	At harvest	At 30 DAS	At 60 DAS	At 90 DAS	At harvest	
Molybdenum (kg ha ⁻¹)									
0	10.15	30.14	51.35	53.01	1.63	5.39	7.94	12.33	7.14
1.0	10.30	36.82	59.23	61.36	1.70	6.82	9.81	14.40	8.64
2.0	10.45	40.54	67.02	68.79	1.74	7.76	11.24	16.26	9.62
SEm ±	0.30	1.01	1.65	1.73	0.05	0.19	0.32	0.36	0.24
CD (P=0.05)	NS	3.04	4.95	5.19	NS	0.56	0.96	1.08	0.72
Boron (kg ha ⁻¹)									
0	10.19	30.31	51.32	53.10	1.64	5.46	7.92	12.39	7.19
1.5	10.29	36.55	59.52	61.47	1.68	6.78	9.90	14.47	8.52
3.0	10.42	40.64	66.76	68.60	1.75	7.72	11.17	16.14	9.68
SEm ±	0.30	1.01	1.65	1.73	0.05	0.19	0.32	0.36	0.24
CD (P=0.05)	NS	3.04	4.95	5.19	NS	0.56	0.96	1.08	0.72

Table-2 : Effect of molybdenum and boron on yield attributes and yields of chickpea.

Treatments	Yield attributes			Yields			
	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	Test weight (g)	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest index (%)
Molybdenum (kg ha⁻¹)							
0	22.01	1.36	145.52	1674	2623	4297	39.00
1.0	27.32	1.76	149.82	2114	3307	5421	39.01
2.0	31.17	1.97	152.03	2346	3652	5998	39.15
SEm ±	0.79	0.04	4.49	62	89	121	0.91
CD (P=0.05)	2.38	0.13	NS	186	266	363	NS
Boron (kg ha⁻¹)							
0	22.30	1.38	145.82	1744	2684	4428	39.33
1.5	27.23	1.71	149.27	2072	3220	5292	39.13
3.0	30.97	2.00	152.28	2320	3678	5997	38.70
SEm ±	0.79	0.04	4.49	62	89	121	0.91
CD (P=0.05)	2.38	0.13	NS	186	266	363	NS

increased bearing capacity due to optimum growth on account of increased in boron application. Our results are in close agreement with the results of Padbhushan *et al.* (2015), Vimalan *et al.* (2017) and Hussain *et al.* (2022).

Conclusions

After conducting the experiment for one year, it was concluded that the application of molybdenum and boron had significant effect on productivity and profitability of chickpea. The application of molybdenum @ 2.0 kg ha⁻¹ produced significantly maximum growth attributes, yield attributes and yield of chickpea. Further, application of boron @ 3.0 kg ha⁻¹ gave significantly higher growth attributes, yield attributes and yield of chickpea. Therefore, application of molybdenum @ 2.0 kg and boron @ 3.0 kg ha⁻¹ may be recommended for higher productivity and higher profitability of chickpea crop.

Competing Interests

Authors have declared that no competing interests exist.

Authors' Contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Effect of Silica and Microbial Consortia on Growth, Yield and Economics of Tomato (*Solanum lycopersicum* L.)

Neha Meena^{1*}, H.L. Bairwa¹, S. Pilania¹, V. Saharan², Gajanand Jat³, R.P. Meena⁴ and Anamika Meena¹

¹Department of Horticulture, RCA, MPUAT, Udaipur, Rajasthan

²Department of MBBT, MPUAT, Udaipur, Rajasthan

³Department of Soil Science and Agricultural Chemistry, MPUAT, Udaipur, Rajasthan

⁴College of Agriculture, Dungarpur, MPUAT, Udaipur, Rajasthan

* Corresponding Author Email : neha.masar2020@gmail.com

Abstract

The present investigation entitled “Effect of Silica and microbial consortia on growth, yield and economics of Tomato (*Solanum lycopersicum* L.)” was carried out at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur. The twelve treatments for the tomato crop were evaluated with three replications under randomized block design. Variety “USM- Kareena (Hybrid)” of tomato was used in this experiment. The results exhibit the significant effect of various treatments on growth, yield and economics of tomato. The growth parameters viz., maximum plant height at 60 DAT, 90 DAT and at harvesting (63.60 cm, 91.90 cm and 126.60 cm), respectively, leaf area index (3.93), number of branches (8.12), 50% flowering (54.12), minimum days to harvest (77.39), stem diameter (1.55 cm) was obtained in treatment T₁₂ (RDF(NPK) 50% +Silica 50 kg ha⁻¹ + silica solubilising bacteria +NPK consortium). Similarly, yield attributes and yield namely maximum number of fruits per plant (18.21), fruit weight (86.88 g), fruit volume (93.33 cc), specific gravity (1.07 g/cc), yield per plant (1.55 kg) and yield per ha (61134 kg ha⁻¹) was recorded with treatment T₁₂ (RDF (NPK) 50% +Silica 50 kg ha⁻¹ + silica solubilising bacteria +NPK consortium).

Key Words : Silica, microbial consortia, growth, yield, economics, tomato, NPK consortia.

Introduction

India's diverse climate ensures the availability of all varieties of fresh fruit and vegetable. It ranks 2nd in vegetable production in the world, after China. As per NHB (3rd Advance estimates) published by NHB, during 2021-22, India produce 204.84 million metric tonnes of vegetables. (Anonymous, 2022)

The tomato, or *solanum lycopersicum* L. is a vegetable crop grown annually all over the world and is a member of the Solanaceae family. Tomato is termed as “functional food” due to rich in antioxidants such as carotenoids, vitamin C, phenolics and tocopherols (Ranieri *et al.* 2004). Consumption of fresh tomatoes and tomato products restrict the development of different types of cancer (Giovannucci 1999). Antioxidants play a potential role in scavenging free radicals and prevent many degenerative and chronic diseases, such as cancer, cardiovascular diseases, cataract, digestive tract tumour's, hypertension, diabetes, obesity and immunity system dysfunctions (Canene-Adams *et al.* 2005). Lycopene is the principle carotenoid (> 80% of the total carotenoid) present in fully red-ripe tomato fruits and is responsible for the characteristic red colour (Shi and Le-Maguer 2000). and a high nutritive, a good source of vitamins A and B as well as an excellent source of vitamin

C. It is delicious, relieves constipation and has a pleasant taste (Ronga *et al.*, 2018).

Tomatoes covers approximately 4.73 million hectares area and produces 163.96 million tonnes globally (Anonymous, 2016). In India, tomato is ranked third after potato and onion with world's second most popular crop after potatoes having second only to China with an average production of 20366 MT with acreage of 841 M ha of yearly production (Anonymous, 2022). Its area and production in Rajasthan were 20504 hectares and 232864 tonnes, respectively. The district of Udaipur has its area and production to the tune of 189 ha and 1928 M.T, respectively (Anonymous, 2022).

Silicon is known to affect the availability of nutrients in soils and effectiveness with which plants utilize nutrient. Studies revealed that silicon application dramatically accelerated rice growth and raised the crop's grain and straw yields (Zhang *et al.*, 2021). Furthermore, silicon (Si) is required for the structural rigidity of cell walls, when plants have a passive or selective absorption or they are poor accumulators as Solanaceae, the proportion of silicon taken and present in the plants is lower than 1%, yet its presence can provide significant benefits to the plant before it faces biotic and abiotic challenges. Si also undoubtedly strengthens plant defence against a variety of biotic and abiotic stresses (Zhang *et al.*, 2017). Despite

being widely present in soil, most silica sources are poorly soluble and not available to plants. To make silica available to plants, Silica solubilising bacteria (SSB) have an important role in increasing the available silica (Brindavathy *et al.*, 2012).

Bio fertilizer NPK consortia have become more popular recently. The bio NPK consortium is a one-stop solution for all of a crop's macronutrient (N, P, and K) needs. The use of Bio NPK consortia @ 3-5 ml for root dipping therapy can reduce soil, water and air pollution while increasing growth and production while saving up to 25% on N, P, and K chemical fertilizer. It is used as seed treatment (3-5 ml kg⁻¹), soil application (1 l ha⁻¹), seedling treatment (3-5 ml l⁻¹) and with drip irrigation (1 l ha⁻¹) (Vagela *et al.*, 2019). It is becoming increasingly clear that when a microbial consortium of two or more interacting microorganisms is involved, additive or synergistic result can be expected. They boost soil fertility, encourage diversity and interaction with other beneficial microbes hinder the growth and infectious action of potential pathogens and generally preserve the sustainability of the systems with increased yields of certain crops (Santoyo *et al.*, 2021). Instead of utilizing separate bio fertilizers for each nutrient, consortium bio fertilizers ensure the mineralization and solubilisation of many nutrients with a single application by combining a mixed population of plant growth-promoting rhizobacteria in a single inoculum unlike the earlier practices of using separate biofertilizers for each nutrient with carrier based consortium bio fertilizer, plant growth promoting rhizobacteria are more useful (Babu *et al.*, 2020). Keeping in view the above facts and importance of silica, SSB, microbial consortia on crop development and yield, a field experiment entitled "Effect of silica and microbial consortia on growth and yield of tomato (*Solanum lycopersicum* L.)" was carried out during kharif season, 2022 to assess effect of silica and microbial consortia on growth and yield and economics of tomato (*Solanum lycopersicum* L.).

Materials and Methods

The experiment entitled "Effect of Silica and microbial consortia on growth, yield and economics of Tomato (*Solanum lycopersicum* L.)" was carried out at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur. The twelve treatments for the tomato crop were evaluated with three replications under randomized block design. The twelve treatments consists of T₁ (Control), T₂ (RDF NPK (200:100:80), T₃ (Silica 100kg ha⁻¹), T₄ (NPK consortia), T₅ (Silica Solubilizing Bacteria), T₆ (RDF (NPK) 50% + Silica 100kg ha⁻¹), T₇ (RDF (NPK) 50% + Silica solubilizing bacteria), T₈ (RDF (NPK) 50% + NPK consortia), T₉ (RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica Solubilizing

Bacteria), T₁₀ (RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium), T₁₁ (RDF (NPK) 50% + Silica Solubilizing Bacteria + NPK consortia) and T₁₂ (RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica Solubilizing Bacteria + NPK consortia).

Crop was grown as per standard package of practices recommended by State Horticulture Department of Rajasthan. Variety "USM- Kareena (Hybrid)" of tomato was used in this experiment. The plots of 2.0 m x 2.0 m size were prepared. Basal dose of RDF and Silica were calculated as per treatment and mixed in the soil one week prior to transplanting. Four weeks old seedling were transplanted at the spacing of 50 cm x 50cm as per layout in the evening hours followed by quick light irrigation. Tomato harvesting was started at 60-65 days after transplanting. Harvesting was done by hand picking methods.

Leaf area was calculated using portable leaf area meter (Li-3000) and measured at the time of fruiting and average leaf area was measured and expressed as cm² /plant. Specific gravity of the fruit was worked out by dividing the weight of the fruit by the volume of the same fruit and was expressed as gram per cubic centimetre. Chlorophyll content of leaves was determined using Chlorophyll meter SPAD-502. In order to evaluate the most profitable treatment combination, economics of different treatments were worked out in terms of net returns and net returns per rupee investment. First of all, cost of cultivation was calculated then a gross return was estimated on the basis of the total yield (kg) per ha. The data recorded for the evaluation of different parameters was statistical analyzed using standard procedure for ANOVA of Randomized Block Design in order to test the significance of experimental results. The analysis of variance was done by the method suggested by Fisher (1954) and using analysis as described by Panse and Sukhatme (1995).

Results and Discussion

Effect of silica and microbial consortia on growth attributes of tomato

Plant height : The data showed that application of T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium presented in Table 1, the maximum plant height of 63.60, 91.90, 126.62 cm was recorded at 60, 90 DAT and at harvest respectively with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum was found with T₁-control. Plant height with application T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium was found significantly higher over rest of the treatments. The plant height at harvesting with treatment

Table-1 : Effect of Silica and microbial consortium on plant height (cm) of tomato.

Treatments	Plant height (cm)		
	60 DAT	90 DAT	At harvest
T ₁ : Control	41.75	65.18	95.85
T ₂ : RDF NPK (200:100:80)	52.70	73.37	116.37
T ₃ : Silica 100kg ha ⁻¹	49.78	71.22	114.67
T ₄ : NPK consortium	44.81	69.80	106.93
T ₅ : Silica solubilizing bacteria	42.80	65.62	97.95
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	55.37	75.48	119.85
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	54.40	75.40	116.95
T ₈ : RDF (NPK) 50% + NPK consortium	55.18	76.80	121.27
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	56.20	82.03	122.60
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	58.00	84.67	124.68
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	56.00	78.80	121.60
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	63.60	91.90	126.62
S. Em±	3.00	3.59	5.36
CD at 5%	8.81	10.53	15.73
CV %	9.90	8.20	8.05

Table-2 : Effect of Silica and microbial consortium on growth attributes of tomato.

Treatments	Stem Diameter	Leaf area index	Number of branches	Days to 50% flowering	Days to first fruit harvest
T ₁ : Control	1.12	3.68	5.81	64.32	91.97
T ₂ : RDF NPK (200:100:80)	1.50	3.71	6.96	63.12	90.26
T ₃ : Silica 100 kg ha ⁻¹	1.43	3.62	6.92	63.23	90.42
T ₄ : NPK consortium	1.44	3.60	6.68	61.08	87.35
T ₅ : Silica solubilizing bacteria	1.45	3.60	6.64	60.32	86.25
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	1.52	3.75	7.12	59.10	84.52
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	1.51	3.72	7.03	59.37	84.89
T ₈ : RDF (NPK) 50% + NPK consortium	1.51	3.72	7.11	60.90	87.08
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	1.53	3.76	7.46	58.74	84.00
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	1.54	3.76	7.49	58.08	83.05
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	1.52	3.73	7.32	59.03	84.41
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	1.55	3.77	8.12	54.12	77.39
S. Em±	0.03	0.09	0.32	1.74	2.36
CD at 5%	NS	NS	0.94	5.09	6.94
CV %	3.54	4.07	7.90	5.00	4.76

T₁₂ was 1.51, 3.15 and 24.28 per cent higher than T₁₀, T₉ and T₁, respectively.

Stem Diameter (cm) : It is revealed from the data presented in the Table-2 that application of T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium produced maximum stem diameter (1.55 cm) and minimum (1.12cm) was found with T₁ control. Stem diameter (1.55 cm) in T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium failed to show any significant effect on stem diameter though, it was higher over T₁₀ (1.54 cm), T₉ (1.53 cm), T₁₁ (1.52cm) treatments.

Leaf area index : Evaluation of data Table-2 shows that application of different treatments failed to show any significant effect on the leaf area index. Though maximum leaf area index at (3.93) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (3.68) was found with T₁-control.

Number of branches : Fertilising the tomato crop with various treatment viz., RDF (NPK) 50%, Silica 50 kg ha⁻¹, Silica solubilizing bacteria, NPK consortium exposed a positive and significant effect on number of branches per

Table-3 : Effect of silica and microbial consortium on yield attributes of tomato.

Treatments	No. of fruits per plant	Fruit diameter (cc)	Fruit volume (cc)	Specific gravity (g/cc)
T ₁ : Control	14.67	4.38	77.38	1.02
T ₂ : RDF NPK (200:100:80)	16.05	4.77	81.48	1.03
T ₃ : Silica 100kg ha ⁻¹	15.98	4.62	80.93	1.04
T ₄ : NPK consortium	15.51	4.16	80.04	1.03
T ₅ : Silica solubilizing bacteria	15.13	4.16	81.05	1.03
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	16.98	5.10	88.29	1.06
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	16.37	5.04	85.48	1.04
T ₈ : RDF (NPK) 50% + NPK consortium	16.63	5.06	85.76	1.04
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	17.67	5.18	88.35	1.06
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	17.85	5.25	90.64	1.06
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	17.37	5.20	89.27	1.05
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	18.21	5.27	93.33	1.07
S. Em±	0.69	0.18	1.65	0.00
CD at 5%	2.03	0.54	4.84	0.01
CV %	7.27	6.52	3.35	0.72

Table-4 : Effect of Silica and microbial consortium on yield and economics of tomato.

Treatments	Av. Wet. of fruit (g)	Av. Yield plant ⁻¹ (kg)	Yield (kg ha ⁻¹)	GR (ha ⁻¹)	NR (Rs.ha ⁻¹)	B:C Ratio
T ₁ : Control	6.02	1.15	45803	538,200	396,560	2.80
T ₂ : RDF NPK (200:100:80)	78.72	1.26	49304	590,823	440,843	2.94
T ₃ : Silica 100kg ha ⁻¹	78.17	1.25	49821	582,905	440,453	3.09
T ₄ : NPK consortium	77.99	1.21	48587	566,280	423,840	2.98
T ₅ : Silica solubilizing bacteria	79.00	1.20	47924	560,711	418,271	2.94
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	83.33	1.40	55988	655,058	508,436	3.47
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	82.00	1.35	53843	631,800	485,190	3.31
T ₈ : RDF (NPK) 50% + NPK consortium	82.28	1.37	54792	641,066	494,456	3.37
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	83.03	1.47	58925	687,960	540,944	3.68
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	85.33	1.50	59917	702,000	554,984	3.77
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	84.70	1.45	57854	677,258	529,848	3.59
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	86.88	1.53	61134	728,269	580,453	3.93
S. Em±	1.69	0.08	3464.47			
CD at 5%	4.97	0.23	10161.00			
CV %	3.60	10.12	11.18			

plant at harvest (Table 2). Maximum number of branches (8.12) was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (5.81) was found with T₁ control. T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium produced 7.75, 12.43 and 28.44 per cent higher number of branches over T₁₀, T₉ and T₁, respectively.

Days taken to 50% flowering : The application of various treatment significantly reduced the time to 50% flowering. Data presented in Table-2 showed that a earliest 54.12 days were taken to 50% flowering was recorded under T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium. However, the maximum days taken for 50% flowering 64.32 days with no application of various fertiliser and consortia were found with T₁ control.

Days to first fruit harvest : The application of various treatment significantly reduced the time to for first picking presented in Table 2. The earliest time for first picking 77.39 days under the application of T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium. However, the maximum days taken for first picking 91.97 days was found with T₁ -control.

Improvement in plant growth *i.e.* plant height, leaf area index, number of branches per plant at final harvest, days to flowering, stem diameter and days to harvest of tomato by the conjunction use of NPK, microbial consortium, silica solubilizing bacteria and silicon might have resulted in better nutritional environment in the rhizosphere as well as in the plant system. Zhang *et al.*, 2021 also revealed that Si plays important roles in plant growth and development of the plants. High rates of microbial transformation due to the availability of organic carbon for heterotrophic organisms, hydraulic conductivity, buffering effect, improved soil aggregation, aeration, release of organic acids, etc., which act as stimulants for crop nutrient supply during microbial decomposition and enable the crop to utilise nutrients, may be responsible for the maximum value of growth parameters. These results are in consonance with the findings of Babu *et al.*, 2017. Further, Subbaiah *et al.* (2018) also supported the findings. Further, these results are in close conformity with the findings of Alam *et al.* (2010), Avhad *et al.* (2016) and Angadi *et al.* (2017).

Yield attributes

Number of fruits per plant : Data presented in the Table-3 that number of fruits per plant influenced significantly and produced maximum number of fruits per plant (18.21) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (14.63) was found with T₁-control. T₁₂ produced 19.43, 10.10 and 1.97 per cent higher number of fruits per plant as compared to T₁, T₇ and T₉, respectively.

Fruit diameter (cm) : Perusal of data given in Table-3 indicated that maximum fruit diameter (5.27) was recorded under treatment T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (4.38) was found with T₁-control. Fruit diameter (5.27 cm) in T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium found significantly higher over T₁₀-RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium) (5.25), T₁-control (4.38) and other treatments.

Fruit volume (cc) : Perusal of data given in Table-3 indicated that fruit volume was significantly influenced by application of different treatments. Maximum fruit volume

of 93.33 cc was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (77.38) was found with T₁ -control.

Specific gravity : Perusal of data given in Table-3 indicated that specific gravity has significantly influenced by application of different treatments. Maximum specific gravity of 1.07 g/cc was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (1.02 g/cc) was found with T₁-control.

Yield and Economics

Average weight of fruits (g) : The result of data analysis presented in Table-4 indicated that different treatments increased the fruit weight. Maximum fruit weight (86.88 g) was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (76.02 g) were found with T₁-control. Fruit weight under T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium (86.88 g) found significantly higher over T₁₀-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + NPK consortium) (85.33 g) and T₉-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria (83.03 g) and T₁-control (76.02 g) and other treatments.

Average yield per plant (kg) : The supplementation of tomato crop for recommended dose N, P, K with microbial consortium had shown positive and significant effect on crop yield per plant, presented in Table-4 Maximum yield (1.55 kg) was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (1.15 kg) was found with T₁control. Yield per plant under T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium (2.57 kg) found significantly higher over T₁₀-RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium) (1.50 kg) and T₉-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria (1.47 kg) and T₁-control (1.15 kg) and other treatments. Average yield per plant produced under T₁₂ found to be 25.8, 5.16 and 3.22 per cent higher than T₁, T₉ and T₁₀, respectively.

Yield per hectare (kg ha⁻¹) : A perusal of data given in Table-4 revealed that maximum yield per hectare (61818.6 kg) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (45802.7 kg) was found with T₁-control. Yield under T₁₂ found significantly higher over T₉ -RDF (NPK) 50% + Silica 50 kg ha⁻¹) (58688.0kg) and T₂-RDF (NPK) (50536.1) and T₁-Control (45802.7 kg). The yield per hectare recorded under T₁₂ was 5.06 and 25.9 per cent higher than T₁ and T₉, respectively.

Economics of treatment : Data pertains to economics of tomato for per hectare area under open conditions was affected by various treatments are shown in table-4.

Treatment T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and T₁₀-RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium) gave net return of ₹565453 and ₹552013 and minimum net return of ₹392251 was recorded with T₁ (Control). However, maximum B:C (3.93) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum B:C (2.73) with T₁ (Control).

The application of RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium may result in higher values of all yield attributing parameters due to nutrient supply by combination of fertilisers along with microbial consortium during initial growth period and sustained supply of nutrient and congenial conditions by NPK and induced tolerance against biotic and abiotic stress by Silicon by lowering down the absorption of sodium by plants as supported by Sanchez *et al.*, 2012. The increased commercial production of tomato treated with nano silica is attributable to more and heavier fruits per plant. On tomato, an increase in crop output with Si supplementation has already been established by Kleiber *et al.*, 2015.

Furthermore, increased plant development provides more sites for photosynthesis and the transfer of photosynthates from source to sink (leaves to fruits) has been discovered by Tekale *et al.* (2017). Inorganic sources provide all major and minor growth nutrient and also improve physico-chemical and biological properties of soil which helps plant root to proliferates, resulting in larger coverage of rhizosphere area and better up take of nutrients. Higher fruit weight might be due to solubilization effect of plant nutrients by addition of microbial consortium leading to increased uptake of N, P and K as observed by Bhattarai 2011. Singh *et al.* (2017) found that the application of organic manures had the highest impact on the quantity of fruits per plant and output per hectare in tomato.

Conclusions

Based on results, it can be concluded that among the various treatments T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium as found superior in different growth attributes viz., plant height 60, 90 and at harvesting DAT, number of branches, days to 50% flowering, chlorophyll content of leaf and stem diameter, different yield attributes viz. number of fruits per plant, fruit diameter, fruit weight and fruit volume, yield per plant, yield per hectare, net returns and B:C of tomato.

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Effect of Phosphorus and Molybdenum Fertilization on Yield Attributes and Yield of Chickpea (*Cicer arietinum* L.)

Vikash Dhaka¹, Devi Lal Dhaker^{1*}, O.P. Sharma¹, Harish Kumar Bijarnia¹, Manjeet Dhaka¹, Pradeep Dhaka¹ and Jitendra Singh²

¹Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan

²Department of Agronomy, School of Agriculture, Apex University, Jaipur, Rajasthan

*Correspondence Author Email : devilal.dhaker09@gmail.com

Abstract

A field experiment was conducted at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur during *rabi* season of 2022-23. The factorial experiment was laid out in randomized block design with three replications consisting of twelve treatment combinations by using four levels of Phosphorus (0, 20, 40 and 60 kg/ha) and three levels of Molybdenum (0, 0.5 and 1.0 kg/ha). Results revealed that application of Phosphorus @ 40 kg/ha and Molybdenum @ 1.0 kg/ha considerably enhanced the number of pods/plant, number of seeds/pod, seed, straw and biological yield of chickpea compared to control and other treatments of Phosphorus or Molybdenum.

Key words : Phosphorus, molybdenum, chickpea, yield and treatments.

Introduction

Chickpea (*Cicer arietinum* L.) is also known as gram and Bengal gram. There is a growing demand for chickpea due to its nutritional value as seeds of chickpea contain 20-22% protein, 60-62% carbohydrate, 5% fat and are rich in calcium and iron. Mostly chickpea is grown in South Asia, which accounts for more than 75% of the world chickpea area. India is the largest producer, importer and consumer of the pulses in the world, accounting for 25% of the global production, 15% trade, and 27% consumption; as sizeable population in the country still depends on vegetarian diets to meet its protein requirement (Ali and Kumar, 2007). In India, it is cultivated in an area of 10.91 m ha with the production of 13.75 m ha and productivity of yield of 892 kg/ha. Major states in chickpea production are Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka, Gujarat and Andhra Pradesh (Anonymous, 2022). In Rajasthan, it is cultivated in 6.15 m ha with the production of 4.31 m tonnes and the productivity of 701 kg/ha.

Application of phosphorus to legume is more important than other nutrients because it is a major plant nutrient and required for various metabolic processes such as cell division and development of cell, energy transport, signal transduction, macro molecular biosynthesis, photosynthesis and respiration. Phosphorus is an essential constituent of nucleic acids such as ribonucleic acid (RNA) and deoxy ribonucleic acid (DNA), adenosine diphosphate (ADP) and adenosine triphosphate (ATP), nucleoproteins, amino acids, proteins, phosphatides, phytin, several co-enzymes viz.,

thiamine, pyrophosphate and pyridoxyl phosphate (Verma *et al.*, 2015). The application of phosphorus @ 40 kg/ha produced significantly highest number of pods/plant, number of seeds/pod, seed yield, straw yield and biological yield of chickpea over control and 20 kg/ha phosphorus and at par with 60 kg P₂O₅/ha phosphorus (Balai *et al.*, 2017).

Molybdenum is an important micro-nutrient leading to poor seed yield of pulses in molybdenum deficient soils. It is an essential component of the enzyme nitrate reductase, which catalyses the conversion of NO₃⁻ to NO₂⁻. Molybdenum is a structural component of enzyme nitrogenase which is actively involved in atmospheric nitrogen fixation by root nodule bacteria in leguminous crops. Molybdenum concentration in legume nodules can be 10 times higher than in leaves (Yadav *et al.*, 2017). It also acts in enzymes, which bring about oxidation reduction reaction, especially the reduction of nitrate to ammonia prior to amino acids and protein synthesis in the cells of plant. Molybdenum is essential for the process of symbiotic and non-symbiotic nitrogen fixation. Molybdenum is also known to have an indirect role in increasing the oxygen content and availability of oxygen for root growth, therefore, the higher leghaemoglobin content may be due to greater oxygen concentration in and around the root system. It increases the chlorophyll content in leaves, thereby increasing photosynthetic space in the plant. Therefore, deficiency of molybdenum is considered as one of the constraints in the optimum production of pulse crops (Liu *et al.*, 2020). Kumar and Sharma (2005) found that application of molybdenum @ 1.0 kg/ha, being at par with 1.5 kg Mo/ha, significantly

increased the number of pods/plant, number of seeds/pod, test weight, seed and stover yield of chickpea over control and 0.5 kg/ha.

Materials and Methods

The experiment was conducted during *rabi* 2022-23 at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur. The region's climate is typically semi-arid and marked by temperature extremes in both the summer and the winter. The temperature can go as high as 46°C in the summer and as low as - 1.0°C in the winter. The soil of experimental field contains low organic carbon (0.22%), available N (180.66 kg/ha), available phosphorus (21.08 kg/ha) and available potassium (245.23 kg/ha). Field experiment was laid out in factorial randomized block design with three replications by using four levels of Phosphorus (0, 20, 40 and 60 kg/ha) and 3 levels of Molybdenum (0, 0.5 and 1.0 kg/ha) thereby making 12 treatments combinations. The variety CSJ-515 of chickpea was sown in first week of November at a spacing of 30 cm × 10 cm by using recommended seed rate of 80 kg/ha. The recommended dose of fertilizer nitrogen (20 kg/ha) was applied through urea. The phosphorus and molybdenum was applied at the time of sowing through DAP and sodium molybdate as per treatment and mixed well in the soil. Five plants mean plot were selected and tagged to record the observation on growth and yield parameters. The data observed on different parameters were analyzed by following the standard procedure of analysis of variance technique as described by Gomez and Gomez (1984) at 5% level of significance.

Results and Discussion

The data presented in table-1,2,3 and fig.-1 results showed that plant vegetative growth, yield attributes and yield of chickpea was considerably enhanced with the application of different levels of phosphorus and molybdenum.

Effect of Phosphorus : Graded levels of phosphorus application significantly increased the plant height and dry matter accumulation at different growth stages of crop. Significantly maximum plant height (53.51 and 71.28 cm at 80 and 120 DAS) and dry matter accumulation (8.88 and 14.39 g/plant at 80 and 120 DAS) was recorded with the application of phosphorus up to 60 kg/ha which was significant over 0 and 20 kg/ha but remained at par with 40 kg/ha. This increase in plant height and dry matter accumulation might be due to the better nutrients availability at the critical stage of crop which facilitates better nutrient transfer and accumulation of dry matter. These findings are in line with Singh *et al.* (2021).

Application of phosphorus up to 60 kg/ha gave

significantly higher yield attributes such as number of pods per plant (31.64) and number of seeds per pod (2.01) as compared to 0 and 20 kg/ha phosphorus. However, it was at par with 40 kg/ha phosphorus. Considerable higher grain yield (2258 kg/ha), straw yield (3762 kg/ha) and biological yield (6020 kg/ha) was obtained with increasing level of phosphorus up to 60 kg/ha but statistically at par with 40 kg P₂O₅/ha. While, 40 kg phosphorus/ha also had significant effect over 0 and 20 kg/ha phosphorus. Test weight and harvest index was found non significant with graded levels of phosphorus. These attributes might be due to higher levels of inorganic fertilizers increasing efficiency of photosynthesis and activity of enzymes that is responsible for energy transformation. Rehan *et al.* (2018) also found similar results in their experiment. Thus, application of phosphorus might have resulted in increased carbohydrate accumulation and their remobilization to reproductive parts of the plant, being the closest sink and hence, resulted in increased flowering, pod development and seed formation (Nadeem *et al.*, 2018).

Effect of Molybdenum : Results further showed that application of molybdenum @ 1.0 kg/ha significantly increased the plant height and dry matter accumulation at 80 and 120 DAS over control and 0.5 kg molybdenum/ha. Significantly maximum plant height of 54.22 and 73.43 cm and dry matter accumulation of 9.12 and 14.56 g/plant at 80 and 120 DAS was recorded respectively, with the application of molybdenum @ rate of 1.0 kg/ha. The significant improvement in these characters might also be due to the fact that molybdenum is a component of the enzyme nitrogenase which is essential for the process of symbiotic nitrogen fixation. It is also present in nitrate reductase which is responsible for the reduction of nitrates to ammonia prior to amino acid and protein synthesis in the plant cells causing better growth in terms of plant height and dry matter production (Ahmad *et al.*, 2021).

Yield attributes and yield of crop was improved with graded levels of molybdenum. Higher number of pods/plant (32.19) and number of seeds/pod (2.04) was recorded when 1.0 kg/ha molybdenum was applied and significant over lower levels of molybdenum. Significantly maximum seed yield (2300 kg/ha), straw yield (3777 kg/ha) and biological yield (6078 kg/ha) of chickpea were obtained with the increasing levels of molybdenum up to 1.0 kg/ha. However, it was significantly superior than 0 and 0.5 kg/ha. This might be due to its role in N-fixation and growth hormone metabolism. Molybdenum has unique role in enhancing nitrogen fixation thereby increasing its availability to the plants for efficient growth and development of plants in terms of photosynthetic area which enhanced the photosynthesis and synthesis of other metabolites for plant use (Liu *et al.* 2020). The

Table-1 : Effect of phosphorus and molybdenum on growth parameters of chickpea.

Treatments	Plant height (cm)		Dry matter accumulation (g/ plant)	
	80 DAS	120 DAS	80 DAS	120 DAS
Phosphorus (kg/ha)				
0	40.93	51.03	6.82	10.43
20	49.13	64.72	8.05	12.68
40	53.05	70.72	8.81	13.90
60	53.51	71.28	8.88	14.39
SEm $\pm$	1.29	1.84	0.22	0.35
CD (P=0.05)	3.77	5.39	0.64	1.02
Molybdenum (kg/ha)				
0	42.91	53.46	7.03	10.73
0.5	50.34	66.43	8.27	13.27
1.0	54.22	73.43	9.12	14.56
SEm $\pm$	1.11	1.59	0.19	0.30
CD (P=0.05)	3.27	4.67	0.56	0.89

Table-2 : Effect of phosphorus and molybdenum on yield attributes of chickpea.

Treatments	Yield attributes		
	Number of pods/plant	Number of seeds/pod	Test weight (g)
Phosphorus (kg/ha)			
0	24.63	1.49	145.52
20	28.42	1.79	149.82
40	31.44	1.99	152.03
60	31.64	2.01	153.93
SEm $\pm$	0.83	0.07	4.85
CD (P=0.05)	2.44	0.19	NS
Molybdenum (kg/ha)			
0	25.27	1.58	147.52
0.5	29.64	1.83	150.43
1.0	32.19	2.04	153.02
SEm $\pm$	0.72	0.06	4.20
CD (P=0.05)	2.11	0.17	NS

NS=Non-significant

Table-3 : Effect of phosphorus and molybdenum on yields of chickpea.

Treatments	Yield (kg/ha)			Harvest index (%)
	Seed	Straw	Biological	
Phosphorus (kg/ha)				
0	1648	2863	4512	36.42
20	1967	3273	5240	37.49
40	2192	3646	5838	37.53
60	2258	3762	6020	37.47
SEm ±	63	108	155	0.55
CD (P=0.05)	185	317	456	NS
Molybdenum (kg/ha)				
0	1704	2968	4672	36.40
0.5	2044	3413	5457	37.41
1.0	2300	3777	6078	37.87
SEm ±	55	94	135	0.48
CD (P=0.05)	160	274	395	NS

NS=Non-significant

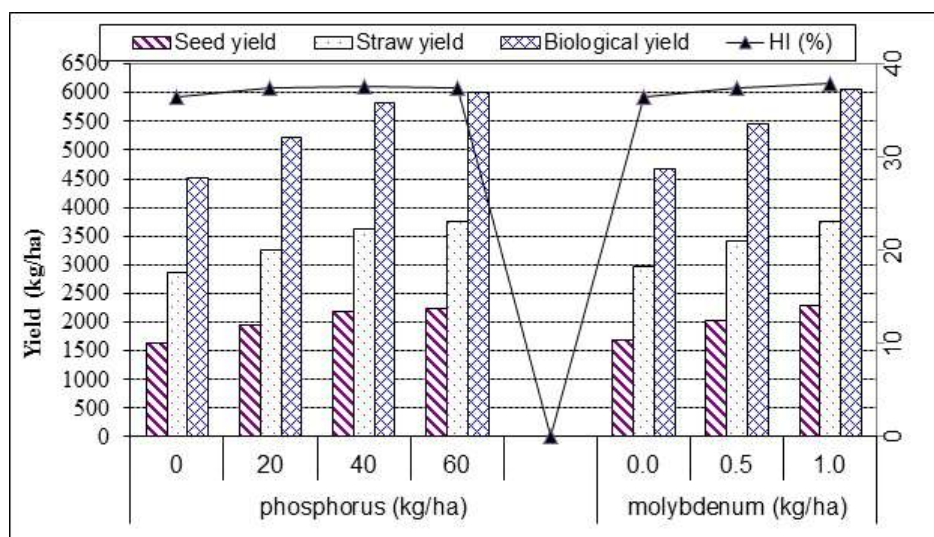


Fig.-1 : Effect of phosphorus and molybdenum on yields of chickpea.

positive influence on nutrient uptake appears to be due to improved growth and nutritional environment in plant system. The improvement in uptake of nutrients seems to be the fact that the uptake of nutrients is function of nutrient content and yield of the crop and increased crop yield also increases the uptake of nutrients in crop (Khan and Prakash 2013).

Conclusions

Based on one year experimentation, it was concluded that application of phosphorus up to 60 kg/ha and molybdenum @ 1.0 kg/ha improved crop growth and yield attributes and gave crop yields as compared to lower level of fertilizers. Hence, application of 40 kg/ha phosphorus and 1.0 kg/ha molybdenum is recommended for higher productivity of chickpea.

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Assessment of Genetic Diversity in Sesame (*Sesamum indicum* L.) Germplasm Based on Yield and Yield Attributing Traits

Jai Prakash Dhavan, Rajani Bisen and Vinod Kumar*

Department of Plant Breeding and Genetics, JNKVV, Jabalpur-482004 (M.P.) India

*Corresponding Author Email : vinod.goyal90@gmail.com

Abstract

A total of 93 sesame germplasm collected from diverse ecologies of India were used in this research work. Analysis of variance revealed significant difference among genotypes for all the fourteen characters studied. Genetic divergence using Mahalanobis D^2 statistics was worked out and based on D^2 values the germplasm lines were grouped into eighteen different clusters. Clustering was not associated with the geographical distribution instead accessions were mainly grouped due to their morphological differences. Maximum inter cluster distance was observed between cluster XVII and XVI (282.6) followed by cluster XVIII and XVI (213.4), while the lowest inter cluster distance was observed between cluster VIII and cluster IV (105.4). Among the fourteen characters studied, number of capsules (48.85) contributed maximum to genetic divergence followed by capsule length (13.04%), plant height (8.84%), 1000 seed weight (6.43%), number of secondary branches per plant (4.72%), leaf area index (4.60%), oil content (3.32%) and seed yield per plant (3.27). Lowest contribution was shown by days to 50% flowering (0.02%). The highest cluster mean value were found for germplasm S-0448 of cluster XVI for number of capsules per plant, chlorophyll content, photosynthetic rate, leaf area index, number of primary branches per plant, number of secondary branches and stomatal conductance while lowest cluster mean values were found in cluster VII having germplasm (PCU-37) for number of secondary branches per plant, chlorophyll content and photosynthetic rate. Greater genetic divergence was found between clusters XVII and XVI followed by clusters XVIII and XVI indicating superior and novel recombinants and explore the fullest range of variability for the characters and to realize good recombinant can be realized by mating between the lines of these clusters in a definite fashion.

Key words : Clustering, D^2 statistics, sesame, genetic divergence, variability.

Introduction

Sesame (*Sesamum indicum* L.) is commonly known as til, a self pollinated crop belonging to family Pedaliaceae with diploid chromosome number $2n = 26$. Only *Sesamum indicum* has been recognized as a cultivated species among the thirty six species of genus *Sesamum* (Alemawu *et al.*, 1998). The crop is highly tolerant to drought, grows well in most of the well drained soils and various agro climatic regions, and is well adapted to different rotations. It can set seed and yield well under fairly high temperature and can grow in stored soil moisture without rainfall and irrigation. However, continuous flooding or severe drought adversely affects the crop resulting in low yield (Mensah *et al.*, 2009). Sesame oil has highest antioxidant content and contains several fatty acids such as oleic acid (43 %), linoleic acid (35%), palmitic acid (11%) and stearic acid (7%). Genetic diversity in crop plants is essential to sustain level of high productivity. Genetic variation survives for agronomically vital characters in sesame but its production is still very low in India. Traditional sesame landraces as well as related wild species are an important source of genetic diversity for breeders and form the backbone of agricultural production. The characterization and

conservation of sesame germplasm are essential for both safe guarding and the future use of existing genetic resources of sesame. Genetic diversity in sesame, based on morphological, biochemical, metabolic, and molecular markers, has been reported by many researchers worldwide (Bedigian 2010a; Yol and Uzun 2012). However, the development of improved plant cultivars is restricted mainly due to narrow genetic pool which results into limited possibility to restructure the sesame crop. The knowledge of genetic diversity among landraces will help in the selection and breeding of high yielding, good quality cultivars that will increase production. Keeping the above points in view, this study was carried out to recognize and categorize genetic variability of 93 sesame accessions collected from diverse environmental conditions throughout India and to choose sesame germplasm with diverse agronomic performances and yield potential from these important assets.

Materials and Methods

Field experiment was conducted at Project Coordinating Unit (Sesame and Niger) Research Farm, JNKVV, Jabalpur (M.P) during *Kharif* 2014. Jabalpur is situated in 'Kymore plateau and Satpura hills agro-climatic region of Madhya Pradesh the total annual rainfall is mainly

Table-1 : Inter and intra cluster D² values for different clusters.

Clusters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X	Cluster XI	Cluster XII	Cluster XIII	Cluster XIV	Cluster XV	Cluster XVI	Cluster XVII	Cluster XVIII
Cluster I	29.71	48.36	69.25	42.67	43.90	49.56	44.46	44.62	70.91	51.53	44.56	49.38	82.97	49.44	52.22	106.25	93.51	74.98
Cluster II		0.00	30.04	78.21	101.84	90.50	94.27	45.14	112.70	120.18	87.80	76.84	28.30	79.39	98.48	48.73	173.21	135.02
Cluster III			38.64	112.16	130.56	106.98	126.64	53.84	157.78	153.98	115.39	78.78	61.12	80.43	110.12	55.61	188.99	157.35
Cluster IV				0.00	33.88	27.93	20.41	105.49	13.88	23.64	27.27	36.48	81.29	51.86	66.46	146.00	47.10	92.88
Cluster V					0.00	59.66	24.04	74.81	53.55	23.12	46.76	61.89	141.89	71.21	65.20	187.51	67.87	72.04
Cluster VI						0.00	40.99	85.54	57.55	48.06	22.71	23.28	94.45	32.56	66.42	122.85	86.29	93.93
Cluster VII							0.00	93.92	35.29	29.35	48.95	48.83	109.60	59.00	74.89	202.27	42.87	84.55
Cluster VIII								0.00	162.95	102.29	83.79	77.62	112.69	70.37	71.99	85.03	167.05	76.83
Cluster IX									0.00	32.12	40.86	75.08	102.75	88.84	98.14	195.91	60.86	131.05
Cluster X										0.00	20.40	69.54	151.81	70.26	72.11	194.98	50.85	54.45
Cluster XI											0.00	52.04	109.60	45.58	77.50	127.10	87.50	70.13
Cluster XII												0.00	85.31	17.76	64.29	117.93	64.32	89.07
Cluster XIII													26.28	97.94	135.11	71.02	188.37	205.17
Cluster XIV														0.00	76.66	114.23	85.87	71.32
Cluster XV															0.00	136.14	94.32	73.16
Cluster XVI																0.00	282.66	213.48
Cluster XVII																	0.00	91.63
Cluster XVIII																		0.00

Bold figures denote the intra cluster distances

received between June last week to end of September last week. Ninety three germplasm were used for this study. All of the germplasm shows national collection which is collected from the different growing region of the Indian country. The soil of experimental area was vertisol having clayey loam texture with uniform topography. The design RCBD was used for this experiment. Distance between the row and within the row was 30 cm and 10 cm. Analysis of variance for yield and quality traits were statistically analyzed on the basis of model described by Cochran and Cox (1950) for randomized complete block design. In order to test the significance of treatments critical difference was computed (Fisher and Yates, 1963). Genetic divergence was estimated using the Mahalanobis D² statistics. Character means were transformed into sets of uncorrelated variables using the pivotal condensation of common dispersion matrix according to Rao (1952). Although the D² statistics can handle a multidimensional situation, higher order interactions do not contribute very much in any experiment. In all the D² combinations, the characters were ranked on the basis of their contribution to D². Grouping of genotypes into different clusters was done according to Tocher's method (Rao, 1952).

Results and Discussion

Analysis of variance indicated that the mean sum of squares due to genotypes were significant for all the characters indicating considerable amount of genetic variability present amongst the material under study. The variation of different traits under study revealed the measure of free variability in the population of different genotypes, which would reflect the unforeseen impact of potential variability on yield. Genetic divergence Genetic divergence among 93 sesame germplasm lines was determined for seed yield, its attributing characters and quality trait. Hierarchical cluster analysis based on agro morphological traits allocated the 93 sesame germplasm into eighteen clusters (Fig.1). Critical assessment of clusters showed that clusters were heterogeneous within themselves and between each other based on major character relations. The composition of clusters and values of inter and intra clusters distances are given in tables 1 and 2, respectively. The results revealed that the inter cluster distance in most cases was larger than intra cluster distance suggesting wider diversity among the

Table-2 : Cluster mean for yield and yield contributing traits of sesame germplasm.

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V	Cluster VI	Cluster VII	Cluster VIII	Cluster IX	Cluster X	Cluster XI	Cluster XII	Cluster XIII	Cluster XIV	Cluster XV	Cluster XVI	Cluster XVII	Cluster XVIII
Days to 50% flowering	37.33	36.67	37.48	36.33	35.67	36.67	38.67	36.33	38.33	38.00	37.33	36.00	37.00	38.67	36.00	36.00	40.33	36.67
Days to maturity	87.37	85.33	87.63	83.33	86.33	87.67	88.00	88.00	87.00	87.67	84.67	86.00	87.56	86.00	90.67	89.67	82.33	83.67
Plant height	92.58	100.30	96.53	88.50	97.70	63.00	90.20	93.90	88.60	88.20	72.00	79.10	90.32	71.20	92.30	81.40	99.33	90.33
No. of primary branches/plant	3.60	4.50	4.21	4.40	3.90	3.50	3.90	3.70	3.50	3.50	2.70	4.37	4.60	4.00	3.20	4.60	4.07	3.93
No. of secondary branches/plant	1.70	2.50	2.30	2.00	1.40	0.30	0.10	2.00	1.40	2.47	1.57	1.10	1.41	0.80	2.00	4.00	1.83	3.00
No. of Capsules	65.60	90.30	90.48	58.30	53.70	50.50	52.00	75.00	51.10	46.40	48.53	65.00	89.10	65.50	55.80	96.80	46.30	55.67
Capsule length	2.89	2.87	2.90	2.71	2.92	2.81	2.78	3.13	2.59	2.85	2.84	2.81	2.67	2.87	2.90	2.91	2.70	3.10
Chlorophyll content	38.50	40.78	41.55	37.58	34.44	33.27	31.76	35.46	37.22	34.86	33.32	38.04	39.99	37.24	35.40	45.78	38.62	40.59
Leaf area index	4.38	4.82	4.29	4.46	4.56	4.35	4.22	4.40	4.42	4.20	4.18	3.74	4.69	3.32	4.62	5.01	3.35	3.60
Photosynthetic rate	15.81	16.92	17.11	15.71	17.28	13.89	13.57	14.37	16.44	14.21	13.73	16.48	16.80	16.59	18.61	19.63	13.91	14.20
Stomatal conductance	0.32	0.42	0.34	0.34	0.37	0.26	0.26	0.32	0.39	0.34	0.34	0.31	0.40	0.27	0.39	0.42	0.28	0.42
1000 seed weight	3.66	3.61	3.87	3.70	3.83	4.02	3.68	3.86	3.55	3.46	3.58	4.07	3.71	3.32	4.09	3.92	3.86	2.90
Oil content (%)	44.05	47.90	44.29	44.26	39.93	46.85	46.96	42.69	44.90	44.52	45.05	45.83	47.30	44.32	37.79	39.69	44.77	50.20
Seed yield per plant	11.72	14.57	14.79	10.20	7.95	10.33	9.50	13.33	8.25	7.25	7.35	12.13	14.61	11.01	17.50	15.57	10.47	12.00

germplasm of different groups. Cluster I possessed the maximum number of 57 genotypes followed by cluster III (18) and cluster XIII (3) in such a way that germplasm lines having minimum genetic distance were grouped in same cluster and vice versa. Rest of the clusters was mono-genotypic one. The range of inter and intra cluster distance was 13.88 to 282.66 and 0.00 to 38.64, respectively (Table-1). The maximum inter cluster distance was found between the cluster XVII and XVI (282.6) followed by cluster XVIII and XVI (213.4), XVI and VII (202.2), IX and VIII (162.9), X and III (153.9), XIII and X (151.8), XV and XIII (135.1), V and III (130.56), VII and III (126.5), XI and III (115.3), IV and III (112.1) and VI and III (106.9). The highest intra cluster distance was observed for cluster III (38.64) followed by cluster I (29.71) and cluster XIII (26.28). It indicates that the germplasm lines of cluster III were more diverged than any other cluster. This was also reflected in the scatter diagram. The germplasm lines belonging to the distant clusters could be used in hybridization programme for obtaining a wider range of variability.

Cluster means of germplasm for fourteen characters in sesame (Table 3) revealed that days to 50% flowering (40.33) in cluster XVII having the check variety GT-10; days to maturity (90.67), 1000 seed weight (4.09) and seed yield (17.50) in cluster XV having the germplasm S-0228; plant height (100.30) and stomatal conductance (0.42) in cluster II having the germplasm EC-14121; number of secondary branches per plant (4.0), number of capsules per plant (96.80), chlorophyll content (45.78), leaf area index (5.01), photosynthetic rate (19.63) and stomatal conductance (0.42) in cluster XVI having the germplasm S-0448; number of primary branches per plant (4.60) in cluster XIII having the germplasm viz., IC-132408, IS 184-1, IS-750-1-84; capsule length (3.13) in cluster VIII having the germplasm SI-199-2-84; stomatal conductance (0.42) and oil content (50.20) in cluster XVIII having the check variety TKG-22. These clusters can be preferred in selecting germplasm lines for respective traits as they recorded good means. Clustering of germplasm was not associated with the geographical distribution and were mainly grouped due to their morphological differences. Thus, showing evidence that geographical isolation is not the only factor causing genetic diversity in sesame. Similarly, the forces other than geographical origin such as genetic drift, natural and artificial selection, exchange of breeding material might have played and important role in the fixation of diversity among the germplasm lines. A few ecological conditions could also direct the gene flow between populations from diverse geographical origins. Although sesame has been described as a self pollinated plant, but these are indications that show the option of natural out-crossing in

Table-3 : Contribution of different characters toward clustering in sesame germplasm.

S. No.	Source	Times ranked 1st	Contribution %
1.	Days to 50% flowering	1	0.02%
2.	Days to maturity	5	0.12%
3.	Plant height	378	8.84%
4.	No. of primary branches/plant	54	1.26%
5.	No. of secondary branches/plant	202	4.72%
6.	No. of capsules/plant	2090	48.85%
7.	Capsule length	558	13.04%
8.	Chlorophyll content	36	0.84%
9.	Leaf area index	197	4.60%
10.	Photosynthetic rate	125	2.92%
11.	Stomatal conductance	75	1.75%
12.	1000 seed weight	275	6.43%
13.	Oil content (%)	142	3.32%
14.	Seed yield/plant	140	3.27%

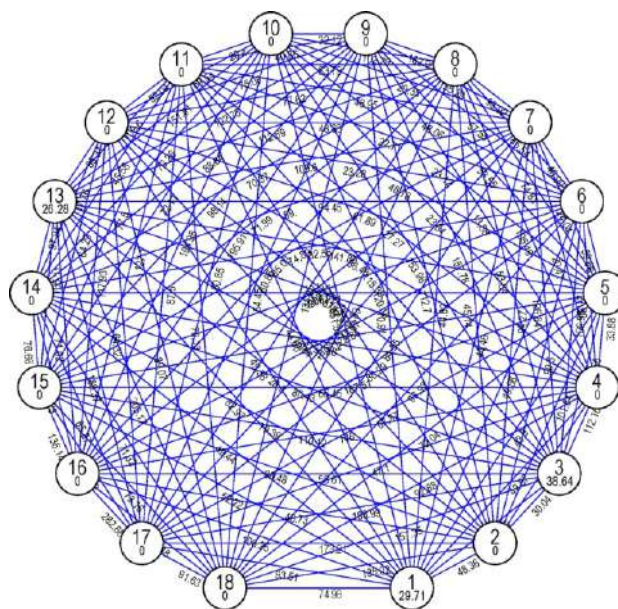


Figure-1 : Diagram showing intra and inter cluster distances among XVIII clusters.

sesame (Baydar & Gurel, 1999). The characters contributing maximum divergence needs greater emphasis for deciding on the clusters for the purpose of selection of parents in the respective cluster for hybridization. The number of times, each of the yield component character appeared first in rank and its respective per cent of contribution towards genetic divergence was presented in Table-3. The results showed that number of capsules (48.85) contributed maximum to genetic divergence by taking 2090 times first rank followed by capsule length (13.04%) by 558 times, plant height (8.84%) by 378 times, 1000 seed weight (6.43%) by 275 times, number of secondary branches per plant (4.72%) by 202 times, leaf area index (4.60%) by 197 times, oil content (3.32%) by 142 times, seed yield per

plant (3.27) by 140 times, photosynthetic rate (2.92%) by 125 times, stomatal conductance (1.75%) by 75 times, number of primary branches (1.26%) by 54 times, chlorophyll content (0.84%) by 36 times, days to maturity (0.12%) by 5 times. Lowest contribution was shown by days to 50% flowering (0.02%) by taking first rank. These results are in agreement with those given by Velusami *et al.*, 2008 for seed yield followed by 1000 seed weight. It indicates that these characters contribute towards the genetic divergence in the present germplasm lines. On the other hand, least variation was recorded for capsule length, number of primary branches and oil per cent showing comparatively less contribution of these characters towards the genetic divergence. On the contrary, Duhoon and Raghuwanshi, 2005 reported that

oil content and days to 50% flowering exhibit maximum genetic divergence. Solanki and Gupta (2003) reported that seed yield, number of capsules per plant, plant height and 1000 seed weight are the important contributing attributes. Sudhakar et al., 2006 reported that 1000 seed weight, number of capsules per plant, plant height, capsule length recorded negligible contribution. The results indicated that the germplasm lines studied had a considerable level of variability that could be exploited in future breeding programs. Hybridization between genetically diverse genotypes in sesame to generate promising breeding material has been suggested by Alarmelu and Ramanathan (1998). Greater genetic divergence was found between clusters XVII and XVI followed by cluster XVIII and XVI indicating that superior hybrids or recombinants can be realized by mating between the lines of these clusters in a definite fashion. Crossing between germplasm belonging to the same cluster might not be expected to yield desirable segregates. This approach is however based on the assumption that suitable parents for crossing may be showing greater amount of genetic divergence. Further research on these selected germplasm will save a lot of time for the breeder in future. Morpho-agronomic traits have some shortcomings in evaluating genetic diversity as these are phenotypic markers and genetically distant germplasm may be morphologically similar. Further research should be done with molecular markers which can be used to determine genetic distance easily and successfully. DNA markers should provide more accurate measures of genetic similarity.

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Impact of Solar Pump Set Scheme on Economic Condition of Vegetable Growers

Pramod^{1*}, Shobhana Gupta², K.C. Sharma¹, B.S. Badhala¹, Vandana Kumari³ and Kamlesh Choudhary⁴

¹Department of Agriculture Extension Education, S.K.N., Agriculture University, Jobner, Jaipur, Rajasthan

²Department of Agricultural Extension and Communication, RVSKVV, Gwalior, M.P.

³Department of Agricultural Economics, SKRAU, Bikaner, Rajasthan

⁴Department of Agricultural Extension and Communication, SKRAU, Bikaner, Rajasthan

*Corresponding Author Email : pramod.ext97@gmail.com

Abstract

Rajasthan has outstanding solar radiation in India and a solar water pump is a great investment that makes money in the long run. The present study was conducted in Jaipur district with 120 beneficiary and non-beneficiary farmers regarding Impact of solar pump set scheme on economic condition of vegetable growers during 2019-20. The impact of solar pump set scheme in terms of cropping pattern, economic development and yield obtained were done by making comparison between before and after adoption of solar pump set scheme. The results of the study showed that the area under vegetable cultivation was increased. The total gross cropped area increased by 4708 hectare and cropping intensity also increased by 20 per cent. The per hectare spending on vegetable production increased by Rs. 3113 after adoption of solar pump set scheme due to fallow land utilization under such crops by the farmer. The per hectare gross income as well as net income of the farmers increased and farmers incurred the additional spending of Rs. 46554 on education, food, clothes, house construction and maintenance.

Key Words : Solar pump, vegetable, economic, beneficiary and cropping pattern.

Introduction

A solar water pump is an entire water pumping system powered by solar energy through the use of solar photovoltaic panels. It does not use any fossil fuels or external electricity to run the pump. There are many benefits to installing a solar water pump to property as pumping water efficiently, reducing operational costs and have a system that could work in any remote location. Start shopping through our solar water pump systems to find what you need. A solar energy-powered water pump is operated on the electricity that is generated by solar photovoltaic modules. It is equivalent to the input and output energy of the solar-pump panels and in addition available voltage security. As per the farmers who set up any of the micro irrigation systems like Drip irrigation, Mini sprinkler or Sprinkler on their fields are only eligible under the solar-pump subsidy scheme. India's irrigation is mostly groundwater well based and India has the world's largest groundwater well equipped irrigation system (about 39 million hectares or 67 per cent of total irrigated area). About 84 per cent of the total available water is consumed for irrigation in the country and it is crucial to provide timely and adequate water supply to ensure improved agricultural productivity (NITI Aayog, 2015; Dhawan, 2017). Since energy is coming from the sun, utility bill will be drastically reduced. Solar pump systems do not have a large operational cost, since they are powered naturally by the sun. Farmers no need to pay a ton of money every time you turn your pump on.

Encouraged by the reducing cost of solar power system and its environmental compensation, but even additional, by its promised to reduce the demand for new electricity connections and subsidized electricity for irrigation, the Government of Rajasthan launched scheme in 2011 with Rs. 515 crore to provide subsidized solar irrigation system to the state's 10,000 farmers for three years. Rajasthan initiated in 2011 with 86 per cent solar pump set scheme financial support to horticulture farmers who utilized drip irrigation and farm ponds. The scheme conventional great interest of the farmers and around 5500 farmers are benefited by the subsidized solar pump set. Taking into deliberation these facts in mind, it is elevated time to access the impact of these solar pump sets used in agriculture.

Research Methodology

The investigation was carried out in Jaipur district of Rajasthan state. Jaipur district is the capital and the largest city of the Indian state of Rajasthan. The district is situated in the east of Rajasthan state with Sikar to its north, Tonk to its south, Alwar, Dausa and Sawai Madhopur to its east, and Nagaur, Ajmer districts in its west. East and North area of Jaipur district is bounded by Aravalli hills. It is situated 268 km from the national capital New Delhi. The total population of the district on the basis of 2011 census is 3.1 million, making it the tenth most populous city in the country. Jaipur district climate is tremendous with hot and humid summers and chilly

winters. Maximum temperature during the summers i.e. from April to July reaches a high of about 45° C. Average annual rainfall of the district is 601 mm, usually first monsoon showers comes between ends of July to early August. The district is having 13 Sub-divisions (blocks); and selected two blocks Govindgarh and Jalsu. To achieve this objective, percentage method was adopted, in which data regarding Jaipur district of Rajasthan was presented selected map.

Results and Discussion

The impact of solar pump set scheme in terms of cropping pattern, economic development and yield obtained was done by making comparison between the before and after the adoption of solar pump set scheme which are as follows :

Cropping pattern of selected vegetable growers : The cropping pattern is an important aspect to assess the impact of solar pump set scheme. The actual area under cultivation of different vegetables before and after adoption of the solar pump set scheme in *Kharif*, *Rabi* and *Zaid* season is presented in Table 1. Table shows that there was little bit increase in the total area under cultivation of *Kharif* vegetable crops after adoption of solar pump set scheme.

The area under okra was reduced by 35 hectares. A total of 5481 hectare area has been additionally devoted to vegetable cultivation by the farmers after adoption of solar pump set scheme in *Kharif*. In case of *Rabi* vegetables also, the area under total cultivation has been increased to 16574 hectares from 16215 hectares showing increase of 359 hectares after adoption of solar pump set scheme. While Pea and Spinach was reduced by 1149 and 1251 hectares in the *Rabi* season.

However, the farmers kept the land fallow for cultivation of *Zaid* vegetables crops like watermelon, muskmelon, Long melon (Kakri), Bottle gourd and Tinda etc. Although the *Zaid* crops were also taken by the farmers prior to adoption of solar pump set scheme but it was reduced by 1132 hectares. The total gross cropped area (4708 ha) and cropping intensity (20%) was increased after the adoption of solar pump set scheme by the farmers. The results revealed that the cropping pattern has been shifted in positive direction by adoption of solar pump set scheme by the farmers. The findings gain support from Hossain *et al.* (2015).

Economic development of selected vegetable growers : The impact of solar pump set schemes in respect of economic development of selected vegetables growers is presented in Table-2 indicated that per hectare spending on vegetables production before adoption of solar pump set schemes was Rs. 23562 whereas, after

adoption of solar pump set schemes, it was Rs. 26675. The spending on vegetables production was increased after adoption of solar pump set schemes due to the area increased under vegetable cultivation and also fallow land utilized under such vegetable crops by the farmers. Thus, per hectare spending on vegetables production was increased about Rs. 3113.

The data show that per hectare gross income of the farmers before adoption of solar pump set schemes was Rs. 53976 which was after adoption of solar pump set scheme Rs. 63999 and it was increased by Rs. 10023. Likewise, per hectare net income of the farmers was increased after adoption of solar pump set scheme in field by Rs. 7035. Further, the table revealed that spending on other aspects such as spending on education, food and clothes, house construction and maintenance, farm implements and mechanical power purchasing, amenities and electricity also indicated that farmers incurred the additional spending on such aspects, because of adoption of solar pump set schemes. Since the farmers generated extra income from vegetable production. Therefore, they incurred more spending on various social aspects. The data in the Table-2 show that total spending on all aspects was Rs. 143002 before adoption of solar pump set and it was Rs. 151800 after adoption of solar pump set. There was an additional spending by the farmers on such aspects Rs. 46554. From the above results it could be accomplished that in respect of economic development of selected vegetables grower, after adoption of solar pump set schemes farmers gain an additional income as a result of adoption of solar pump set schemes improved the livelihood spending of their family. The results seemed to be quite logical that improvement of farm income leads to improved living standard and farmers have incurred more spending in respect of economic development aspects. The findings gain support from Hossain *et al.* (2015).

Yield obtained by the selected vegetable growers : The data presented in Table-3 shows about the impact of solar pump set scheme on the yield obtained by the selected vegetable growers. The average yield of the vegetables crops was computed per hectare and presented below. The impact of solar pump set scheme was visible in *Kharif* vegetables crops where the area has been increased tremendously as well as there has been increased in average yield of crops per hectare like in Tomato 965 qt., Green chilli 4094 qt. and cluster bean 670 qt. after the adoption of solar pump set scheme by the farmers. The area under Brinjal and Okra was

reduced to 285 and 90 hectares. Similar is the case in *Rabi* season vegetables crops where the area under Onion 2352 qt., Pea 3321 qt., Cauliflower 1081 qt. and Spinach 1017 qt. was reduced and only 25 qt. Radish has

Table-1 : Impact of solar pump set scheme on cropping pattern of selectedvegetable growers. (n=120)

S. No.	Cropping pattern	Area under solar pump set vegetable cultivation		
		Before adoption total area (ha)	After adoption total area (ha)	Area increased (+)/decreased (-) total area (ha)
i.	Kharif			
1.	Tomato	7644	9859	2215 (+)
2.	Green chili	2243	5131	2888 (+)
3.	Cluster bean	85	429	344 (+)
4.	Brinjal	615	684	69 (+)
5.	Okra	345	310	35 (-)
Total		10932	16413	5481
%		34.27%	43.12%	22.39%
ii.	Rabi			
1.	Onion	2589	4139	1550 (+)
2.	Pea	10565	9416	1149 (-)
3.	Cauli flower	1576	2784	1208 (+)
4.	Spinach	1432	181	1251 (-)
5.	Radish	53	54	1 (+)
Total		16215	16574	359
%		50.84	43.55	7.62
iii.	Zaid			
1.	Watermelon	1809	1408	401 (-)
2.	Muskmelon	534	333	201 (-)
3.	Long melon (Kakri)	76	803	727 (-)
4.	Bottle gourd	878	926	48 (+)
5.	Tinda	1451	1600	149 (+)
Total		4748	5070	1132 (-)
Percentage (%)		14.88	13.32	24.04 (-)
Gross cropped area		31895	38057	4708
Net cropped area		23452	23452	26452
Cropping intensity (%)		136	162.27	20

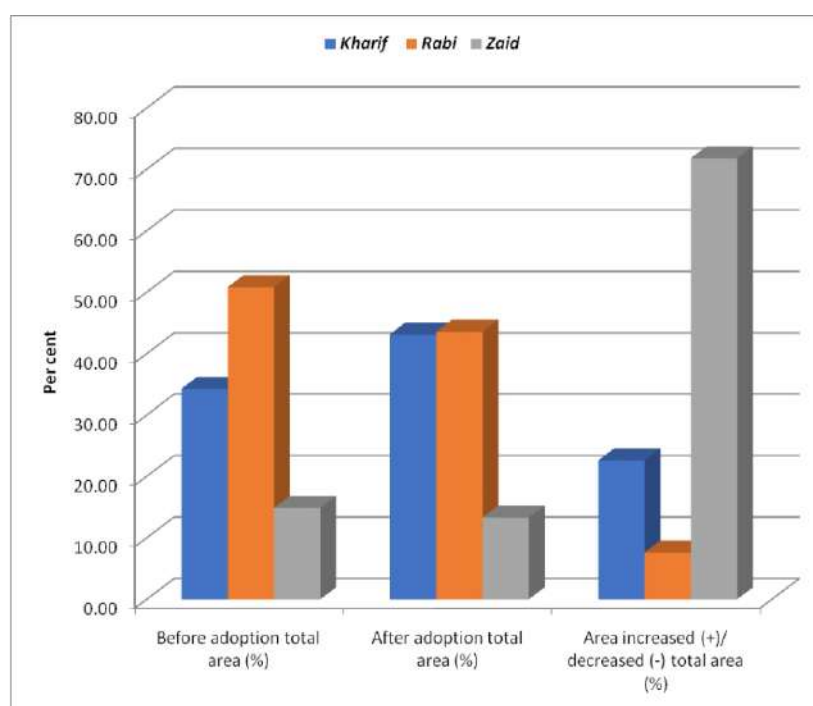


Fig.-1 : Impact of solar pump set scheme on cropping pattern of selectedvegetable growers.

Table-2 : Impact of solar pump set scheme on economic development of selected vegetable growers. (n=120)

S. No.	Particulars	Solar pump set under economic		
		Before adoption of solar pump (In Rs.)	After adoption of solar pump (In Rs.)	Gain as a result of adoption of solar pump (In Rs.)
a.	Spending on vegetable production per hectare	23562	26675	3113
b.	Gross income per hectare	53976	63999	10023
	Net income per hectare	31508	38543	7035
c.	Spending on other aspects (Rs./Year)			
1.	Spending on education to children per farm family	20516	26212	5696
2.	Spending on food and clothes per farm family	31605	37308	5703
3.	Spending on house construction and maintenance per farm family	33242	39998	6756
4.	Spending on farm equipments and mechanical power purchasing per farm family	25364	31578	6214
5.	Spending on amenities per farm family (T.V./Refrigerators /Washing machine/ Tractor/ Pick up/ Loading vehicle)	13397	16704	3307
6.	Spending on electricity	18878	-	18878
Total spending on all aspects		143002	151800	46554

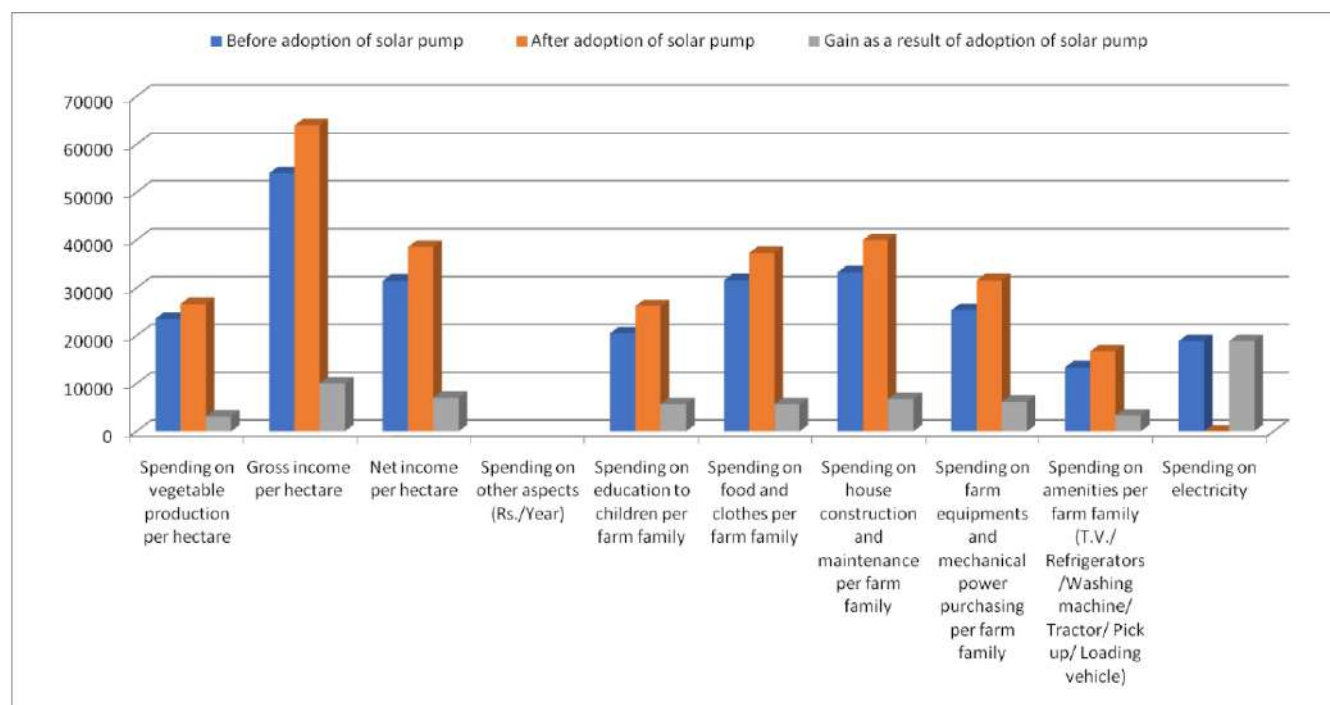


Fig-2 : Impact of solar pump set scheme on economic development of selected vegetable growers.

been increased. The impact of solar pump set scheme was visible in *Zaid* vegetables crops where the area has been increased tremendously as well as there has been increased in average yield of crops per hectare like in long melon (Kakri) 1184 qt. and bottle gourd 202 qt. after the adoption of solar pump set scheme by the farmers. The area under watermelon 7650 qt., muskmelon 921 qt. and Tinda 956 qt. was reduced.

The findings gain support from Rajet *et al.* (2009).

Conclusions

The result of the study shows that the area under vegetable cultivation has increased. The total gross cropped area increased by 4708 hectare and cropping intensity increased by 20 per cent. The per hectare spending on vegetables production increased by Rs. 3113 after adoption of solar pump set scheme due to the area increased under vegetable cultivation and also fallow land

Table-3 : Impact of solar pump set scheme on yield obtained by the selected vegetable growers. (n=120)

S. No.	Crops	Average yield per ha/ Quintal		Gain as a result of adoption of solar pump
		Before adoption of solar pump	After adoption of solar pump	
i.	Kharif			
1.	Tomato	22437	23402	965
2.	Green chili	5566	9660	4094
3.	Cluster bean	216	886	670
4.	Brinjal	1741	1456	-285
5.	Okra	650	560	-90
Total		30610	35964	5354
ii.	Rabi			
1.	Onion	9358	7006	-2352
2.	Pea	16433	13112	-3321
3.	Cauli flower	5076	3995	-1081
4.	Spinach	1285	268	-1017
5.	Radish	75	100	25
Total		32227	24481	-7746
iii.	Zaid/ summer			
1.	Watermelon	11576	3926	-7650
2.	Muskmelon	1821	900	-921
3.	Long melon (Kakri)	178	1362	1184
4.	Bottle gourd	2074	2276	202
5.	Tinda	3580	2624	-956
Total		19229	11088	-8141

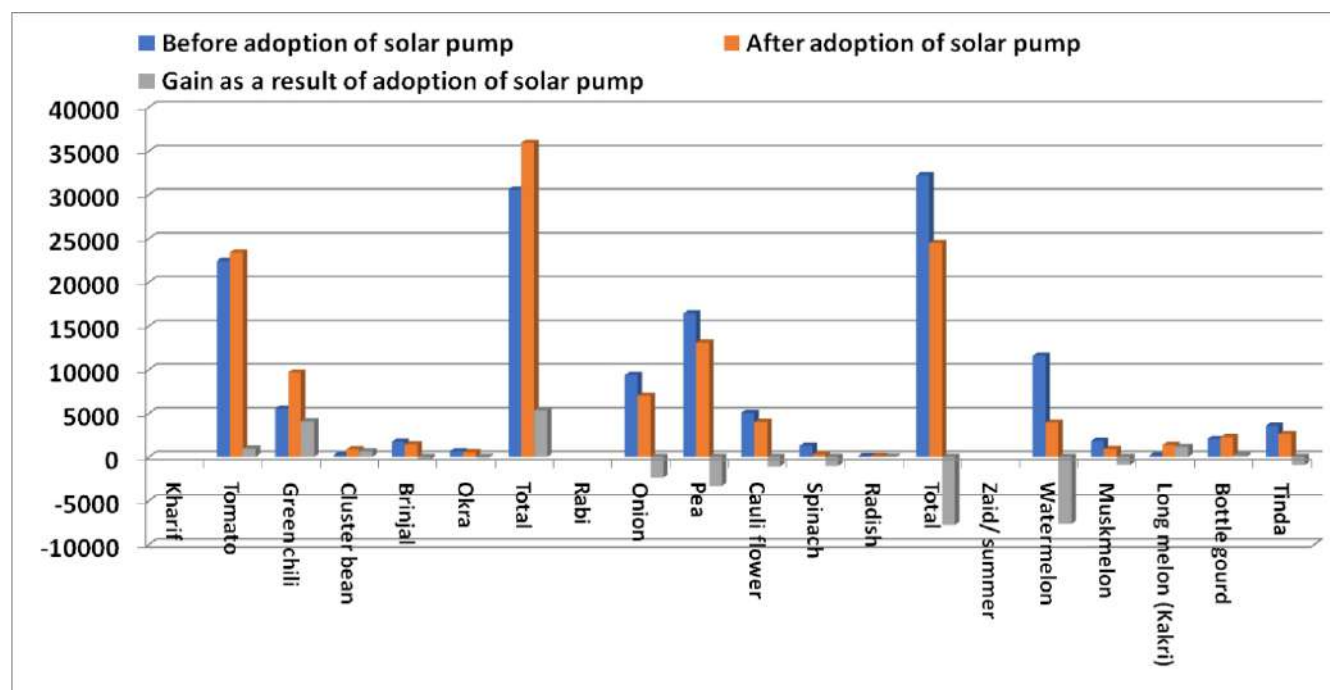


Fig.-3 : Impact of solar pump set scheme on yield obtained by the selected vegetable growers.

utilized under such crops by the farmer. The per hectare gross income as well as net income of the farmers increased and farmers incurred the additional spending of Rs. 46554 on education, food, clothes, house construction and maintenance. Since the farmers generated more

income, it was observed that per hectare average yield of vegetable crops increased significantly after the adoption of solar pump set scheme indicating the positive impact of solar pump set scheme.

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Effect of Cow Based Bio-Formulations on Vegetable Crops—A Review

Sumit Kumar^{1*}, Sunil Kumar Gola¹, Rahul² and Jyoti Rani³

¹Department of Vegetable Science CCS Haryana Agricultural University, Hisar, Haryana

²Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar, Haryana

³Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur-492012, Chattisgarh

*Email : sumitbidlan2@gmail.com

Abstract

Panchgavya and Jeevamrit have become well-known bio-fertilizers and plant growth boosters. Cow dung, cow urine, jaggery, and gram flour are traditionally combined to make jeevamrit, which is then fermented to produce a nutrient-rich solution. Ghanajeevamrit and Jeevamrit that has been concentrated to increase the potency of its active ingredients. However, Panchgavya, which is a mixture of cow-derived substances comprising milk, curd, ghee, cow urine, and cow dung, is renowned for its ability to promote growth. It is critically evaluated how these organic compositions affect the development, productivity, nutrient content, and disease resistance of vegetable crops. The beneficial effects of these cow based bio-formulations seen on the crop growth, such as height, leaf area, and root development. Additionally, the application of these formulations has increase crop yields by enhancing flowering, fruit setting, and overall plant vigour. Moreover, the presence of beneficial microorganisms in these formulations enhances soil microbial diversity, leading to better nutrient cycling and disease suppression. The effectiveness of these formulations is also influenced by factors such as soil type, climate, and crop management practices.

Key word : Cow products, ghanajeevamrit, panchgavya, jeevamrit.

Introduction

Indian Agriculture during 1960s transformed the India to food grain surplus country from the deficit one. Green revolution played a crucial role in the socio-economic development of the Indian people especially the rural India. But the intensive agriculture has led towards a major degradation of the fragile agro-ecosystem (Kumari *et al.* 2022). Loss of long-term soil fertility, soil erosion, diminishing water resources, soil and water pollution, salinized ground water, higher incidences of human, plant and animal diseases and increased global warming are the major adverse impacts of over exploitation of agricultural technologies adopted during Green Revolution (Rahman, 2015). The traditional methods of cow-based organic farming can serve the dual purposes of boosting the crop output and enhancing soil fertility (Münster 2018). Well-known organic fertilizers that have been in use for centuries include cow dung and cow urine. A traditional organic product known as panchagavya, jeevamrit and ghanajeevamrit are made utilizing different cow products, including cow dung, cow urine, cow milk, cow ghee, cow curd, gram flour and soil (Dhama *et al.* 2005). It has the capacity to boost plant development and immunity, which gives resistance to pathogens and pests. The mineral nutrients N, P and K, as well as other micronutrients necessary for plant growth and development are abundant in Panchagavya. (Rakesh *et al.*, 2017). It also contains various amino acids, vitamins,

plant growth regulators like Auxins and Gibberellins (Sreenivasa *et al.*, 2010). It is also rich in beneficial microorganisms like *Pseudomonas*, *Azotobacter* and Phosphorous solubilizing bacteria etc. (Singh *et al.*, 2018). Cow based bio-formulations can be applied as an irrigation water additive, foliar spray, pre-sowing, or pre-storage treatment for seeds. It was found that using Panchagavya improved the quality of fruits and vegetables. (Swaminathan *et al.*, 2007). Jeevamrit is a liquid organic manure made by combining soil, gram flour, cow dung, and cow urine. The quality of cow dung and urine improves the soil fertility. Jeevamrit application has been found to boost vegetable crop yields. (Boraiah *et al.*, 2017).

Jeevamrit : Jeevamrita is a fermented microbial culture which acts as a catalytic agent in the soil to proliferate the microbial diversity along with increase in the earthworm activity. Different concentrations of Jeevamrit for enhancing growth, yield and quality of vegetable crops and best of concentrations can be determined for optimum growth, yield and quality of vegetable crops (Khan *et al.* 2022).

Ghanajeevamrit : Ghanajeevamrit, also known as Ghanajeevamrut, is a potent organic/cow based bio-formulation that are the combination of various bioactive components. The primary ingredients include cow dung, cow urine, jaggery, gram flour, soil and water. (Kumar 2023).

Panchgavya : Panchagavya an organic product has the potential to play the role of promoting growth and providing immunity in plant system. Panchagavya consists of nine products viz. cow dung, cow urine, milk, curd, jaggery, ghee, banana, Tender coconut and water. When suitably mixed and used, these have miraculous effects (Archana *et al.* 2020).

Effect of Cow based bio-formulations on growth of vegetable crops :

Cow based bio-formulations increases the root length, formation of root nodules, plant height, number of branches, number of leaves, chlorophyll content, and leaf area index (LAI), contributing to higher photosynthetic activity and increasing fresh and dry weight. This effect may be attributable to the presence of various growth enzymes that favours rapid cell division and cell-multiplication, promoting the overall growth and development of plants and improving yields. As a result, panchagavya is crucial to the growth and development of plants. Natarajan (2002) came to the conclusion that panchagavya improved the growth, vitality, resilience to pests and diseases, as well as the maintenance of fruit and vegetable quality in a variety of crops, including turmeric, onion, gingelly and other vegetables and curry leaf.

Effect of Panchagavya : According to Velmurugan (2005) the greatest plant height (26.75 cm) and highest number of leaves (14.0) among the treatments for radish were generated with application of panchagavya. According to Vennila and Jayanthi (2008), spraying 2% panchagavya and the full recommended dose of fertiliser increased the height of the plants (131.7 cm) and the amount of dry matter produced per plant (5.9 g) in okra. Jain *et al.* (2014) found that panchagavya application increases germination percentage, germination index, root and shoot length, fresh and dry weight of the seedlings, plant height, and chlorophyll content. It also affects the availability of macro and micronutrients like Zn, Cu, and Mn and microbial activity as compare to FYM and vermicompost. Rakesh S. *et al.* (2017) carried out a field experiment and discovered that panchagavya's effects on growth and yield parameters increased at low concentrations. It is advised that panchagavya be applied as a spray after being adequately diluted to 3%. Gajjela and Chatterjee (2019) study the effect of foliar application of Panchagavya and Vermiwash on yield and quality of bitter gourd (*Momordica charantia* L.) and found that foliar application of Panchagavya; Vermiwash; and their interaction recorded highest fruit length (12.79 cm; 11.13 cm and 17.74 cm), number of fruits per plant (21.86, 21.38 and 25.50), single fruit weight (62.31 g, 57.59 g and 75.93 g). Panda *et al.*, (2020)

revealed that the application of organics (Panchagavya and Jeevamrit) improved the growth and yield attributes of tomato. The highest values of growth parameters viz. height (118.4 and 131.7 cm), stem girth (2.56 and 3.25cm), number of leaves per plant (80.5 and 104.2) were recorded maximum with 3% Panchagavya at 50 and 75 DAT. Gore and Sreenivasa (2011) investigated the effect of liquid organic manures such as panchagavya, jeevamrit and beejamrit on growth, nutrient content and yield of tomato and concluded that the application of RDF + beejamrit + jeevamrit + panchagavya was shown significantly maximum plant height at 75 DAS (83.15 cm) and 160 DAS (143.21 cm) and root length at 75 DAS (15.57 cm) and 160 DAS (19.80 cm) as compared to other treatments. Nileema and Sreenivasa (2011) concluded that the soil treatment of RDF + beejamruth (as seed inoculant) + jeevamrit (as soil conditioner) + panchagavya foliar spray @ 3.0% showed significant increase in plant height (143.2 cm), root length (19.8 cm) and dry matter (7.94 g plant⁻¹) compared to other treatments as well as control in tomato.

Effect of Jeevamrit : Basavaraj *et al.* (2015) reported that soil drenching with jeevamrit at 1000 litre ha⁻¹ and foliar application of panchagavya @ 3.0% resulted in significantly higher numbers of pods plant⁻¹ (15.89 and 15.40), pod weight plant⁻¹ (81.58 and 79.42 g) of french bean as compared to without jeevamrit (13.67 and 69.56 g) respectively. Boraiah *et al.* (2017) performed a field experiment to determine the effect of organic liquid formulations on growth and yield of capsicum and concluded that application of jeevamrit led to significant increase in fruit yields (32.26, 39.55, 51.63, 121.20, 100.28, 86.40, 50.05 q ha⁻¹ at 60, 70, 80, 90, 100, 110 and 120 DAT respectively) as compared to other organic liquid formulations used in the study. Vedagiri *et al.* (2022) conducted an experiment to study the influence of different concentrations of Jeevamrit on growth, yield and quality parameters of Chilli (*Capsicum annum* L.) and found that the 10% Jeevamrit spray treatment produced the significant results with maximum increases in plant height at 30 DAT (39.59 cm) and at last harvest (59.65 cm), days to 50% flowering (35.92 days), fruit length (7.21 cm), weight (5.80 g), fruit girth (3.27 cm) as compare to other treatments.

Effect of Cow based bio-formulations on yield of vegetable crops

The use of panchagavya led to the attainment of better and greater yields. Additionally, the yield showed increased levels of dry matter, protein, fresh and dry weights, root yield, fruit weight, fruit quantity, seed weight, grain weight, cob length and girth, oil content, and protein content. Thus, Panchagavya has a significant impact on

Jeevamrit

Ingredient	Quantity
Cow dung	25 kg
Cow urine	25 L
Jaggary	5 kg
Gram flour	5 kg
Soil	Hand full
Water	500 L

(Raghavendra *et al.* 2014)**Panchagavya**

Ingredient	Quantity
Fresh cow dung	10 kg
Cow urine	10 L
Cow milk	2 L
Cow curd	2 L
Cow ghee	1 kg
Tender coconut water	3 L
Sugarcane juice	3 L
Ripened banana	12 numbers
Yeast	100 gm

(agritech.tnau.ac.in)

Physico chemical and biological properties of Panchagavya

Chemical composition	
pH	5.45
EC (dSm ²)	10.22
Total N (ppm)	229
Total P (ppm)	209
Total K (ppm)	232
Sodium	90
Calcium	25
IAA (ppm)	8.5
GA (ppm)	3.5
Microbial load	
Fungi	38800/ml
Bacteria	1880000/ml
Lactobacillus	2260000/ml
Total anaerobes	10000/ml
Acid formers	360/ml
Methanogen	250/ml

(agritech.tnau.ac.in)

the yield and yield-related characteristics of a number of crops.

Effect of Panchagavya : With the help of panchagavya, improved yields were also seen in crops including French bean and chilli by Selvaraj in 2003 and Subhashini *et al.* According to Birendra and Christopher (2007), foliar treatment of 3% panchagavya significantly improved yield qualities. According to Vennila and Jayanthi (2008) observations, panchagavya application increased the number of fruits produced per plant, the weight of each fruit (in grammes), and the yield of quintals produced per hectare of okra. According to Kumawat *et al.* (2010), the foliar application of neem + panchagavya boosted yield in cumin and cluster bean. Neem + panchagavya (1259 kg/ha) and Tumbo + panchagavya (1068 kg/ha) had a greater cumin equivalent yield under the groundnut - cumin system as compared to According to Sunil *et al.* (2012), the cumin crop had increased plant dry matter following the treatment of neem + panchagavya spray at 30%, 54%, and 80% at 55 and 80 days after planting than the control. According to Boraiah *et al.* (2017), panchagavya spray produced a notable output per

hectare, a greater shelf life of 18.58 days, and a higher capsaicin concentration of 0.32% in the capsicum. When compared to other treatments, Suchitra *et al.* (2017) found that 3% panchagavya spray produced the most fruits (19) and fruit weight (30.67 mg/fruit) in *Abelmoschus esculentus*. Gajjela and Chatterjee (2019) study the effect of foliar application of Panchagavya and Vermiwash on yield and quality of bitter gourd (*Momordica charantia* L.) and found that foliar application of Panchagavya, Vermiwash, and their interaction recorded highest yield per plant (1.37 kg, 1.21 kg and 1.94 kg), yield per plot (8.20 kg/5.4 m², 7.26 kg/5.4 m² and 11.62 kg/5.4 m²), yield per hectare (13.66 t/ha, 12.11 t/ha and 19.37 t/ha). Panda *et al.*, (2020) revealed that the application of organics (Panchagavya and Jeevamrit) improved the growth and yield attributes of tomato. The yield attributes viz. fruit length (5.60 cm), number of fruits per plant (46.1), fruit diameter (4.41 cm), fruit yield per plant (2.81 kg) were recorded maximum with the application of 3% Panchagavya followed by 5% Panchagavya and 3% Jeevamrit.

Effect of Jeevamrit : Kumbar and Devakumar (2017) investigated the impact of jeevamrit and panchagavya on yield of french beans and resulted that jeevamrit application of 2000 l ha⁻¹ significantly increase the green pod yields (134.3 and 156.9 qha⁻¹) in consecutive two years. Whereas, treatment of panchagavya @ 6% improved pod yields over the course of two years, measuring 124.4 and 142.8 qha⁻¹, as compared to (101.4 and 120.1 qha⁻¹ respectively) without panchagavya application. Hameedi *et al.* (2018) studied that the jeevamrit (applied twice, as a soil soaking @ 5.0% at the time of transplanting and a foliar spray @ 3.0% at 45 DAT and vermicompost (applied at 7.0 t ha⁻¹) increased capsicum annual yield by 82.4% in comparison to control. Vedagiri *et al.* (2022) conducted an experiment to studied the influence of different concentrations of Jeevamrit on growth, yield and quality parameters of chilli (*Capsicum annum* L.) and found that the application of 10% Jeevamrit spray resulted the maximum average fruit yield per plant (0.46 kg), fruit yield per ha (5.07 t).

Effect of Cow based bio-formulations on quality of vegetable crops

Effect of Panchagavya : Gajjela and Chatterjee (2019) study the effect of foliar application of Panchagavya and Vermiwash on yield and quality of bitter gourd (*Momordica charantia* L.) and found that foliar application of Panchagavya, Vermiwash and their interaction recorded highest total soluble solids (1.70°Brix, 1.48°Brix and 0.97°Brix), ascorbic acid (82.80 mg/100g, 75.26 mg/100g and 55.73 mg/100g), protein (1.52 %, 1.45 % and 1.06 %). Panda *et al.*, (2020) revealed that the application of organics (Panchagavya and Jeevamrit) improved the growth and yield attributes of tomato. The values quality parameters i.e., chlorophyll carotenoids, TSS, ascorbic acid and lycopene were maximum under 3% Panchagavya. Amareswari and Sujathamma (2014a) investigated the effects of jeevamrit, panchagavya and composted kitchen waste on the ascorbic acid and riboflavin content of french beans. The findings showed that straw mulch, vermicompost and panchagavya were combined to produce fresh pods with the greatest ascorbic acid content, which was statistically at par with straw mulch, jeevamrit and panchagavya. The highest riboflavin content values were found in plots treated with panchagavya, NPK fertilisers and straw mulch. Rohith *et al.* (2022) carried out an experiment in order to determine how the application of various organic (neem cake, panchagavya and vermicompost) and RDF @ 100:50:50 kg/ha affects the growth, yield and quality of the chill crop. The highest capsaicin content (0.46 g g⁻¹) was obtained when panchagavya @ 3 % with neem cake @ 250 kg ha⁻¹ applied.

Effect of Jeevamrit : Vedagiri *et al.* (2022) conducted an experiment to study the influence of different concentrations of Jeevamrit on growth, yield and quality parameters of Chilli (*Capsicum annum* L.) and found that the 10% Jeevamrutha spray treatment produced the best results in TSS (8.10° B) as compared to other treatment used in this experiment. Kachave (2019) reported that TSS (Total Soluble Solids) of tomato fruits was highest with 100% NPK (5.79°B), followed by combine application of Panchgavya + Jeevamruth (5.25°B), Panchgavya (5.02°B) and least with Jeevamruth (4.87°B). It showed that, TSS becomes high with the combine application of both bio-manures compared to sole application. Spehia *et al.* (2018) reported that the treatment of HNS + 5% spray of jeevamrit with NFT to lettuce crop recorded the maximum protein content in 10 g of leaves and 10 g of roots (1.39 and 0.61, respectively) and carbohydrates content in 10 g of leaves and 10 g of roots (2.60 and 0.77, respectively).

Conclusions

As organic supplements for the growth of vegetable crops, Jeevamrit, Ghanajeevamrit, and Panchgavya have a lot of potential. They show potential in improving growth, output, and nutritional value while promoting sustainable agriculture techniques. These organic formulations might be crucial in fostering both productivity and environmental responsibility as global agriculture looks for more sustainable practises. By lengthening the roots, stems, branches, and leaves as well as other quality and yield metrics and associated criteria including leaf area index, chlorophyll content, oil content, and protein content, the cow-based bio-formulations boost productivity.

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Morphological Characterization of Sesame (*Sesamum indicum* L.) Germplasm

Jai Prakash Dhavan, Rajani Bisen*, Vinod Kumar and Stuti Sharma

Department of Plant Breeding and Genetics, JNKVV, Jabalpur-482004 (M.P.) India

*Corresponding Author Email : rajanitomar20@gmail.com

Abstract

The current study's objective is to characterize ninety three sesame genotypes (*Sesamum indicum* L.) using the DUS descriptors at Research Farm, Project Coordinated Unit (S&N), JNKVV, Jabalpur. The experiment was carried out in Randomized Complete Block Design with three replications. Sesame varieties were assessed for twelve morphological features using DUS descriptors. Observations were recorded on leaves, stem, flowers and capsule of plants at different stages. Most of the analyzed traits showed a significant amount of variation. These differences in physical traits were useful for identifying particular sesame genotypes. The aforementioned study highlighted the distinctive qualities of sesame varieties and demonstrated that morphological variances exist in these genotypes due to variations in genetic makeup, suggesting that breeders may make greater use of these variations in the selection process based on their particular breeding programme. These differences in morphological traits were useful in identification and conservation of individual sesame genotypes.

Key words : DUS characterization, sesame, genotypes, morphological variation.

Introduction

The oldest oilseed that humans are aware of and have utilized is sesame (*Sesamum indicum* L.). In the tropics and warm subtropics, where it is often produced in tiny plots, it is grown as a rainfed crop. Sesame (*Sesamum indicum* L.) is commonly known as til, a self pollinated crop belonging to family Pedaliaceae with diploid chromosome number $2n = 26$. Only *Sesamum indicum* has been recognized as a cultivated species among the thirty six species of genus *Sesamum* (Alemawu et al., 1998). The crop is highly tolerant to drought, grows well in most of the well drained soils and various agro climatic regions, and is well adapted to different rotations. Sesame oil has highest antioxidant content and contains several fatty acids such as oleic acid (43 %), linoleic acid (35%), palmitic acid (11%) and stearic acid (7%). Under changing climatic conditions, breeding of climate resilient varieties is becoming more important. Understanding genetic diversity is essential for developing disease and pest resistance cultivars as well as selecting elite parents for high grain and oil yield. A new genotype must pass the DUS (distinctness, uniformity, and stability) tests in order to be registered as a commercial variety. To be registered as a commercial variety, a new genotype must be distinct (D) from all other released varieties, uniform (U), and stable (S). The characteristics of the plant and seed must be properly investigated and recorded in order to identify genotypes by morphological traits. Such characterization studies are lacking in sesamum Therefore, the present study was undertaken to characterize the genotypes of sesame using DUS descriptors.

Materials and Methods

Field experiment was conducted at Project Coordinating Unit (Sesame and Niger) Research Farm, JNKVV, Jabalpur (M.P). Jabalpur is situated in 'Kymore plateau and Satpura hills agro-climatic region of Madhya Pradesh. Ninety three germplasm were used for this study. The recommended agronomical and plant protection package of practices were followed for the raising successful crop. The observations were recorded on 5 randomly selected plants for each character in each replication at different crop growth stages. Data were collected on 11 qualitative traits including morphological characters. DUS characterization was done as per the guidelines developed by IPGRI Rome, Italy and NBPGR New Delhi, India. Observations were recorded on 12 morphological traits viz, flower petal color, flower petal hairiness, plant branching pattern, plant branching habit, stem hairiness, leaf lobes, leaf size, leaf serration of margin, capsule shape, capsule arrangement, capsule hairiness and seed coat colour

Results and Discussion

DUS descriptors were used to analyze the morphological characteristics of the sesame germplasm. The ninety three genotypes could be distinguished from one another based on differences in morphology. The findings showed that almost all of the characters recorded had a significant amount of variation. The sesame genotypes were divided into groups based on differences in physical traits, with the goal of identifying each genotype individually using descriptors. Based on morphological variation, the eight genotypes could be identified from each other. The result

Table-1 : Categorization of sesame germplasm based on morphological characters.

Character	Classes	Germplasm
1. Flower Petal Color	White	-
	Light purple	All germplasm and Check (GT-10), (TKG-22), (RT-54)
	Purple	-
2. Flower petal hairiness	Absent	-
	Sparse	EC-14121, RJS-29, MT-6262, NIC-8984, SI-2940, GRT-8359-1, NIC-16236, TKG-22, GT-10, RT-54
	Dense	KIS-297-2, KIS-357-A, VOSI-5846, VOSI-8458, SP-41, EC-334952, IC-132408, NIC-8202, IS-172, IS-101, IS-136, IS-750-1-84, IS-184-1, IS-92-2, IS-146, SI-931, SI-3265-5, SI-44, SI-199-2-84, SI-3275, SI-982, PCU-34, PCU-35, PCU-36, PCU-37, PCU-38, NIC-8322, SI-3265, DSK-1, 49-E-SPS-6, ES-29, NIC-8559, EC-334950, S-0439, IC-131485, IC-204595, RJS-124, NIC-8202, NIC-10622, KMR-38, KANPUR LOCAL, KMR-77, IS-649, SI-1818, NIC-7943, ES-28, NIC-16347, SI-2174, B-7-11, TS-261, ES-40, IC-204648, NIC-16407, Pallae lu-2, ES-3707, IS-190, IS-3082, SI-2973, S-0308, NIC-16328, GRT-83125, IS-56, NIC-16268, MT-67-25, IS-355, MIC-8526, NAL/28/27/31/4, IC-14093, IS-351-2, S-0448, S-0448, B-203, IC-14160-1, S-0337, KMR-17, IC-96128, S-0228, S-0434, ES-110-C, SI-1926, NIC-13598, SI-2008, IS-309, IC-382-2
3. Plant branching pattern	Basal	KIS-357-A, KIS-297-2, VOSI-5846, VOSI-8458, EC-14121, EC-334952, IC-132408, NIC-8202, IS-172, IS-101, IS-136, IS-146, SI-931, SI-3265-5, SI-44, SI-199-2-84, SI-3275, SI-982, PCU-37, PCU-38, NIC-8322, SI-3265, TKG-22, SI-2973, S-0308, NIC-16328, GRT-83125, IS-56, NIC-16268, NIC-8984, MT-67-25, MIC-8526, NAL/28/27/31/4, IC-14093, IS-351-2, S-0448, IC-14160-1, S-0337, KMR-17, IC-96128, S-0228, S-0434, ES-110-C, NIC-16236, SI-1926, GRT-8359-1, SI-2008, IS-309, SI-2940, IC-382-2, GT-10, 49-E-SPS-6, ES-29, EC-334950, S-0439, IC-131485, IC-204595, RJS-124, KMR-38, KANPUR LOCAL, KMR-77, IS-649, SI-1818, NIC-7943, ES-28, MT-6262, NIC-16347, B-7-11, TS-261, NIC-16407, Pallae lu-2, IS-190, IS-3082, RT-54
	Top	IS-750-1-84, IS-184-1, IS-92-2, RJS-29, SP-41, PCU-34, PCU-35, PCU-36, IS-355, B-203, NIC-13598, NIC-8559, NIC-8202, NIC-10622, SI-2174, ES-40, IC-204648, ES-3707, DSK-1
	ES-3707, DSK-1	
4. Plant Branching habit	Few	NIC-7943
	Medium	SP-41, VOSI-5846, VOSI-8458, NIC-8202, IS-101, IS-92-2, SI-931, SI-3265-5, SI-199-2-84, SI-982, PCU-34, PCU-35, PCU-37, PCU-38, NIC-8322, SI-3265, TKG-22, SI-2973, GRT-83125, IS-56, NIC-16268, NIC-8526, B-203, S-0228, ES-110-C, NIC-13598, GRT-8359-1, SI-2008, IS-309, SI-2940, IC-382-2, GT-10, DSK-1, 49-E-SPS-6, ES-29, NIC-8559, EC-334950, S-0439, IC-131485, IC-204595, RJS-124, NIC-8202, NIC-10622, KMR-38, KANPUR LOCAL, KMR-77, ES-28, MT-6262, SI-2174, B-7-11, TS-261, ES-40, IC-204648, NIC-16407, Pallae lu-2, ES-3707, IS-190, IS-3082, RT-54
	Profuse	KIS-357-A, KIS-297-2, RJS-29, EC-14121, EC-334952, IC-132408, IS-172, IS-136, IS-750-1-84, IS-184-1, IS-146, SI-44, SI-3275, PCU-36, S-0308, NIC-16328, NIC-8984, MT-67-25, NAL/28/27/31/4, IC-14093, IS-351-2, S-0448, IC-14160-1, S-0337, KMR-17, IC-96128, S-0434, NIC-16236, SI-1926, IS-649, SI-1818, NIC-16347
6. Leaf lobes	Sparse	49-E-SPS-6, ES-29, EC-334950, IC-131485, RJS-124, NIC-16347, TS-261, IC-204648, ES-3707, VOSI-5846, VOSI-8458, EC-334952, NIC-8202, IS-101, IS-136, NIC-8984, MT-67-25, IC-14160-1, IC-96128, S-0228, NIC-16236, NIC-13598
	Dense	DSK-1, NIC-8559, S-0439, IC-204595
	Light lobed	KIS-297-2, EC-14121, EC-334952, IC-132408, SI-44, SI-199-2-84, TKG-22, PCU-38, PCU-34, PCU-35, SI-3265, SI-3275, SI-982, S-0308, NIC-16328, IS-355, MIC-8526, NAL/28/27/31/4, IC-14093, IS-351-2, B-203, IC-14160-1, KMR-17, S-0228, NIC-16236, SI-1926, NIC-13598, GRT-8359-1, SI-2008, GT-10, RJS-124, NIC-8202, KMR-38, MT-6262, NIC-16347, B-7-11, TS-261, ES-3707, IS-190, RT-54
7. Leaf size	Deeply lobed	MT-67-25, S-0337, IC-96128, 49-E-SPS-6, ES-29, NIC-8559, NIC-10622
	Small	IC-132408, IS-101, SI-3275, PCU-38, S-0308, GRT-83125, NIC-8984, MIC-8526, S-0448, B-203, KMR-17, S-0228, S-0434, ES-110-C, NIC-16236, SI-1926, NIC-13598, NIC-8559, IC-131485, IC-204595, KMR-38, KANPUR LOCAL, MT-6262, NIC-16347, SI-2174, B-7-11, TS-261, Pallae lu-2
	Medium	KIS-297-2, RJS-29, VOSI-8458, EC-14121, EC-334952, NIC-8202, IS-172, IS-750-1-84, IS-184-1, S-146, SI-931, SI-3265-5, SI-44, SI-199-2-84, SI-982, PCU-34, PCU-35, PCU-37, SI-3265, TKG-22, NIC-16328, IS-56, NIC-16268, MT-67-25, IS-355, NAL/28/27/31/4, IS-351-2, IC-14160-1, S-0337, IC-96128, SI-2008, IS-309, SI-2940, IC-382-2, GT-10, DSK-1, ES-29, EC-334950, S-0439, RJS-124, NIC-8202, NIC-10622, KMR-77, IS-649, SI-1818, NIC-7943, ES-28, MT-6262, NIC-16347, SI-2174, B-7-11, TS-261, IC-204648, NIC-16407, Pallae lu-2, IS-190, IS-3082, RT-54
	Large	NIC-8322, PCU-36, IS-92-2, IS-136, VOSI-5846, SP-41, KIS-357-A

Contd....

Character	Classes	Germplasm
8. Leaf serration of margin	Absent	IS-56
	Light	SP-41, GRT-83125, SI-1926, IC-382-2, S-0439, KMR-77, NIC-7943, SI-2174, RT-54
	Deep	KIS-357-A, KIS-297-2, RJS-29, VOSI-5846, VOSI-8458, EC-14121, EC-334952, IC-132408, NIC-8202, IS-172, IS-101, IS-136, IS-750-1-84, IS -184-1, IS-92-2, IS-146, SI-931, SI-3265-5, SI-44, SI-199-2-84, SI-3275, SI-982, PCU-34, PCU-35, PCU-36, PCU-37, PCU-38, NIC-8322, SI-3265, TKG-22, SI-2973, S-0308, NIC-16328, NIC-16268, NIC-8984, MT-67-25, IS-355, MIC-8526, NAL/28/27/31/4, IC-14093, IS-351-2, S-0448, B-203, IC-14160-1, S-0337, KMR-17, IC-96128, S-0228, S-0434, ES-110-C, NIC-16236, NIC-13598, GRT-8359-1, SI-2008, IS-309, SI-2940, GT-10, DSK-1, 49-E-SPS-6, ES-29, NIC-8559, EC-334950, IC-131485, IC-204595, RJS-124, NIC-8202, NIC-10622, KMR-38, KANPUR LOCAL, IS-649, SI-1818, ES-28, MT-6262, NIC-16347, B-7-11, TS-261, ES-40, IC-204648, NIC-16407, Pallae lu-2, Es-3707, IS-190, IS-3082.
9. Capsule Shape	Tapered	-
	Narrow oblong	KIS-357-A, KIS-297-2, RJS-29, SP-41, VOSI-5846, VOSI-8458, EC-14121, EC-334952, IC-132408, NIC-8202, IS-172, IS-101, IS-750-1-84, IS -184-1, IS-92-2, IS-146, SI-931, SI-3265-5, SI-44, SI-199-2-84, SI-3275, SI-982, PCU-34, PCU-35, PCU-36, PCU-37, PCU-38, NIC-8322, SI-3265, TKG-22, SI-2973, S-0308, NIC-16328, GRT-83125, IS-56, NIC-16268, NIC-8984, IS-355, MIC-8526, NAL/28/27/31/4, IC-14093, IS-351-2, B-203, IC-14160-1, S-0337, KMR-17, IC-96128, S-0228, S-0434, ES-110-C, NIC-16236, SI-1926, NIC-13598, GRT-8359-1, SI-2008, IS-309, SI-2940, IC-382-2, GT-10, DSK-1, 49-E-SPS-6, ES-29, NIC-8559, EC-334950, S-0439, IC-131485, IC-204595, RJS-124, NIC-8202, NIC-10622, KMR-38, KANPUR LOCAL, KMR-77, IS-649, SI-1818, NIC-7943, ES-28, MT-6262, NIC-16347, SI-2174, B-7-11, TS-261, ES-40, IC-204648, NIC-16407, Pallae lu-2, Es-3707, IS-190, IS-3082, RT-54
	Broad oblong	IS-136, MT-67-25, S-0448
10. Capsule arrangement	Alternate	KIS-357-A, KIS-297-2, RJS-29, VOSI-5846, EC-14121, EC-334952, NIC-8202, IS-146, SI-931, SI-3265-5, SI-44, SI-3275, SI-982, PCU-34, NIC-8322, SI-3265, TKG-22, NIC-16328, GRT-83125, NIC-8984, MT-67-25, IS-355, MIC-8526, NAL/28/27/31/4, IC-14093, S-0337, KMR-17, S-0434, ES-110-C, GT-10, ES-29, NIC-8559, S-0439, IC-131485, IC-204595, RJS-124, NIC-8202, KMR-77, SI-1818, ES-28, SI-2174, TS-261, IC-204648, RT-54
	Opposite	SP-41, VOSI-8458, IC-132408, IS-172, IS-101, IS-136, IS-750-1-84, IS -184-1, IS-92-2, SI-199-2-84, PCU-35, PCU-36, PCU-37, PCU-38, SI-2973, S-0308, IS-56, NIC-16268, IS-351-2, S-0448, B-203, IC-14160-1, NIC-16236, SI-1926, NIC-13598, GRT-8359-1, SI-2008, IS-309, SI-2940, IC-382-2, IC-96128, S-0228, DSK-1, 49-E-SPS-6, EC-334950, NIC-8202, NIC-10622, IS-649, NIC-7943, MT-6262, NIC-16347, B-7-11, ES-40, NIC-16407, Pallae lu-2, ES-3707, IS-190, IS-3082
11. Capsule hairiness	Glabrous	SI-199-2-84, MT-67-25, NIC-10622, ES-40
	Sparse	SP-41, EC-14121, NIC-8202, IS-101, IS-750-1-84, TKG-22, SI-931, SI-3265-5, SI-44, SI-3275, SI-3265, IS -184-1, SI-2973, S-0308, NIC-16328, S-0228, IS-56, NIC-16268, NIC-8984, IS-355, MIC-8526, NAL/28/27/31/4, IS-351-2, IC-14160-1, B-203, S-0337, KMR-17, GRT-83125, SI-1926, GT-10, GRT-8359-1, SI-2008, SI-2940, IC-382-2, NIC-13598, DSK-1, ES-29, RJS-124, NIC-8202, KMR-38, KANPUR LOCAL, IS-649, NIC-7943, TS-261, B-7-11, IS-3082, NIC-16407, Pallae lu-2, IS-190, RT-54, IC-204648
	Dense	KIS-357-A, KIS-297-2, RJS-29, IS-92-2, IS-146, EC-334952, IC-132408, IS-172, IS-136, VOSI-5846, VOSI-8458, SI-982, PCU-34, PCU-35, PCU-36, PCU-37, PCU-38, NIC-8322, IC-14093, S-0448, IC-96128, IS-309, S-0434, ES-110-C, NIC-16236, 49-E-SPS-6, NIC-8559, EC-334950, S-0439, IC-131485, IC-204595, KMR-77, SI-1818, ES-3707, ES-28, MT-6262, NIC-16347, SI-2174
12. Seed coat colour	White	KIS-357-A, KIS-297-2, RJS-29, SP-41, VOSI-5846, VOSI-8458, EC-14121, EC-334952, IC-132408, NIC-8202, IS-172, IS-101, IS-136, IS-750-1-84, IS -184-1, IS-92-2, IS-146, SI-931, SI-3265-5, SI-44, SI-199-2-84, SI-3275, SI-982, PCU-34, PCU-35, PCU-36, PCU-37, PCU-38, NIC-8322, SI-3265, TKG-22
	Black	SI-2973, S-0308, NIC-16328, GRT-83125, IS-56, NIC-16268, NIC-8984, MT-67-25, IS-355, MIC-8526, NAL/28/27/31/4, IC-14093, IS-351-2, S-0448, B-203, IC-14160-1, S-0337, KMR-17, IC-96128, S-0228, S-0434, ES-110-C, NIC-16236, SI-1926, NIC-13598, GRT-8359-1, SI-2008, IS-309, SI-2940, IC-382-2, GT-10
	Light brown	DSK-1, 49-E-SPS-6, ES-29, NIC-8559, EC-334950, S-0439, IC-131485, IC-204595, RJS-124, NIC-8202, NIC-10622, KMR-38, KANPUR LOCAL, KMR-77, IS-649, SI-1818, NIC-7943, ES-28, MT-6262, NIC-16347, SI-2174, B-7-11, TS-261, ES-40, IC-204648, NIC-16407, Pallae lu-2, Es-3707, IS-190, IS-3082, RT-54

of characterization for each qualitative trait is presented in the Table-1. Results revealed wide range of variation among the ninety three genotypes for almost all the qualitative traits studied (Table-1).

Petal colour is the important characters for morphological characterization. Based on petal colour, the genotypes were grouped as white, light purple and purple. All the germplasm under study were light purple in colour. Based on Petal hairiness of flower, the genotypes were grouped as sparse and dense. Ten germplasm lines were having sparse flower petal hairiness and eighty three were having dense flower petal hairiness. This observation in sesame is in accordance with Suhasini, (2003); Bhagwat Singh *et al.* (2017) and Palakshappa *et al.* (2020). The genes determine the colour of the petal by developing or blocking of anthocyanin pigmentation.

In the present study basal and top branching patterns and branching habit were observed and it was indicated that the inheritance of branching habit was determined by one single dominant gene. Based on plant branching habit, germplasm were categorized in three groups *i.e.* few, medium and profuse. One the germplasm showed few branching habit, sixty germplasm had shown medium branching habit and thirty two germplasm profuse branching habit. Based on branching pattern Seventy four were having basal and nineteen top branching pattern. Similar findings and grouping of genotypes based on flower and stem morphological characters were made by Parameshwarappa *et al.* (2020); Frary *et al.* (2015); Sarita *et al.* (2015); Azeez *et al.* (2017) and Ozcinar and Sogut, (2017) in sesame.

On the basis of Stem hairiness, Sixty seven germplasm had glabrous stem, twenty two sparse and four germplasm showed dense stem hairiness. Based on leaf lobes, Forty six germplasm had no lobes, forty had light lobes and seven had deep lobes. Based on leaf size, germplasm were categorized in three groups *i.e.* small, medium and large leaf size. Twenty eight germplasm had small leaf, fifty medium leaf size and fifteen had large leaf size. On the basis of leaf Margin, One germplasm had no leaf serration of margin, nine germplasm showed light leaf serration of margin, whereas, eighty three lines showed deep leaf serration of margin. Suhasini (2003) and Palakshappa *et al.* (2020) observed the similar results in sesame.

Based on capsules arrangement, Forty five germplasm lines showed alternate capsule arrangement and forty eight showed opposite capsule arrangement. Based on Shape of the capsule, Ninety germplasm lines had narrow oblong capsule shape and three were broad oblong in shape. "Hairiness is the significant character for improving more seed yield and natural defense

mechanism for biotic and abiotic factors. So this character may be recognized as ideal plant type. Based on Capsule hairiness, Four germplasm lines had glabrous capsule, fifty one had sparse haired capsule and thirty eight showed dense capsule hairiness. Hairiness and pubescence is reported in effective for conferring resistance to insect pests in *Dolichos bean*" reported by Jagadeesh *et al.* (2008); Baydar *et al.* (2005); Falusi *et al.* (2007) and Sarita *et al.* (2013).

Based on seed coat colour the germplasm were categorized in three groups *i.e.*, white, black and light brown. Thirty one germplasm lines had white seed coat colour, thirty one black and thirty one had light brown seed coat colour. A wide range of variation, *i.e.* white, grey, and light brown, dark brown and black was observed for seed coat colour against the reported white, brown and black. All earlier researchers in sesame, outlined seed coat colour to be under digenic control with several confusing segregants (Subashini *et al.* 2003; Weiss, 1983 and Zhang *et al.* 2013). Based on variation in physical characteristics, it was attempted to group the sesame genotypes and identify each and every one of them through descriptors. Based on morphological variation, the ninety three could be identified from each other. The result of characterization for each qualitative trait is presented in the Table 1. Results revealed wide range of variation among the ninety three genotypes for almost all the qualitative traits studied.

Conclusions

Morphological features of genotypes have been a major component of varietal identification. It is not possible to identify varieties using any single parameter. A detailed morphological description of plants and seeds should therefore be prepared. Utilization of these features in sequential fashion is useful and convenient to distinguish different genotypes. The information about inheritance of three capsules per leaf axil could be beneficial for genetic improvement of sesame targeting higher seed yield.

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Effect of Nutrient Management on Growth and Yield of Mustard [*Brassica juncea* (L.) Czern & Coss] Varieties

Rajni Kumari*, P.K. Sharma and Pallishree Biswal

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : rjnkumari1411@gmail.com

Abstract

A field experiment was conducted during Rabi season of 2022-23 at Research Farm, Vivekananda Global University, Jaipur. The experiment was laid out in factorial randomized block design with three replications. The treatments consisting four varieties of mustard (Bio-902, NRCHB-506, RH-725 and Giriraj) and four treatment of nutrient management (Control, 50% NPS + 2.5 t/ha VC, 75% NPS + 2.5 t/ha VC and 100% NPS + 2.5 t/ha VC). The experimental results showed that mustard variety giriraj produced significantly higher plant height and dry matter accumulation at 80 DAS and at harvest, number of siliqua/plant, number of seeds/siliqua, seed yield, stover yield and biological yield over Bio-902 and NRCHB - 506. While, different varieties were failed to cause significant variation on plant stand at 20 DAS, plant height and dry matter accumulation at 40 DAS, test weight, harvest index of mustard. Results further showed that application of 100% NPS + 2.5 t/ha VC significantly increased the plant height and dry matter accumulation at 80 DAS and at harvest, number of siliqua/plant, number of seeds/siliqua, seed yield, stover yield and biological yield of mustard. The application of 75% NPS + 2.5 t/ha VC with mustard variety giriraj may be recommended for higher productivity of mustard crop.

Key words : Growth, nutrient, variety and yield.

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss] is a major rabi oilseed crop of the country and occupies a prominent place being next in importance to soybean and groundnut, both in area and production. It belongs to family Brassicaceae and have chromosome no. of $2n=36$. Indian mustard gives edible oil which is used as cooking medium in North India. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The leaves of young plants are used as vegetable. The oil content in mustard seeds varies from 37 to 49 per cent and its oil is utilized for human consumption for cooking and frying purposes.

Yield potential of mustard in Rajasthan is not being exploited fully due to many factors, among which use of low yielding varieties are the most important ones because proper varietal selection could be responsible for high crop production. There is a great deal of evidence to show that suitable varieties respond differently to agronomic practices. Field observations by many researchers revealed a large amount of variations in plant growth, number of branches and yield components such as number of siliqua, number of seeds per siliqua and seed yield between different varieties. High yield potential varieties play a pivotal role in increasing per hectare yield under optimum growing season. Bora (1997) has reported that the yield potential of different mustard varieties may differ under different agro-climatic conditions because of their inherent capacity. The mustard variety differ in their

yielding ability, this calls for a need to generate more information on the response of mustard variety to the nutrient management for greater yields in a given agro-climatic conditions.

N and P are the major nutrients for plant growth and these nutrients status in soils of this region are low. Nitrogen being a structural part of plant body which helps in synthesis of protein and important for photosynthetic activities in the plants. The soils of this region being poor in texture and organic matter content, will require split application of nitrogen rather than single application for better absorption. Likewise, phosphorus is the key element in the process of conservation of solar energy into chemical energy.

The use of organic manure or other farm waste is the tool to improve the physical, chemical and biological properties of the soil. The vermi-composting is an eco-friendly and effective way to recycle agricultural and kitchen wastes. The application of vermicompost not only adds plant nutrients (macro and micro) in soil and acts as growth regulators to one but also increases soil water retention, microbial population, and humic substances of the soil, mineralization and release of nutrients. Besides these, vermicompost also improves soil aeration, reduction of soil erosion, reduces of evaporation losses of water, accelerates the process of humification; stimulates the microbial activity, deodourification of obnoxious smell, destruction of pathogens and detoxification of pollutant in soil.

Table-1 : Treatments details with their symbols.

S. No.	Treatment	Symbol
A Varieties		
1.	Bio-902 (Pusa Jai Kisan)	V1
2.	NRCHB - 506	V2
3.	RH - 725	V3
4.	Giriraj (DRMRIJ 31)	V4
B Nutrient management		
1.	Control	NM0
2.	50% NPS + 2.5 t/ha Vermicompost	NM1
3.	75% NPS + 2.5 t/ha Vermicompost	NM2
4.	100% NPS + 2.5 t/ha Vermicompost	NM3

Table-2 : Effect of varieties and nutrient management growth parameters of mustard.

Treatments	Plant population m ⁻¹ row length	Plant height (cm)			Dry matter accumulation (g m ⁻¹ row length)		
		At 40 DAS	80 DAS	At harvest	At 40 DAS	80 DAS	At harvest
Varieties							
Bio-902	9.87	37.35	160.88	187.47	91.93	231.27	299.47
NRCHB - 506	9.66	36.77	166.10	190.24	95.88	240.91	303.39
RH - 725	9.80	35.75	181.79	206.43	94.68	262.52	330.52
Giriraj	9.49	37.67	183.15	207.77	90.79	269.24	333.39
SEm ±	0.26	0.89	4.43	5.19	2.18	5.99	8.20
CD (P=0.05)	NS	2.56	12.78	14.99	6.30	17.29	23.68
Nutrient management							
Control	9.72	37.22	149.16	168.09	94.35	218.81	264.35
50% NPS + 2.5 t/ha VC	9.84	37.29	169.68	194.37	96.72	246.33	309.05
75% NPS + 2.5 t/ha VC	9.54	36.36	185.70	213.93	88.03	268.37	343.79
100% NPS + 2.5 t/ha VC	9.71	36.68	187.38	215.51	94.19	270.43	349.56
SEm ±	0.26	0.89	4.43	5.19	2.18	5.99	8.20
CD (P=0.05)	NS	0.97	0.53	2.66	6.30	17.29	23.68

Table-3 : Effect of varieties and nutrient management on yield and yield attributes of mustard.

Treatments	Yield attributes			Yield (kg/ha)			
	No. of siliqua/plant	No. of seeds/siliqua	Test weight (g)	Seed	Straw	Biological	Harvest index (%)
Varieties							
Bio-902	132.95	14.61	3.96	1722	3546	5268	32.80
NRCHB - 506	139.01	15.11	4.07	1787	3667	5454	32.81
RH - 725	153.28	16.94	4.54	1963	4041	6004	32.73
Giriraj	155.75	17.24	4.57	1990	4150	6141	32.39
SEm ±	3.68	0.38	0.11	55	106	140	0.67
CD (P=0.05)	10.63	1.10	NS	159	306	404	NS
Nutrient management							
Control	126.81	13.84	4.16	1596	3236	4832	33.02
50% NPS + 2.5 t/ha VC	142.49	15.66	4.27	1820	3780	5600	32.58
75% NPS + 2.5 t/ha VC	155.19	17.12	4.34	1992	4146	6138	32.47
100% NPS + 2.5 t/ha VC	156.50	17.29	4.37	2054	4242	6296	32.65
SEm ±	3.68	0.38	0.11	55	106	140	0.67
CD (P=0.05)	10.63	1.10	NS	159	306	404	NS

Materials and Methods

The experiment was conducted during *Rabi* 2022-23 at Research Farm, Vivekananda Global University, Jaipur. Geographically, the study area is located at 75°88'99" E longitude and 26°81'17" N latitude and this region falls under Semi-arid Eastern Plain Zone of agro-climatic zone of Rajasthan. The experiment consisting of 16 treatment

combinations was laid out in Factorial Randomized Block Design. Treatments details along with their symbols of experiment are presented in table 1. Seeds of mustard variety Bio-902, NRCHB - 506, RH – 725 and Giriraj were treated with bavistin @ 3 g kg⁻¹ seed to prevent seed borne disease. The crop was sown by “kera” method in rows spaced at 30 cm apart and plant spaced at 10 cm on 5 November 2022 using seed rate of 4 kg/ha.

Statistical analysis : Experimental data recorded in various parameters were statistically analyzed with the help of Fisher's analysis of variance technique (Fisher, 1950). The critical difference (CD) for the treatment comparisons was worked out wherever the variance ratio (F test) was found significant at 5% level of significance.

Results and Siscussion

Effect of varieties on growth attributes : The data showed that different wheat varieties significantly influenced plant height and dry matter accumulation at different periodically growth stages (Table-2). Plant height is mainly controlled by the genetic makeup of genotype, but it is also affected by environmental conditions thus it varies from variety to variety. Plant height was significantly affected among varieties in this study. The maximum plant height was recorded in giriraj which was significantly taller than Bio-902 and NRCHB – 506 varieties. The minimum plant height was recorded in Bio-902. The differences in plant height among various varieties are in general, due to their genetic constitution. Growth and yield potential of crop or variety are the outcome of genomic, environment and agronomic interactions. Since, all the varieties were grown under identical agronomic environment, the observed variation in overall growth of the varieties could be ascribed to their internal genetically make up and external environmental factors to which these were exposed during their life cycle. These results are in line with those of Kumari *et al.* (2012), Singh *et al.* (2017a) and Patel *et al.* (2017). The dry-matter accumulation capacity of varieties varies significantly. Variety giriraj recorded significantly higher dry matter accumulation at 80 DAS and at harvest over Bio-902 and NRCHB – 506. The difference in dry-matter accumulation among varieties was mainly due to the difference in their tiller and leaf production capacity as number of tiller and leaf had positive correlation. These results are well comparable with Afroz *et al.* (2011), Jha *et al.* (2012), Kumari *et al.* (2012) and Patel *et al.* (2017).

Effect of varieties on yield attributes and yield : Yield attributing characters viz. number of siliqua/plant, number of seeds/siliqua and seed, straw and biological yield were affected due to different varieties of mustard (Table-3). The number of siliqua in four varieties under study showed significant difference. Giriraj and Bio-902 produced maximum and minimum number of siliqua/plant, respectively. This difference in general, attributed because of different genetics potential of varieties to produce tillers. Similar results had also been reported by Afroz *et al.* (2011) and Jha *et al.* (2012). Number of seeds/siliqua is an important yield contributing factor of mustard which is significantly influenced by the prevailing growing conditions and genetic potential of a cultivar. The

number of seeds/siliqua did varied significantly among varieties. However, the number of seeds/siliqua was highest in giriraj. Probably these results are consequences of similar genetic potential of varieties to grains formation. Afroz *et al.* (2011) and Jha *et al.* (2012) also reported significant differences in number of seeds/siliqua of mustard varieties. The seed yield is the sum total of different yield contributing factors controlled both genetically and environmentally. The highest seed yield was produced by Variety giriraj which was significantly higher over Bio-902 and NRCHB – 506. High yield of giriraj may be attributed to its higher biomass accumulation due to higher number of siliqua, leaves and its proper partitioning as evident from equally higher harvest index; and good yield attributes i.e. siliqua length, number of siliqua and test weight. Variety Bio-902 recorded lowest seed yield due to lower biomass accumulation as a result of less number of siliqua and leaves; and its lower test weight. These findings are similar to that of Shah and Rahman (2009), Afroz *et al.* (2011), Singh *et al.* (2015) and Singh *et al.* (2017a). Difference in straw yield of varieties was significant. The maximum straw yield was recorded in giriraj. Variety giriraj was efficient in utilizing biomass towards grain formation as evident from its highest harvest index its vice-versa for Bio – 902. These findings are in close conformity with those of Singh *et al.* (2015) and Singh *et al.* (2017a) Maurya *et al.* (2019), who also found significant difference in straw yield of varieties.

Effect of nutrient management on growth attributes :

The findings of the investigation showed that integrated nutrient management treatments significantly enhanced the vegetative growth in terms of plant height and dry matter accumulation of mustard. The maximum value of these growth parameters was recorded with 100% NPS + 2.5 t/ha VC (Table-2). The increase in growth attributes of mustard might be due to increase in availability of major nutrients (N and P) due to direct addition in the form of chemical fertilizer and through organic fertilizers. Nitrogen is one of the major essential plant nutrient required for growth and the increased availability of nitrogen due to direct addition of nitrogen in the form of fertilizer on otherwise poor soil might have increased number of cells and cell size leading to better growth in terms of height dry matter accumulation and number of branches. Phosphorus is the second most indispensable nutrient required for growth and development of plant and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformation. It is the main constituent of co-enzyme of ATP and ADP, which acts as energy currency within the plants. Thus, Phosphorus application affects photosynthesis, biosynthesis of proteins,

phospholipids and nucleic acids, membrane transport and cytoplasmic streaming. The results of the present investigation are in close conformity with the findings of, Dhruw *et al.* (2017), Murali *et al.* (2018), Singh *et al.*, (2018) and Yadav *et al.* (2018) in mustard crop.

Effect of nutrient management on yield and yield attributes : In the investigation, there was significant improvement noted in yield attributes (number of siliqua/plant and number of seeds/siliqua) and yield (seed, stover and biological) of mustard with nutrient management treatments. The maximum mean values of number of siliqua/plant, number of seeds/siliqua, seed yield, stover yield and biological yield of mustard was obtained with the application of 100% NPS + 2.5 t/ha VC which was significantly higher as compared to control and application of 50% NPS + 2.5 t/ha VC (Table-3). The beneficial response of inorganic sources of nutrient with organic manure on yield attributes and yield of mustard might be due to the availability of sufficient amount of plant nutrients throughout the growth period of crop resulting in better uptake of nutrients, plant vigour and improved yield. The increased growth in terms of plant height, dry matter accumulation and number of branches/plant might also provide better sites for silique formation and seed development. As a result, almost all yield attributes of crop resulted into significant improvement due to fertilizer application. Organic matter is also a source of energy for soil micro-flora, which brings about the transformation of organic form of nutrients present in soil, into available form. The increase in seed and stover yields with the application of chemical fertilizers might be due to better nutritional environment in low status of nitrogen and phosphorus soil as evidenced by their uptake in the plant and due to the increased supply of N and P and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters, resulted in increased seed and stover yield of the crop. The results of the present study are in close conformity with findings of Thaneshwar *et al.* (2017) and Murali *et al.* (2018) in mustard crop.

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Effect of Integrated Nutrient Management on Growth and Yield of Wheat (*Triticum aestivum* L.)

Saurabh Jadhav*, P.K. Sharma and Sunil Kumar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India 303012

*Corresponding Author Email : saurabhjadhav7903@gmail.com

Abstract

A field experiment was conducted at Research Farm, Vivekananda Global University, Jaipur during *Rabi* season of 2022-23. The experiment consisting of nine treatment combinations of agrochemicals viz., NPK (80:40:40 kg/ha) (T1), FYM @ 5 t/ha + PSB + Azotobacter (T2), VC @ 2 t/ha + PSB + Azotobacter (T3), NPK (80:40:40 kg/ha) + Gypsum @ 140 kg/ha (T4), FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha (T5), VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha (T6), NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha (T7), FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha (T8) and VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha (T9) were laid out in randomized block design with three replications. For experimentation, variety NAIW-301 (Trambak) was used. The results of one-year study clearly showed that integrated nutrient management brought an additive effect in increasing growth, yield attributes of wheat. Maximum plant height, dry matter accumulation, number of effective tillers m⁻², number of grains spike⁻¹, spike length, grain yield, straw yield, biological yield was obtained with NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha (T7) which was closely followed by application of NPK (80:40:40 kg/ha) (T1), NPK (80:40:40 kg/ha) + Gypsum @ 140 kg/ha (T4), VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha (T6), FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha (T8) and VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha (T9). The plant population, plant height and dry matter accumulation at 30 DAS, test weight and harvest index of wheat was remained unchanged due to integrated nutrient management treatments. Therefore, application of either NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha (T5) or FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha (T8) or VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha (T9) was found most suitable as it gave highest grain yield of wheat.

Key words : Growth, nutrient and yield.

Introduction

Wheat [*Triticum aestivum* (L.)] is the most important staple food crop of the world and emerged as the backbone of India's food security. It is one of the most important and remunerative *Rabi* cereal crop of India not only in terms of acreage, but also in terms of its versatility for adoption under wide range of agro climatic conditions and crop growing situations. In India, major wheat growing states are UP, M.P., Punjab, Haryana, Rajasthan and Bihar. In India, wheat is cultivated in 31.61 million hectares area with production of 109.52 MT and productivity of 34.64 q ha⁻¹ (Anonymous, 2022). In Rajasthan, wheat is grown in an area of 3.00 million ha with an annual production and productivity of 11.04 million tons and 36.76 q ha⁻¹, (Anonymous, 2022). Though current wheat production in India is sufficient to meet its demand, but it has to be increased to 140 million tonnes per annum by 2050 (Vision 2050, 2015), for which there is a need to develop highly productive varieties responsive for improved production technology which fulfill the fast requirement of increasing population, maintenance of adequate buffer stock and to meet demand for processing industries.

Nitrogen is universally deficient plant nutrient in most of the Indian soils. Nitrogen is an essential constituent of

many compounds such as nucleotides, phospholipids, enzymes, hormones and vitamin etc. Nitrogen being an essential constituent of protein nucleic acid and chlorophyll plays a major role in photosynthesis and chlorophyll synthesis (Kanwar, 1976). Phosphorus is another important nutrient next to nitrogen. The phosphorus input in Indian agriculture comes from fertilizers, organic manures and to a very small extent from crop residues. It has beneficial effects on root development, growth and also hastens maturity as well as improves quality of crop produce. The availability and form of phosphorus in the soil depends upon the native and/or added sources of phosphate fertilizer and organic matter content from external sources. Potassium plays an active role in the maintenance of turgidity in plant cells in the formation of oils and in the increasing disease resisting. Potassium is also constituent unit for a number of metabolic processes in plants, viz., synthesis of simple sugar and starch, translocation of carbohydrates, reduction of nitrate and synthesis of protein; particularly in the meristematic tissues.

Bio-fertilizers are known to play a number of vital roles in increasing soil fertility, crop productivity and production in agriculture. Application of bio-fertilizers results in increased mineral and water uptake, root

Table-1 : Treatments details with their symbols.

S. No.	Treatment	Symbol
1.	N:P:K (80:40:40 kg/ha)	T1
2.	FYM @ 5t/ha + PSB + Azotobacter	T2
3.	Vermicompost @ 2 t/ha + PSB + Azotobacter	T3
4.	N:P:K (80:40:40 kg/ha) + Gypsum @ 140 kg/ha	T4
5.	FYM @ 5t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha	T5
6.	VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha	T6
7.	NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha	T7
8.	FYM @ 5t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha	T8
9.	VC @ 2t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha	T9

Table-2 : Effect of integrated nutrient management on growth parameters of wheat.

Treatments	Plant population	Plant height (cm)				Dry matter accumulation (g m ⁻²)			
		At 30 DAS	At 60 DAS	At 90 DAS	At harvest	At 30 DAS	At 60 DAS	At 90 DAS	At harvest
N:P:K (80:40:40 kg/ha)	26.0	14.53	49.02	85.01	97.28	140.9	394.0	876.2	1184.0
FYM @ 5 t/ha + PSB + Azotobacter	25.7	14.21	39.23	67.55	78.81	137.9	313.3	715.3	981.3
VC @ 2 t/ha + PSB + Azotobacter	26.0	14.40	40.98	69.88	81.44	139.3	324.0	737.3	998.0
N:P:K (80:40:40 kg/ha) + Gypsum @ 140 kg/ha	26.3	14.70	51.89	87.10	100.75	142.0	412.3	902.0	1219.0
FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha	26.5	14.83	41.84	71.23	83.35	144.2	337.7	751.0	1019.0
VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha	24.6	13.51	49.89	85.88	98.32	130.9	399.3	883.9	1196.0
NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha	25.0	13.68	52.64	88.91	101.71	133.0	417.0	923.0	1238.0
FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha	25.5	13.84	48.78	83.78	96.48	135.1	388.0	868.0	1172.0
VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha	25.5	14.01	50.34	86.34	99.35	136.4	405.0	892.0	1211.8
SEm+	1.3	0.66	1.98	3.78	3.89	6.7	15.1	33.4	47.0
CD (P = 0.05)	NS	NS	5.94	11.33	11.68	NS	45.3	100.1	141.0

development, vegetative growth and nitrogen fixation. Azotobacter is a free-living bacterium in non-legume crops and secretes some growth promoting substances. These organisms in addition to providing phosphorus to the plants also facilitate plant growth by different mechanism. PSB encourages early root development increase compatibility of other beneficial microbes with the plant and helps in rapid cell developments in the plant and consequently increase the tolerance toward disease (Kim *et al.*, 1998).

The integration of chemical fertilizers with organic manures and biofertilizers has been found to be quite promising not only in maintaining higher productivity but also in providing greater stability in crop production (Nambiar and Abrol, 1992). A judicious combination of organic and inorganic fertilizers can maintain long-term fertility and sustain higher productivity of crops. Integrated nutrient management approaches involving mineral sources of nutrients, vermicompost and biofertilizers need to be standardized.

Materials and Methods

The experiment was conducted during *Rabi* 2022-23 at Research Farm, Vivekananda Global University, Jaipur. Geographically, the study area is located at 75°88'99" E longitude and 26°81'17" N latitude and this region falls under Semi-arid Eastern Plain Zone of agro-climatic zone of Rajasthan. The experiment consisting of 9 treatment combinations was laid out in Randomized Block Design. N: P: K (80: 40: 40 kg/ha) was applied as per treatments. Half dose of nitrogen and full dose of phosphorus and potash will be applied as basal at sowing through urea, DAP and MOP and remaining half dose of nitrogen was top dressed at first and second irrigations. Gypsum (70-80% pure) of agriculture grade, containing 16 per cent sulphur and 16-19 per cent calcium, was applied before sowing as per treatment and was incorporated well into the soil. The seeds of wheat variety 'NAIW – 301 (Trambak)' were sown on 16th November 2022. The sowing was done at row spacing of 20 cm using a seed rate of 100 kg per ha by 'Kera' method with the help of desi

Table-3 : Effect of integrated nutrient management on yields and Yield attributes of wheat.

Treatments	Yield attributes				Yield (kg/ha)			
	Number of effective tillers m ⁻²	Number of grains spike ⁻¹	Spike length (cm)	Test weight (g)	Grain	Straw	Biological	Harvest index (%)
N:P:K (80:40:40 kg/ha)	342.0	32.24	7.91	38.28	4003	6138	10141	39.5
FYM @ 5 t/ha + PSB + Azotobacter	272.0	25.73	6.38	37.52	3123	4892	8015	39.0
VC @ 2 t/ha + PSB + Azotobacter	286.0	26.56	6.42	37.81	3278	5049	8327	39.4
N:P:K (80:40:40 kg/ha) + Gypsum @ 140 kg/ha	358.0	33.76	8.22	38.58	4178	6391	10569	39.5
FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha	292.0	27.12	6.58	38.86	3345	5167	8512	39.4
VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 140 kg/ha	347.0	32.88	7.99	35.78	4067	6184	10251	39.7
NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha	365.0	34.00	8.34	35.93	4234	6479	10713	39.5
FYM @ 5 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha	338.0	31.89	7.81	36.76	3988	6056	10044	39.7
VC @ 2 t/ha + PSB + Azotobacter + Gypsum @ 280 kg/ha	354.0	33.12	8.07	36.99	4123	6322	10445	39.5
SEm+	14.9	1.36	0.33	1.98	170	275	439	0.4
CD (P = 0.05)	44.6	4.07	1.00	NS	510	824	1317	NS

plough. The seeds were dropped manually in furrow opened by plough at a depth of 4-5 cm. Details of treatments along with their symbols are presented in table-1.

Statistical analysis : Experimental data recorded in various parameters were statistically analyzed with the help of Fisher's analysis of variance technique (Fisher, 1950). The critical difference (CD) for the treatment comparisons was worked out wherever the variance ratio (F test) was found significant at 5% level of significance.

Results and Discussion

Effect of integrated nutrient management on growth attributes : The experimental data showed that different integrated nutrient management treatments bring significant effect on growth of wheat. The application of NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha (T7) produced significantly highest plant height and dry matter accumulation at 60, 90 DAS and at harvest of wheat (Tables 2). The increase in plant height might be due to increase in availability of major nutrients (N, P and K) due to direct addition in the form of fertilizer. Nitrogen is one of the major essential plant nutrients required for growth and the increased availability of nitrogen due to direct addition of nitrogen in the form of fertilizer in nutrient deficient soil might have increased number of cells and cell size leading to better growth in terms of plant height. Nitrogen also accelerates photosynthetic rate and thereby increases the supply of carbohydrates to plant, which might have in turned into increased dry matter production in wheat.

Similarly, increased supply of available phosphorus has long been considered as an essential constituent of all living organisms and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformations. Increased availability of phosphorus owing to its application in low to medium phosphorus soils might have improved: the availability of phosphate and resulted in more uptakes and in turned into increased all the growth attributes of the plants. It is known fact that that exchangeable potassium helps in the protein synthesis, chlorophyll formation and increasing resistance against stress which might have improved growth and development of the plant.

The increase in growth attributes of wheat with the application of vermicompost mainly due to that organic manures improved the physical, chemical and biological properties of soil and supplies almost all the essential plant nutrients for growth and development of plants along with growth hormones and beneficial microbes which might have developed more favorable nutritional environment in soil for longer period resulted in increased plant height, new shoots and increased dry matter accumulation. Thus, increased availability of macro and micro nutrients might also be the reason of improved growth parameters of the crop. Further biofertilizers had beneficial effect on growth attributes because of certain growth promoting substances secreted by microbial inoculants and thus increased the availability of nutrients. Addition of biofertilizers in relation to N and P fertilization is instrumental in increasing the growth attributes in every

level of plant growth. The favorable effect of bacterial inoculation could be attributed to increase in N and P supply in inoculated plots due to NP-fixation ability of these bacteria. The faster availability of nutrients from adequate supply of inorganic fertilizers with organic manure and biofertilizers through-out the cropping period enhances the nutrient requirement of the crop and production of greater number of photo-synthetically active leaves which might have led to higher production of carbohydrates and phytohormones which resulted in increased dry matter accumulation and plant height. The results of the present investigation are in close conformity with those of Kumawat (2015), Kakraliya *et al.* (2017), Kaur *et al.* (2018), Singh *et al.* (2021) and Kumar *et al.* (2022) in wheat and barley crops.

Effect of integrated nutrient management on yield and yield attributes : The data showed that the yield attributes and yield of wheat significantly influenced with the application of different integrated nutrient management treatments. Application of NPK (80:40:40 kg/ha) + Gypsum @ 280 kg/ha (T7) gave highest number of effective tillers, spike length, number of grains spike⁻¹, grain yield, straw yield and biological yield of wheat (Table-3). The beneficial response of inorganic sources of nutrient with organic manure and biofertilizers on yield attributes and yield of wheat might be due to the availability of sufficient amount of plant nutrients throughout the growth period of crop resulting in better uptake of nutrients, plant vigour and improved yield. The positive effect of chemical fertilizer application in combination with vermicompost and biofertilizer on yield attributing characters of wheat seems to be due to cumulative effect on growth and vigour of plants. Increased growth components due to increased fertilizer levels might have provided stability in higher supply of photosynthates towards the sink (grains spike⁻¹). The increased growth in terms of plant height, dry matter accumulation and number of tillers might also provide better sites for spike formation and grain development. Organic matter is also a source of energy for soil micro-flora, which brings about the transformation of organic form of nutrients present in soil, into available form. The increase in the yield attributes with the application of vermicompost ascribed to direct addition of plant nutrients (macro and micro) and growth regulators and also due to increased microbial population of soil, which accelerated the process of humification, removal of obnoxious smell and detoxification of soil pollutants (Manna and Viswas, 1996). As a result, almost all yield attributes of crop resulted into significant improvement due to applied treatments. The increase in grain and straw yields might be due to better nutritional environment in low nutrient status soil as evidenced by their uptake in the

plant and due to the increased supply of N, P and K and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters, resulted in increased grain and straw yield of the crop. Further inoculation of Azotobacter + PSB might have played an important role in making the unavailable forms of nutrients into available forms because it has direct role in nitrogen and phosphorus fixation which resulting in increased yield of wheat. The results of the present study are in close conformity with findings of Jat *et al.* (2018), Kaur *et al.* (2018), Reddy *et al.* (2021), Singh *et al.* (2021), Sunag *et al.* (2022) and Kumari *et al.* (2022) in wheat and barley.

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Optimizing Germination Test and Evaluating Seed Quality Parameters in Medicinal herb Tulsi (*Ocimum tenuiflorum* L.)

Sultan Singh, Axay Bhuker, Digamber, Rahul Kumar and Gagandeep Singh

Department of Seed Science and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125004

*Corresponding Author Email : sultan.hau@gmail.com

Abstract

This study was conducted for optimizing germination test and evaluating seed quality parameters in Tulsi during 2022 in the laboratories of Department of Seed Science and Technology. The results revealed no germination was recorded at 15°C and 20°C temperatures in any substrates. Maximum germination was recorded in Top of Paper (22.67%) method at 25°C, followed by BP (20.00%) at 25°C. Maximum hard seeds (90.67%) were recorded in BP at 15°C, followed by TP (87.33%) at 15°C. The other seed quality parameters viz., seedling length, seedling dry weight, vigour Indices and radicle emergence were also observed maximum at 25°C. The radicle emergence was started on 3rd day only at 25°C temperature. Therefore, it is concluded from the study that to conduct the germination test in Tulsi 25°C temperature is optimum and top of the paper (TP) or between paper (BP) methods are suitable.

Key words : Hard seeds, *Ocimum tenuiflorum*, radicle emergence test, seed germination, substrates, temperatures.

Introduction

Medicinal plants are currently gaining significant attention due to their valuable healing properties, and they are preferred for their minimal side effects. As a result, cultivating medicinal crops has become essential to meet the demand and preserve their genetic diversity for future needs. Seeds serve as the basic input in the cultivation process, and it is only high-quality or vigorous seeds that can yield superior planting material for farming. Assessing the worth of seeds and conducting seed testing is a crucial step to increase their planting potential and minimize the risk of failure when using seeds with low vigour (Ahad *et al.*, 2021). In the realm of medicinal plants, many valuable species remain underutilized, and some of them are both commercially and economically significant. Tulsi, scientifically known as *Ocimum tenuiflorum* L. is a significant medicinal herb that is grown from seeds and valued for its essential oil content. Tulsi seeds are oval shaped, black in color, and swell up when soaked in water, producing a gelatinous mass. This herb is traditionally engaged to alleviate conditions like cough, cold, asthma, blood pressure, blood sugar levels and overall weakness (Bahl *et al.*, 2000; Suthar, 2022). It is commercially cultivated for its leaves in hot and humid parts of India. The primary chemical compound found in the leaves essential oil is eugenol, phenol, terpenoids, alkaloids which has various applications in the flavouring and pharmaceutical sectors (Hanumanthaiah *et al.*, 2020). The pharmacological effects of holy basil are primarily attributed to the antioxidant properties of its constituents. Holy basil extracts contain phenolic compounds such as eugenol, cirsilineol, isothymusin, isothymonin, rosmarinic

acid, orientin, and vicenin, which have been recognized as effective antioxidants. Additionally, holy basil is notably rich in the antioxidant mineral zinc (Vrinda and Devi, 2001). The quality of seeds plays a critical role in enhancing the yield of medicinal herbs. It depends on several factors, such as the potential for germination and the vigour of the seeds. Seed germination and vigour stand out as the paramount seed quality parameters that influence the outcome of a crop. Assessments of vigour and germination are indispensable for growers to secure and enhance crop performance (Finch-Savage *et al.*, 2016). Temperature has a significant impact on the capacity for seed germination, affecting factors such as seed deterioration rates, dormancy and the germination process. The temperature prerequisites for seed germination are contingent upon the specific species, variety, genetic makeup and the agro-climatic conditions prevailing in the crop cultivation region (Carrera-Castaño *et al.*, 2020). The ideal germination temperature is the one that leads to the highest germination rate in the shortest possible time. In seed testing various tests used to determine seed quality. The germination test holds particular significance as it ensures the reproducibility, reliability, and uniformity of seeds. Germination is a complex biological process, where multiple factors must align for a seedling to emerge successfully. Among the essential characteristics of seeds used in farming, the percentage of germination holds significant importance. Radicle emergence test can be used as a quick test to predict germination percentages in small seeded crops which can save time in seed testing procedure (Bhuker *et al.*, 2022). To establish quality seed for Indian basil, it is imperative to have data on the ideal germination potential,

the temperature at which the maximum germination percentage is attained, and the specific days for recording germination percentage. This information is important for seed quality assessment in testing laboratories. Keeping in the view, the present investigation was undertaken to standardize germination test, and analysis of optimum temperature for various seed quality parameters in Tulsi seeds.

Materials and Methods

The study was conducted on freshly harvested seeds of Tulsi variety Hisar Selection-1 which were procured from Medicinal, Aromatic and Potential Crops Section, Department of Genetics and Plant Breeding and study was conducted in the laboratories of Department of Seed Science and Technology, CCS Haryana Agricultural University, Hisar during 2022. Three substrates i.e. between paper (BP), top of the paper (TP) and sand were used for assessing the seed quality parameters at various temperatures such as 15°C, 20°C, 25°C, 30°C and alternate temperature of 20-30°C (20°C for 16 hrs. and 30°C for 8 hours). Germination test was conducted by placing 100 seeds in three replications in between paper method, top of the paper and sand. On the day of final count, the seedlings were evaluated for germination percentage. Normal seedlings, abnormal seedling, dead and hard seeds were evaluated as per ISTA, 2019 rules. The seeds were observed on a daily basis for the emergence of both the radicle and plumule, and the final count of such seeds was recorded until maximum germination was achieved *i.e.* on 8th day for Tulsi.

Germination (%)

$$= \frac{\text{Number of normal seedlings}}{\text{Total number of seeds kept for germination}} \times 100$$

Hard seeds were observed and expressed in percentage in between paper and top of the paper substrates. To determine the average seedling length, ten normal seedlings were chosen randomly from each of the three replications and expressed in the centimeter from all the substrates. The same 10 seedlings were used for the seedling dry weight and dried at 80°C±2 for 24 hours in the hot air oven and then recorded average seedling dry weight in mg. Vigour indices were calculated using the formula recommended by Abdul-Baki and Anderson (1973) in all substrates, which is outlined as follows:

Vigour index-I = Germination (%) × Average seedling length (cm)

Vigour index-II = Germination (%) × Average seedling dry weight (mg)

A radicle emergence test was performed using the "Top of the paper" method. The count of seeds that

exhibited radicle emergence of at least 2 mm in length was recorded at 24-hour intervals, starting from the initiation of radicle emergence and continuing for maximum radicle emergence for each of the replicates.

Radicle emergence (%) =

$$= \frac{\text{No. of seeds with 2 mm radicle length}}{\text{Total no. of seeds sown}} \times 100$$

Statistical analysis of data collected during the study was done by using the factorial complete randomized design as described by Panse and Sukhatme (1985). All the values described as mean of the replicates with the evaluation of CD at 5% level of significance by using software OPSTAT.

Results and Discussion

The results revealed that there was a significant difference in germination (%) in Tulsi seeds due to substrates and temperatures (Table-1). No germination was recorded at 15°C and 20°C temperatures in any substrates. Maximum germination was recorded in TP (22.67%) at 25°C, followed by BP (20.00%) at 25°C and lowest germination was observed in sand substrate (10.67%) at 30°C. While considering the mean of all temperatures, the highest germination (19.33%) was recorded at 25°C and lowest germination (13.78%) was observed at 30°C. Among the mean of all substrates, the highest germination (11.60%) was observed in top of the paper and lowest germination (7.87%) was recorded in sand. These seed quality parameters showed the maximum performance at 25°C in top of the paper method. The lowest performance was observed at 15°C and 20°C, where no germination was observed across all substrates. Maximum hard seeds were recorded in BP (90.67%) at 15°C, followed by TP (87.33%) at 15°C and lowest hard seeds were observed in TP (49.33%) at 25°C. While considering the mean of all temperatures, the maximum hard seeds (89.00%) were recorded at 15°C and minimum hard seeds (50.67%) were observed at 25°C. Among the mean of all substrates, the highest hard seeds (68.67%) was observed in between paper and lowest hard seeds (65.87%) was recorded in TP. More than 90% hard seeds were observed during germination test, it indicates that dormancy breaking test should be applied for better germination. The maximum seedling length (5.15 cm) was observed in top of the paper method at 25°C, at par seedling length (4.87 cm) in between paper at 25°C and minimum seedling length (4.03 cm) was observed in sand at 30°C. When taking the mean of all temperatures, the highest seedling length (4.87 cm) was achieved at 25°C, while the least seedling length (4.31 cm) observed at 30°C. Among the average results for all substrates, the highest seedling length (2.90 cm) was observed in top of the paper, and the lowest

Table-1 : Effects of substrata, temperature on Germination, Hard seeds, Seedling length (cm) in Tulsi seeds.

Temp. (T)	Germination (%)			Hard seeds (%)			Seedling length (cm)		
	Substrate (S)			Substrate (S)			Substrate (S)		
	BP	TP	Sand	Mean	BP	TP	Mean	BP	TP
15°C	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	90.67 (72.20)	87.33 (69.21)	89.00 (70.71)	0.00	0.00
20°C	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	83.33 (65.94)	80.67 (63.91)	82.00 (64.92)	0.00	0.00
25°C	20.00 (26.54)	22.67 (28.42)	15.33 (23.03)	19.33 (26.00)	52.00 (46.13)	49.33 (44.60)	50.67 (45.36)	4.87	5.15
30°C	14.67 (22.50)	16.00 (23.54)	10.67 (19.04)	13.78 (21.69)	61.33 (51.53)	59.33 (50.36)	60.33 (50.95)	4.34	4.54
20-30°C	17.33 (24.59)	19.33 (26.05)	13.33 (21.40)	16.67 (24.01)	56.00 (48.43)	52.67 (46.51)	54.33 (47.47)	4.66	4.81
Mean	10.40 (14.72)	11.60 (15.60)	7.87 (12.69)		68.67 (56.85)	65.87 (54.92)		2.78	2.90
	CD (P=0.05)			S.Em±	CD (P=0.05)			S.Em±	
S	0.894			0.308	2.039			CD (P=0.05)	
T	1.154			0.398	3.224			0.082	
S x T	1.998			0.689	NS			0.106	
								0.183	
								0.063	

Values in the parenthesis are arc-sine transformed of the original.

Table-2 : Effects of substrata, temperature on Seedling dry weight, Vigour index-I, Vigour index-II in Tulsi seeds.

Temp. (T)	Seedling dry weight (mg)			Vigour index-I			Vigour index-II		
	Substrate (S)			Substrate (S)			Substrate (S)		
	BP	TP	Sand	Mean	BP	TP	Mean	BP	TP
15°C	0.00	0.00	0.00	0.00	0	0	0	0	0
20°C	0.00	0.00	0.00	0.00	0	0	0	0	0
25°C	0.44	0.46	0.43	0.44	97	117	95	8.67	10.67
30°C	0.36	0.38	0.34	0.36	64	73	60	5.33	6.00
20-30°C	0.39	0.42	0.37	0.39	81	93	77	6.67	8.00
Mean	0.24	0.25	0.23		48	56		4.13	4.93
	CD (P=0.05)			S.Em±	CD (P=0.05)			S.Em±	
S	0.009			0.003	3.870			CD (P=0.05)	
T	0.012			0.004	4.996			0.387	
S x T	0.020			0.007	8.653			0.500	
								0.865	
								0.298	

Table-3 : Effect of temperatures on Radicle emergence (%) of Tulsi seeds.

Duration	Temperatures					Mean
	15°C	20°C	25°C	30°C	20-30°C	
1 st day (24 hr)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2 nd day (48 hr)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
3 rd day (72 hr)	0.00 (0.00)	0.00 (0.00)	3.33 (10.40)	0.00 (0.00)	0.00 (0.00)	0.67 (2.08)
4 th day (96 hr)	0.00 (0.00)	0.00 (0.00)	8.67 (17.09)	2.67 (9.26)	3.33 (10.40)	2.93 (7.35)
5 th day (120 hr)	0.00 (0.00)	0.00 (0.00)	15.33 (23.03)	5.33 (13.16)	6.00 (14.04)	5.33 (10.05)
6 th day (144 hr)	0.00 (0.00)	0.00 (0.00)	23.33 (28.87)	14.00 (21.93)	16.67 (24.05)	10.80 (14.97)
7 th day (168 hr)	0.00 (0.00)	0.00 (0.00)	24.00 (29.31)	16.00 (23.54)	21.33 (27.48)	12.27 (16.07)
Mean	0.00 (0.00)	0.00 (0.00)	10.67 (15.53)	5.43 (9.70)	6.76 (10.85)	
C.D. (P=0.05)	S=0.780		T=0.659		SxT=1.745	
SE.m (±)	S=0.276		T=0.233		SxT=0.617	

#Values in the parenthesis are arc-sine transformed of the original.

seedling length (2.60 cm) was recorded in the sand substrate. The maximum seedling dry weight (0.46 mg) was observed in top of the paper method at 25°C, at par seedling dry weight (0.44 mg) in between paper at 25°C and minimum seedling dry weight (0.34 mg) was observed in sand at 30°C. When taking the mean of all temperatures, the highest seedling dry weight (0.44 mg) was recorded at 25°C, while the lowest seedling dry weight (0.36 mg) observed at 30°C. Among the mean of all substrates, the maximum seedling dry weight (0.25 mg) was observed in top of the paper, and the minimum seedling dry weight (0.23 mg) was recorded in the sand substrate. The maximum vigour index-I (117) was achieved using TP at 25°C and followed by vigour index-I (97) at 25°C in BP, while the lowest vigour index-I (43) was observed in the sand substrate at 30°C. When considering the average across all temperatures, the maximum vigour index-I (95) recorded at 25°C and lowest vigour index-I (60) observed at 30°C. In terms of substrates mean, the highest germination (56) was found on the top of the paper, whereas the lowest vigour index-I (34) was recorded in the sand substrate. The maximum vigour index-II (10.67) was observed in top of the paper method at 25°C, followed by vigour index-II (8.67) in between paper at 25°C and minimum vigour index-II (3.67) was observed in sand at 30°C. When calculating the mean across all temperatures, the highest vigour Index-II (8.67) was observed at 25°C, while the lowest vigour Index-II (5.00) was recorded at 30°C. Among the mean outcomes for all substrates, the highest vigour Index-II (4.93) was observed in the top of the paper, and the lowest vigour Index-II (3.07) was observed in the sand substrate. Low temperatures (15°C and 20°C) have an adverse effect on both seed viability and vigour.

There was no radicle emergence recorded at 15°C and 20°C at any day. There was also no radicle emergence at 1st and 2nd day at 20°C, 25°C and 20-30°C. The radicle emergence was started on 3rd day only at 25°C temperature. At 3rd day, the radicle emergence was recorded (3.33%) at 25°C. At 4th day, radicle emergence

observed in 25°C, 30°C and 20-30°C. At this 4th day, the highest radicle emergence (8.67%) was observed in 25°C, followed by (3.33%) in 20-30°C temperature and lowest radicle emergence (2.67%) recorded in 30°C. Till the 7th day, the maximum radicle emergence was achieved. On 7th day, the highest radicle emergence (24.00%) was observed at 25°C, followed by (21.33%) at 20-30°C and lowest radicle emergence (16.00%) at 30°C. While considering mean of each temperature, the highest radicle emergence (10.67%) was recorded at 25°C, followed by (6.76%) at 20-30°C and lowest (5.43%) at 30°C. When comparing the mean of all days, the 7th day recorded the highest radicle emergence (12.27%), whereas at the 3rd day the lowest radicle emergence (0.67%) was observed (Table 3). These results were in accordance with (Swapna, 2003; Gowda *et al.*, 2013), who recorded highest germination at 25/30°C as compared to 20°C and 30°C in *Ocimum sanctum*, *Ocimum basilicum*, and *Ocimum gratissimum*. An optimal temperature of 25°C for Tulsi was identified by Kumar (2012), resulting in higher germination percentages and improved seedling vigour indexes I and II. Substantial decrease in germination percentages and seedling vigour indexes I and II were reported at 15, 20, 30, and 35°C. This inconsistency can be attributed to the substantial influence of temperature on the dynamic aspects of germination, particularly during the initial lag phase and the ultimate germination process. Consequently, no germination was recorded at 15°C and 20°C. The low germination and other seed quality parameters at 30°C and 20-30°C alternate temperature indicated that this temperature is less favourable to the Tulsi crop. Sharma *et al.* (2022) found that the germination percentages at 20 and 25°C were at par and were higher compared to those at 30 and 35°C. Seedling vigour parameters reached their peak at 25°C and experienced a decline at elevated temperatures in wheat. In quinoa crop, 25°C temperature was recorded optimum and Top of Paper (TP) and Between Paper (BP) methods can be used for germination test (Bhuker *et al.*, 2020). Angelini *et al.* (2021) also highlighted a significant challenge in the

large-scale cultivation of medicinal plant *Passiflora incarnata*, is attributed low germination rates primarily associated with the apparent and notable seed dormancy. Seed vigour is a complex trait influenced by various factors, including the genetic makeup of the variety, environmental conditions, maternal plant nutrition, harvest maturity, seed size and weight, mechanical damage, aging, and the presence of pathogens. It is spontaneously evident that uniformity plays a crucial role in determining seed vigour (Oakley *et al.*, 2004; Kumar *et al.*, 2011). These results were supported by study of Bhuker *et al.* (2020) who conducted radicle emergence test and found that the completion of 2mm radicle emergence in pearl-millet occurred after 32 hours at 25°C. For mustard, this process took 40 hours, and for wheat, it took 45 hours at a temperature of 20°C, specifically for fresh seed lots. Bhandari *et al.* (2020) found the 25°C as optimal temperature for seed germination, onset of germination, completion of germination and speed of germination of Tulsi crop in a seed germinator.

Conclusions

Germination percentage, seedling vigour index-I, vigour index-II and other seed quality parameters were recorded maximum at 25°C with the top the paper method which were at par with between paper method at same temperature. Therefore, it is concluded from the study that germination test in Tulsi should be conducted at 25°C either in top of the paper (TP) or between paper (BP) method.

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Viral Diseases of Cucumber (*Cucumis sativus* L.) and their Management

Amber Ejaz* and Vijay Bahadur

Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, U.P.

*Email : amberejaz.ejaz@gmail.com

Abstract

Cucumber is a popular vegetable that belongs to the gourd family, Cucurbitaceae. It is known for its mild, crisp texture and refreshing taste. Cucumbers are commonly eaten raw in salads, sandwiches, and as a snack. Cucumbers offer various health benefits, including aiding in hydration, promoting digestion, and providing antioxidants that can help reduce the risk of chronic diseases. They are also often used in skincare due to their soothing and cooling properties. It has now gained recognition as one of the important market vegetables in the tropics because of the continued awareness of the numerous health benefits attached to its consumption. This has progressively affected its cultivation and thereby, increased outbreak of diseases of the crop. High incidence of disease infections occurs in *Cucumis sativus* L. due to extreme temperatures, heavy rainfall and high humid condition resulting there from, causing huge losses through reduction in yield, lowered quality of harvested produce and increased cost of production. Viral diseases are known to contribute to the losses recorded on the crop in India, some of which will be discussed in this chapter.

Introduction

Perhaps because of its enormous nutritional, therapeutic, and commercial potential, cucumber (*Cucumis sativus* L.) is regarded as the fourth most important vegetable in the world. Along with watermelon and long melon, cucumber is considered an important cucurbit in terms of global total production. The crop was considered insignificant in India due to its low yield and previous underutilization of the good. Due to ongoing campaigns touting the many advantages of the crop, cucumber demand is currently rising daily in India. Despite the growing importance of cucumbers, several factors, such as a lack of suitable planting materials, restricted access to capital, climatic conditions, and plant pests and diseases, among others, severely restrict production. More than 40 ailments brought on by bacterial, fungal, viral, and nematode pathogens have a significant negative impact on cucumber cultivation and production (Chand *et al.*, 2014). It is important to identify and manage insect pests before they become an infestation because it is reported that they consume enough crops to feed an additional one billion people worldwide. The spotted cucumber beetle (*Diabrotica undecimpunctata*) and striped cucumber beetle are the most frequent pests of cucumber, just like other cucurbits. Three virus genera, namely *Potyvirus*, *Cucumovirus*, and *Crinivirus*, primarily affect cucumber in India (Priyanka, 2019). Viruses that severely affect cucumber include the Zucchini Yellow Mosaic Virus (ZYMV), Watermelon Mosaic Virus (WMV), Moroccan Watermelon Mosaic Virus (MWMV), Papaya Ringspot Virus (PRSV), Cucumber Mosaic Virus (CMV), and Beet Pseudo-Yellows Virus. Other viruses of less significance include tomato spotted wilt virus, melon necrotic spot

virus, squash mosaic virus, and cucurbit yellow stunting disorder virus. Reduced plant growth, lower yields, harmed fruit quality, difficult reproduction, increased susceptibility of the host plant to other pathogens, and financial losses to farmers are all consequences of plant virus infections (Bagri *et al.*, 2019).

Many fungi attack cucumber seedlings, leading to major losses, especially in favourable environmental conditions. Numerous pathogenic fungi have been linked to the rotting of cucumber fruits in India, including *Alternaria tenuis*, *Alternaria alternata*, *Fusarium equiseti*, *Fusarium solani*, *Aspergillus spp.*, *Phytophthora capsici*, *Penicillium oxalicum*, *Bipolaris spp.*, *Botrytis cinerea*, and *Cladosporium tenuissimum*, among others. Downy mildew, powdery mildew and anthracnose also cause substantial losses. Scab affects aboveground plant parts, including the fruits. Root-knot nematodes are prevalent destructive pathogens of Cucumber because even at low levels, high yield losses result. Other nematodes include species of *Rotylenchus*, *Benololaimus*, *Pratylenchus*, *Paratylenchus* and *Trichodorus*. Angular leaf spot is the most common bacterial disease of cucumber, although it affects all cucurbits. Bacterial wilt disease has also been reported in India.

A new pathogen or vector could potentially be introduced into new areas due to the rising trend of local and international movement of seedlings, cuttings, and fruits. Pathogens may spread more successfully and establish themselves in places where they were previously unwelcome due to changing climatic conditions. To reduce the detrimental effects of diseases, insect and weed pests on productivity, a holistic approach to disease management is necessary. This highlights the

significance of this review on the current and emerging pests and diseases of cucumber in India.

Viral diseases of Cucumber

1. Genus: *Potyvirus*

One of the largest genera of plant viruses, Potyvirus affects several economically significant cucurbits all over the world. The monopartite genome of potyviruses is made up of a single positive-sense RNA that is covalently linked to the viral protein genome at one end and a polyadenylate tail at the other. Potyviruses are non-enveloped, flexuous filamentous viruses that measure approximately 680–900 nm long and 11–15 nm wide. Mosaics on leaves, leaf distortion, leaf reduction, fruit deformation, yellowing, and wilting are among the typical symptoms brought on by potyviruses. Zucchini yellow mosaic virus (ZYMV), watermelon mosaic virus (WMV), Moroccan watermelon mosaic virus (MWMV), and papaya ringspot virus (PRSV) are the main potyviruses that affect cucumber in Asia (McKern *et al.*, 1993).

1.1. Zucchini yellow mosaic virus (ZYMV)

The naturally occurring zucchini yellow mosaic virus (ZYMV) affects cucurbits, mainly cultivated species, along with a few ornamentals and weeds (Svoboda *et al.*, 2013).

Epidemiology

ZYMV is primarily transmitted by aphids, particularly the *Aphis gossypii* species. These aphids acquire the virus when feeding on infected plants and subsequently transmit it to healthy cucumber plants. The transmission of the virus is often non-persistent, meaning that the virus is not retained for an extended period in the aphid's body. ZYMV can infect a wide range of cucurbitaceous plants, including cucumbers. Understanding the host range is crucial in assessing the potential sources of infection and devising effective control strategies. Environmental conditions, such as temperature and humidity, can impact the epidemiology of ZYMV in cucumbers. The virus is more likely to spread rapidly under conditions that favor aphid activity and virus transmission. Additionally reported transmission methods include mechanical and seed.

Symptoms

1. Mosaic Patterns: ZYMV often causes mosaic patterns on cucumber leaves. This is characterized by irregular, light and dark green mottling, or mottling on the foliage. The mosaic pattern may vary in intensity and distribution across the leaves.

2. Leaf Curling: Infected cucumber plants may exhibit leaf curling or distortion. The leaves may become twisted or cupped because of the virus infection.

3. Stunted Growth: ZYMV-infected cucumber plants often experience stunted growth. This is particularly noticeable in young plants, where growth may be slowed down.

4. Reduced Fruit Size and Quality: The virus can impact the size and quality of cucumber fruit. Infected plants may produce smaller, deformed, or less marketable fruits. Fruit shape and color may also be affected.

5. Necrosis: In some cases, ZYMV can cause necrosis or death of plant tissues. This can lead to yellowing, browning, or drying out of portions of the leaves and stems.

6. Fruit Deformities: Cucumber fruits may develop irregular shapes, such as crooked or misshapen fruit. This can result in a reduction in the quality and marketability of the crop.

7. Reduced Yield: Overall, ZYMV infections can lead to reduced cucumber yields due to the impact on plant growth and fruit development.

8. Systemic Symptoms: ZYMV symptoms are not limited to leaves; the virus can affect various parts of the plant, including stems and fruit. It can cause systemic symptoms that affect the entire plant.

9. Aphid-Transmitted: It's important to note that ZYMV is primarily transmitted by aphids, and these insects can spread the virus to healthy cucumber plants, exacerbating the symptoms.

Management of ZYMV

1. Use Virus-Resistant Cucumber Varieties: Plant cucumber varieties that have been bred for resistance to ZYMV. Resistant cultivars can significantly reduce the risk of infection and the severity of symptoms.

2. Crop Rotation: Implement a crop rotation strategy, avoiding the planting of cucurbits (including cucumbers) in the same area for multiple growing seasons. This can help break the virus's cycle and reduce reservoirs of infection.

3. Weed Control: Control weeds in and around cucumber fields, as some weed species can serve as hosts for ZYMV. Weeds can act as a source of infection, so their removal is essential.

4. Sanitation: Practice good sanitation in your fields and greenhouses. Remove and destroy infected plants as soon as symptoms appear to prevent the spread of the virus.

5. Insect Management: Control aphid populations, which are the primary vectors of ZYMV. Use insecticides when necessary to manage aphids. Employ physical barriers such as row covers to protect plants from aphid infestation.

6. Early Detection: Regularly monitor cucumber plants for symptoms of ZYMV. Early detection allows for the prompt removal of infected plants and reduces the potential for further virus transmission.

7. Virus-Free Seed: Use certified virus-free cucumber seeds to start your crop. This can help prevent the introduction of the virus from the beginning.

1.2. Watermelon mosaic virus (WMV)

The Cucurbitaceae, Apiaceae, Chenopodiaceae, Fabaceae, Malvaceae, Orchidaceae, and several weeds are among the many plant families that the Watermelon Mosaic Virus (WMV), formerly known as WMV-2, can infect. In nations like Bangladesh, Myanmar, and India on the Indian subcontinent, WMV has been reported (Parry and Persley 2005).

Epidemiology

WMV is primarily transmitted by aphids, especially the *Aphis gossypii* species. Aphids acquire the virus when feeding on infected plants and then transmit it to healthy cucurbit plants, which can include cucumbers. WMV affects a wide range of cucurbitaceous plants, and cucumbers are susceptible hosts. Understanding the host range is important to assess potential sources of infection. Environmental conditions, including temperature and humidity, can influence the epidemiology of WMV in cucumbers. Conditions favoring aphid activity can enhance the spread of the virus. Wild or weed species can serve as reservoir hosts for WMV, which can act as a source of infection for cucumbers. Identifying and managing these reservoir hosts is important in disease management.

Symptoms

1. Mosaic Patterns: WMV commonly causes mosaic-like patterns on cucumber leaves. This symptom is characterized by irregular, light and dark green mottling or mottling on the foliage. The mosaic pattern may vary in intensity and distribution across the leaves.

2. Leaf Distortion: Infected cucumber leaves may become distorted or exhibit irregular shapes. This can include leaf curling, cupping, or twisting.

3. Stunted Growth: WMV-infected cucumber plants often display stunted growth. This stunting can be particularly noticeable in young plants, which may not grow as vigorously as healthy plants.

4. Fruit Deformities: Cucumber fruits produced on infected plants may develop irregular shapes or deformities. This can result in smaller or misshapen fruit.

5. Reduced Yield: Overall, WMV infections can lead to

reduced cucumber yields due to the impact on plant growth and fruit development.

6. Necrosis: In some cases, WMV can cause necrosis or death of plant tissues. This can result in yellowing, browning, or drying out of portions of the leaves and stems.

7. Mottling on Fruits: WMV can also affect cucumber fruit. Infected fruit may exhibit mottling or discoloration, reducing their market value and quality.

8. Systemic Symptoms: WMV symptoms are not limited to leaves and fruit; the virus can affect various parts of the plant, including stems and even the entire plant.

Management of WMV

1. Use Resistant Cucumber Varieties: Plant cucumber varieties that are resistant to WMV. Resistant cultivars can significantly reduce the risk of infection and the severity of symptoms. Consult with seed suppliers for WMV-resistant cucumber varieties.

2. Weed Control: Control weeds in and around cucumber fields, as some weed species can serve as hosts for WMV. Weeds can act as a source of infection, so their removal is essential.

3. Aphid Management: Aphids are the primary vectors of WMV. Implement aphid management practices, including the use of insecticides when necessary to control aphid populations. Employ physical barriers such as row covers to protect plants from aphid infestation.

4. Early Detection: Regularly monitor cucumber plants for symptoms of WMV. Early detection allows for the prompt removal of infected plants and reduces the potential for further virus transmission.

5. Sanitation: Practice good sanitation in your fields and greenhouses. Remove and destroy infected plants as soon as symptoms appear to prevent the spread of the virus.

6. Certified Virus-Free Seed: Use certified virus-free cucumber seeds to start your crop. This can help prevent the introduction of the virus from the beginning.

7. Transplant Inspection: If using transplants, ensure they are virus-free and come from a reputable source. Transplants can carry WMV if not properly managed.

8. Crop Rotation: Implement a crop rotation strategy, avoiding the planting of cucurbits (including cucumbers) in the same area for multiple growing seasons. This can help break the virus's cycle and reduce reservoirs of infection.

9. Reservoir Hosts: Identify and manage any wild or weed species that serve as reservoir hosts for WMV.

Reducing these alternative hosts can help decrease the virus source.

10. Monitoring and Early Detection: Regularly monitor cucumber crops for the presence of WMV and aphids. Early detection allows for the implementation of control measures before the virus spreads extensively.

11. Integrated Pest Management (IPM): An IPM approach, combining various strategies like biological control, use of beneficial insects, and selective pesticide applications, can be effective in managing aphid vectors and WMV in cucumbers.

12. Quarantine Measures: In regions where WMV is a known problem, quarantine measures can help prevent the introduction of the virus through the movement of infected plant material.

13. Farm Hygiene: Maintain good farm hygiene practices to reduce the potential spread of WMV from one area of the farm to another.

1.3. Moroccan watermelon mosaic virus (MWMV)

The Moroccan watermelon mosaic virus, a severe strain of WMV that affects a variety of cucurbits, was first discovered in Morocco in 1972. Based on biological and serological characteristics, MWMV was later identified as a unique potyvirus species that is distantly related to Papaya ringspot virus (PRSV). The only plants that can host the MWMV are papaya and members of the Cucurbitaceae family (Miras *et al.*, 2013).

Epidemiology

MWMV is primarily transmitted by aphids, particularly the *Aphis gossypii* species. These aphids acquire the virus when feeding on infected plants and subsequently transmit it to healthy cucumber plants. The transmission of the virus is often non-persistent, meaning that the virus is not retained for an extended period in the aphid's body. MWMV can infect a wide range of cucurbitaceous plants, including cucumbers. Understanding the host range is crucial in assessing the potential sources of infection and devising effective control strategies. MWMV infections may exhibit seasonal patterns, with higher disease incidence during certain times of the year. This can be influenced by factors like temperature, aphid populations, and the presence of virus reservoirs.

Symptoms

1. Mosaic Patterns: MWMV often causes mosaic-like patterns on cucumber leaves. This symptom is characterized by irregular, light and dark green mottling or mottling on the foliage. The mosaic pattern may vary in intensity and distribution across the leaves.

2. Leaf Distortion: Infected cucumber leaves may

become distorted or exhibit irregular shapes. This can include leaf curling, cupping, or twisting.

3. Stunted Growth: MWMV-infected cucumber plants often display stunted growth. This stunting can be particularly noticeable in young plants, which may not grow as vigorously as healthy plants.

4. Fruit Deformities: Cucumber fruits produced on infected plants may develop irregular shapes or deformities. This can result in smaller or misshapen fruit.

5. Reduced Yield: Overall, MWMV infections can lead to reduced cucumber yields due to the impact on plant growth and fruit development.

6. Necrosis: In some cases, MWMV can cause necrosis or death of plant tissues. This can result in yellowing, browning, or drying out of portions of the leaves and stems.

7. Systemic Symptoms: MWMV symptoms are not limited to leaves and fruit; the virus can affect various parts of the plant, including stems and even the entire plant.

Management of MWMV

1. Use Resistant Cucumber Varieties: Plant cucumber varieties that are resistant to MWMV. Resistant cultivars can significantly reduce the risk of infection and the severity of symptoms. Consult with seed suppliers for MWMV-resistant cucumber varieties.

2. Weed Control: Control weeds in and around cucumber fields, as some weed species can serve as hosts for MWMV. Weeds can act as a source of infection, so their removal is essential.

3. Aphid Management: Aphids are the primary vectors of MWMV. Implement aphid management practices, including the use of insecticides when necessary to control aphid populations. Employ physical barriers such as row covers to protect plants from aphid infestation.

4. Early Detection: Regularly monitor cucumber plants for symptoms of MWMV. Early detection allows for the prompt removal of infected plants and reduces the potential for further virus transmission.

5. Sanitation: Practice good sanitation in your fields and greenhouses. Remove and destroy infected plants as soon as symptoms appear to prevent the spread of the virus.

6. Certified Virus-Free Seed: Use certified virus-free cucumber seeds to start your crop. This can help prevent the introduction of the virus from the beginning.

1.4. Papaya ringspot virus (PRSV)

Global papaya and cucurbit cultivation is greatly impacted economically by the papaya ringspot virus (PRSV).

Cucurbits' designated biotype is PRSV-W (Bujarski *et al.*, 2012).

Epidemiology

PRSV is mainly transmitted by aphids, including species like the green peach aphid (*Myzus persicae*). Aphids acquire the virus when feeding on infected papaya plants and can transmit it to healthy cucurbit plants, including cucumbers, during subsequent feeding. Papaya ringspot virus (PRSV) primarily affects papaya and other cucurbit crops. It is not typically considered a disease of cucumbers. However, in regions where cucurbits are cultivated,

Symptoms

1. Ring Spots: Circular, ring-like spots or lesions on the leaves are a characteristic symptom. These spots can vary in size and color, often starting as light green or yellow and later turning brown.

2. Mosaic Patterns: PRSV can cause mosaic patterns on the leaves, characterized by a mixture of light and dark green areas. This mosaic effect can give the leaves a mottled appearance.

3. Leaf Deformation: Leaves may become distorted or exhibit irregular shapes, curling, cupping, or twisting.

4. Stunted Growth: Infected papaya plants often display stunted growth, with reduced vigor and smaller leaves.

5. Fruit Deformities: PRSV can also affect papaya fruit, causing deformities, such as rings or grooves, and reduced fruit size.

6. Reduced Yield: The impact of PRSV on papaya plants can lead to reduced fruit yield and quality.

Management of PRSV

1. Prevention: Plant certified virus-free cucumber seeds or transplants from reputable sources. Implement strict sanitation measures to prevent the introduction of infected plant material to your cucumber crop. Practice good farm hygiene to reduce the risk of virus transmission between plants.

2. Aphid Control: Aphids are the primary vectors of PRSV. Implement aphid management practices to reduce aphid populations, which can help prevent virus transmission. Use insecticides when necessary to control aphid infestations. Consider the use of physical barriers, like row covers, to protect cucumber plants from aphid infestation.

3. Early Detection and Monitoring: Regularly inspect cucumber plants for symptoms of viral infection. Promptly remove and destroy infected plants to prevent further virus

spread. Isolate infected plants to prevent virus transmission to healthy plants.

4. Crop Rotation: Implement a crop rotation strategy to avoid planting cucumbers in the same area for multiple growing seasons. This can help break the virus's cycle.

5. Reservoir Host Management: Identify and manage any wild or weed species that may serve as reservoir hosts for PRSV. Reducing these alternative hosts can help decrease the virus source.

6. Cultural Practices: Use virus-resistant cucumber varieties if available in your region. Maintain proper spacing between cucumber plants to reduce the risk of virus transmission. Avoid excessive fertilization, as it can promote excessive vegetative growth that is more susceptible to viral infection.

7. Integrated Pest Management (IPM): Consider implementing IPM practices that include biological control, the use of beneficial insects, and selective pesticide applications for aphid control.

2. Genus : *Cucumovirus*

Over 1200 plant species worldwide have been infected by viruses in this genus. Virions are icosahedral particles with a diameter of about 29 nm that are constructed from 180 subunits of a single capsid protein. Three single-stranded, linear, positive-sense RNA molecules make up the genus (Daunde *et al.*, 2020). The major *Cucumovirus* infecting cucumber is Cucumber mosaic virus (CMV).

2.1. Cucumber mosaic virus (CMV)

In 1916, the Cucumber Mosaic Virus was identified as the first virus to infect cucurbits. In temperate and tropical regions of the world, CMV is very significant. Tanzania and South Africa were the first countries in Africa to report CMV infections on cucurbits (Arogundade *et al.*, 2020).

Epidemiology

CMV is primarily transmitted through several mechanisms, including aphids, mechanical transmission (e.g., by tools or human handling of infected plants), and through seeds. Aphids are the most common vectors responsible for CMV transmission. They acquire the virus when feeding on infected plants and subsequently transmit it to healthy plants during subsequent feeding. Aphids are the primary vectors of CMV. The epidemiology of the disease involves studying the population dynamics of aphids, their feeding behavior, and their role in transmitting the virus to cucumbers. Environmental conditions, such as temperature, humidity, and wind patterns, can influence the epidemiology of CMV. Conditions that favor aphid activity, such as mild temperatures, can enhance the spread of the virus from infected to healthy plants.

Symptoms

- 1. Mosaic Patterns:** CMV often causes mosaic-like patterns on cucumber leaves. This symptom is characterized by irregular, light and dark green mottling or modeling on the foliage. The mosaic pattern may vary in intensity and distribution across the leaves.
- 2. Leaf Distortion:** Infected cucumber leaves may become distorted or exhibit irregular shapes. This can include leaf curling, cupping, or twisting.
- 3. Stunted Growth:** CMV-infected cucumber plants often display stunted growth. This stunting can be particularly noticeable in young plants, which may not grow as vigorously as healthy plants.
- 4. Fruit Deformities:** Cucumber fruits produced on infected plants may develop irregular shapes or deformities. This can result in smaller or misshapen fruit.
- 5. Reduced Yield:** Overall, CMV infections can lead to reduced cucumber yields due to the impact on plant growth and fruit development.
- 6. Necrosis:** In some cases, CMV can cause necrosis or death of plant tissues. This can result in yellowing, browning, or drying out of portions of the leaves and stems.
- 7. Systemic Symptoms:** CMV symptoms are not limited to leaves and fruit; the virus can affect various parts of the plant, including stems and even the entire plant.

Management of CMV

- 1. Use Resistant Cucumber Varieties:** Plant cucumber varieties that are resistant to CMV. Resistant cultivars can significantly reduce the risk of infection and the severity of symptoms. Consult with seed suppliers for CMV-resistant cucumber varieties.
- 2. Weed Control:** Control weeds in and around cucumber fields, as some weed species can serve as hosts for CMV. Weeds can act as a source of infection, so their removal is essential.
- 3. Aphid Management:** Aphids are the primary vectors of CMV. Implement aphid management practices, including the use of insecticides when necessary to control aphid populations. Employ physical barriers such as row covers to protect plants from aphid infestation.
- 4. Monitoring and Early Detection:** Regularly monitor cucumber crops for the presence of CMV and aphids. Early detection allows for the implementation of control measures before the virus spreads extensively.
- 5. Integrated Pest Management (IPM):** An IPM approach, combining various strategies like biological

control, use of beneficial insects, and selective pesticide applications, can be effective in managing aphid vectors and CMV in cucumbers.

3. Genus: *Crinivirus*

Members of the genus *Crinivirus* have cross-banded flexuous particles, five gene nodules, and an infection that only affects vascular tissues. The Beet pseudo-yellows virus is a typical member of this genus that infects cucurbits in Africa (Bujarski *et al.*, 2012).

3.1. Beet pseudo-yellows virus (BPYV)

The host range of the beetroot pseudo-yellows virus is wide and includes weeds, ornamentals, and cucurbits. The dimensions of BPYV particles are 1500–1800 nm long and 12 nm wide. South Africa has received reports of BPYV (Boubourakas *et al.*, 2006).

Epidemiology

BPYV is primarily transmitted by aphids, specifically the green peach aphid and white fly (*Bemisia tabaci*). Aphids acquire the virus when feeding on infected plants and can transmit it to healthy plants during subsequent feeding. While sugar beet is the primary host for BPYV, the virus can potentially infect other plant species, including cucumbers. Understanding the host range is important for assessing potential sources of infection in cucumbers. Aphids play a central role in the epidemiology of BPYV, and their population dynamics, feeding behavior, and role in transmitting the virus are key factors to consider.

Symptoms

- 1. Mosaic Patterns:** Infected cucumber plants may display mosaic-like patterns on their leaves. These patterns consist of light and dark green areas, giving the leaves a mottled appearance.
- 2. Leaf Deformation:** Cucumber leaves can become distorted or misshapen. This may include curling, cupping, or twisting of leaves.
- 3. Stunted Growth:** Infected cucumber plants often exhibit stunted growth, with reduced vigor and smaller overall plant size.
- 4. Fruit Deformities:** Viral infections can lead to fruit deformities, such as misshapen or smaller cucumbers.
- 5. Reduced Yield:** The impact of viruses on cucumbers can result in reduced fruit yield and quality.

Management of BPYV

Prevention of incidence of whitefly infestation, practicing crop rotation and regular weeding are recommended ways of managing BPYV. Elimination of inter-cropping of old and young plants and good sanitation are also effective.

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Variability and Heritability Research on Fine Slender Rice Genotypes (*Oryza sativa* L.)

Anant Kumar Pandey*, D.J. Sharma, R. Parihar, A.P. Agrawal and Rakesh Kumar

Department of Genetics and Plant Breeding, B.T.C. College of Agriculture and Research Station, IGKV, Bilaspur, C.G.

*Corresponding Author Email : anantpandey0809@gmail.com

Abstract

In this experiment, thirty nine aromatic rice accessions comprising of four checks namely Dubraj, Chhattisgarh Sugandhit Bhog, CG Devbhog and Indira Sugandhit Dhan-1 were used. The investigation used randomized block design (RBD) with three replication. Analysis of variance disclosed that there was a substantial variability in the experimental material for all of the traits. viz. days to fifty percent flowering, plant height (cm), days to maturity, tillers hill⁻¹, panicles hill⁻¹, peduncle length (cm), main panicle length (cm), number of grains main panicles⁻¹, 1000 grain weight (g), biological yield (q ha⁻¹), harvest index %, grain length (mm), grain width (mm), length breadth ratio of grain and grain yield (q ha⁻¹). The estimates for GCV and PCV were found to be high for traits such as 1000 grain weight(gm) followed by grain yield (q ha⁻¹), L/B ratio of grain and number of grains main per panicle indicating the importance of selection for improving the yield of fine slender rice. Furthermore, high heritability combined with high genetic advancement as a percent of the mean was ascertained for number of grains per main panicle, 1000 grain weight (g), plant height(cm), tillers hill⁻¹, panicles hill⁻¹, biological yield (q ha⁻¹), grain length, L/B ratio of grain and grain yield (q ha⁻¹). These characteristics are thought to be regulated by additive gene action and selection for them can be advantageous.

Key words : Slender grain rice, GCV, PCV, Heritability, Genetic advance, Genetic advance as percent of mean

Introduction

Rice (*Oryza sativa* L.) having chromosome number (2n=24), family member of a Poaceae (Graminae) and belonging to genus *Oryza*, is a dietary staple devoured by 70% of the global population. Rice is a short-day autogamous crop that requires a hot humid climate with an average temperature ranging from 21°C to 37°C throughout its life cycle. As the of food grain production increased, the food grains including rice was in surplus quantity which initiated a paradigm shift in the consumption preferences of people which gave rise to the demand of quality rice for consumption, people are becoming more interested in consuming slender and aromatic grain due to its flavour, palatability, and aroma. To meet the growing demand for quality rice, genetic variability is the keystone of any varietal development program's success. Aimed at valuable selection in a varietal development programme, variability presence is the most crucial factor. To quantify the amount of variation in a population, genetic parameters such as "Genetic advance", "Heritability", "Genotypic Coefficient of Variation (GCV)" and "Phenotypic Coefficient of Variation (PCV)" can be used.

Materials and Methods

The investigation was executed by means of "Randomized Block Design (RBD)" having three

replications at the experimental farm of "B.T.C. College of Agriculture and Research Station, under IGKV, Bilaspur (C.G.)" during the *kharif* season of 2020-21. Thirty nine fine slender rice accessions consisting four checks namely Dubraj, Chhattisgarh Sugandhit Bhog, Chhattisgarh Dev Bhog, Indira Sugandhit Dhan-1. Every genotype in each replication was assigned a plot size of 10 m².

The character undertaken for investigation were Days to fifty percent flowering, Days to maturity, Panicle hill⁻¹, Plant height (cm), Tillers hill⁻¹, Peduncle length (cm), Grains per main panicle, 1000 grain weight (g), Main panicle length (cm), L/B ratio of grain, Grain width (mm), Grain length (mm), Biological yield (q ha⁻¹), Grain yield (q ha⁻¹) and Harvest index percent.

Genotypic coefficient of variation (GCV) :

The factor of variation at genotypic level was determined by

$$GCV\% = \frac{\sqrt{\frac{\sum x_i^2}{n}}}{\bar{X}_i} \times 100$$

Where, $\bar{X}_i$ = the average of ith character's observations

$\frac{\sum x_i^2}{n}$ = the genotypic variance

Phenotypic coefficient of variation (PCV) : The coefficient of variation at phenotypic level can be determined by

$$PCV\% = \frac{\sqrt{\frac{\sigma_p^2}{\bar{X}_i}}}{\bar{X}_i} \times 100$$

Where, $\bar{X}_i$ = the average of i^{th} character's observations;

σ_p^2 = phenotypic variance

The values of GCV and PCV as stated by "Sivasubramanian and Menon (1973)", is considered to be low if it is below 10%, moderate if it is between 10% and 20% and high if it is higher than 20 percent.

Heritability (Broad sense) : The proportion of genotypic variance (σ_g^2) and phenotypic variances (σ_p^2) applying the following method suggested by "Allard (1960)" gives Heritability (bs).

$$H^2(bs) = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

The heritability values as stated by "Hanson *et al.*, (1956)" are classified as low if they are less than 30%, moderate if they are between 30% and 60%, and high if they are greater than 60%.

Genetic advance (GA) : As elaborated by "Johnson *et al.*, (1955)", the genetic advancement for the character was computed as;

$$GA = K \sigma_p h^2$$

Where, h^2 = the heritability

σ_p = the phenotypic standard deviation

K = Constant, value (2.06), at 5% selection

Genetic advancement as percentage of mean : As elaborated by "Johnson *et al.*, (1955)", the genetic advancement of the characters as percentage of mean was computed as;

$$GA \text{ as } \% \text{ mean} = \frac{GA}{\bar{X}} \times 100$$

Where, $\bar{X}$ = mean of the character

GA = genetic advance,

The extent of genetic advancement of the characters as a percentage of mean as stated by "Johnson *et al.*, (1955)" is classified as low when it is below 10%, moderate when it is between 10-20% and high when it is above 20 percent.

Results and Discussion

The variance study indicated that among all the characters, the genotypes differed significantly (Table-1), implying that the genotypes used in the research could be of various origins. The range of

variability indicated that per hectare grain yield, biological yield, plant height and number of grains per main panicle had a variability of wide range, indicating the diverse origin of their parents and the utility of these characters for further selection. The results obtained are in accordance "Sharma *et al.* (2020), Bhattacharya *et al.* (2019), Kumar *et al.* (2018), Akter *et al.* (2018), Sharma *et al.* (2016) and Kishore *et al.* (2015)".

Range (Table-2) of days to fifty percent flowering was between 86 days (R2032-87-1-23-1) to 118 days (Samundrachini 5-50). The days to maturity varied from 125 days (R2032-87-1-23-1) to 154 days (Samundrachini 5-50). The plant height of genotypes varied from 93.54 cm (Nagri Dubraj Mutant-1) to 163.35 cm (CG Devbhog). The tillers per hill ranged from R2281-308-1-185-1 (10) and the lowest for Kasturi (5). The panicles per hill ranged from 5 (Kasturi) to 9 (R2281-308-1-185-1). The range of main panicle length was from 18.40 cm (Ker ghul) to 27.93 cm (RL910 (LAYCHA)). The peduncle length varied from 26.33 cm (R2032-87-1-23-1) to 39.66 cm (R2400-562-2-340-1). The grains per main panicle varied from 123 (Jeeraphool Mutant 5) to 328 (Samundrachini 5-50). The range of 1000 grain weight was from 8.53 g (Samundrachini 5-50) to 29.25 g (R1624-61-3-61-1). The biological yield value varied from 56.67 q/ha (Samundrachini 5-50) to 146.67 q/ha (R 1656-2151-1-412-1). The harvest index % value varied from 28.59 % (JDP-2520-2-4-1) to 54.95 % (R2032-87-1-23-1). The grain length varied from 5.53 mm (R1656-2151-1-412-1) to 10.65 mm (R2032-87-1-23-1). The grain width varied from 2.15 mm (Ker ghul) to 3.30 mm (R2369-475-1-251-1). The L/B ratio of grain varied from 1.88 (R1656-2151-1-412-1) to 4.39 (RM 504 (Mahraji)). The mean value for yield varied from 20.99 q ha⁻¹ (RM 504 (Mahraji)) to 57.33 q ha⁻¹ (R2281-308-1-185-1).

Simple measures of variability include genotypic and phenotypic coefficients of variation. These coefficients' relative values indicate the degree of variability in a genetic population. In this study, estimates of PCV were comparably larger compared to GCV estimates (Table-2), with small differences for each of the traits examined, suggesting lesser environmental influence on all trait expression. The highest GCV and PCV were documented for 1000 grain weight (g) followed by grain yield (q ha⁻¹), per main panicle grain number and length breadth ratio of grain revealing that the above mentioned traits were primarily influenced by genetic factors and showed lesser variation due to environmental factors thus

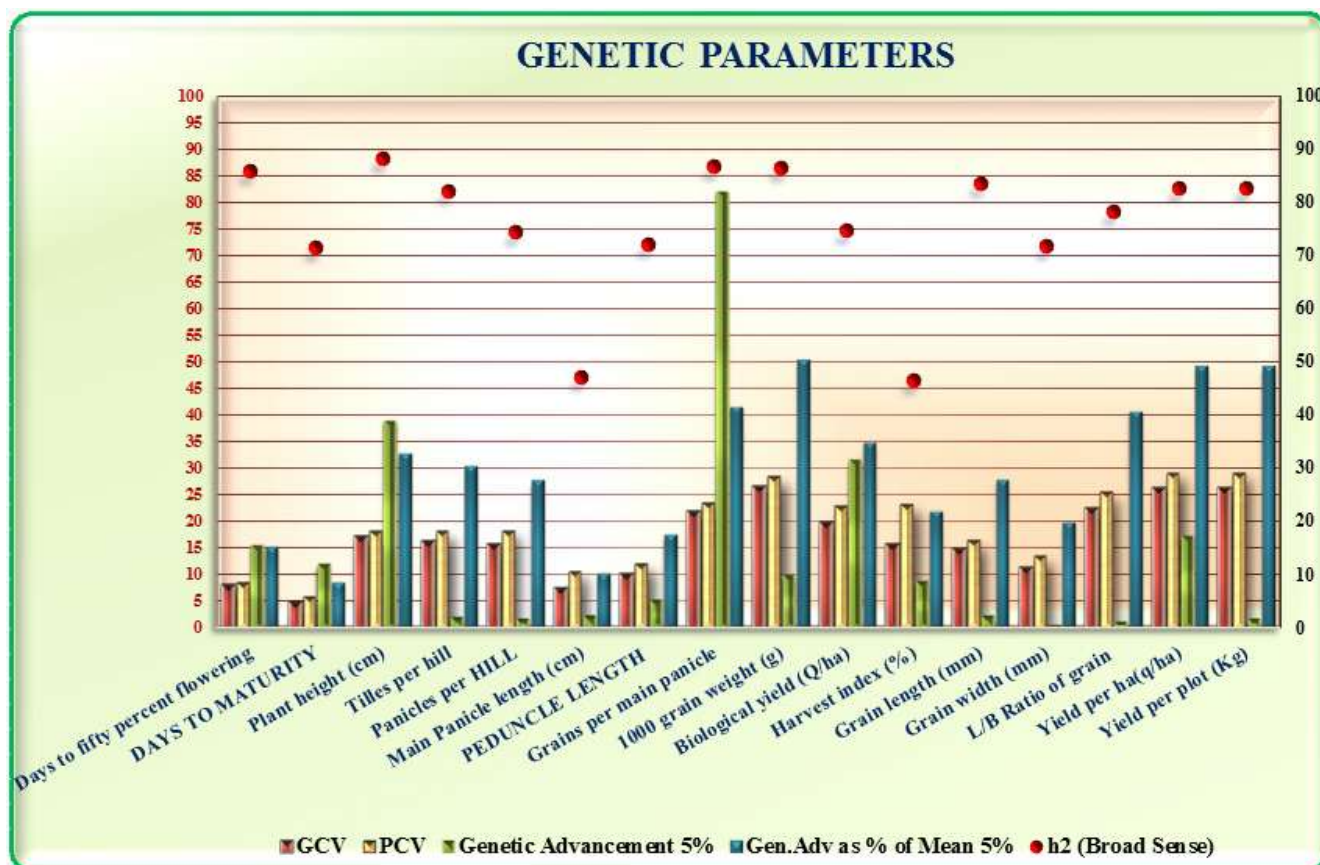


Figure : Graphical representation of genetic parameters.

Table-1 : MSS values of ANOVA for various traits under study.

Sr. No.	Sources of variation	RMS (df=2)	TMS (df=38)	EMS (df=76)
1.	Days to fifty percent flowering	124.837**	214.763**	11.483
2.	Days to maturity	203.034**	160.454**	19.277
3.	Plant height (cm)	17.9710	1294.437**	57.382
4.	Tillers per hill	0.2610	4.241**	0.298
5.	Panicles per hill	0.8910	2.976**	0.312
6.	Main panicle length (cm)	1.9730	12.424**	3.423
7.	Peduncle length (cm)	22.706**	32.395**	3.785
8.	Grains per main panicle	313.1950	5830.21**	289.347
9.	1000 grain weight (g)	1.0690	83.914**	4.257
10.	Biological yield (q ha ⁻¹)	1496.162**	1060.462**	109.066
11.	Harvest index (%)	184.995*	160.207**	44.757
12.	Grain length (mm)	0.0120	4.601**	0.291
13.	Grain width (mm)	0.0010	0.327**	0.038
14.	L/B Ratio of grain	0.010	1.536**	0.134
15.	Yield per ha (q ha ⁻¹)	29.6390	280.548**	18.816

**Significant at 5% probability level, ** Significant at 1% probability level"

"RMS= Replication MSS, TMS= Treatment MSS, EMS= Error MSS, MSS =Mean sum of squares"

depicting the importance of these traits for future development. The obtained results were similar to the results of "Sharma *et al.* (2020), Kumar *et al.* (2020), Bhattacharya *et al.* (2019), Kumar *et al.* (2018), Biswaranjan *et al.* (2018) and Islam *et al.* (2016)".

Heritability governs the resemblance between subsequent generations, whereas genetic advancement provides predictions of future gain for a specific character following selection. In the current set of materials, higher heritability coupled with higher

Table-2 : Different parameters of variation in fine slender rice genotypes.

Sr. No.	Characters	Mean	Range		Pheno. SD	Variance		Coefficient of variation		h ² (BS)	GA 5%	GAM 5%
			Min	Max		Genotypic	Phenotypic	GCV%	PCV%			
1.	Days to fifty percent flowering	103.23	86	118	8.9	67.76	79.24	7.97	8.62	85.51	15.68	15.19
2.	Days to maturity	139.85	125	154.33	8.15	47.06	66.34	4.91	5.82	70.94	11.9	8.51
3.	Plant height (cm)	118.99	93.54	163.35	21.67	412.35	469.73	17.07	18.22	87.78	39.19	32.94
4.	Tillers hill ⁻¹	7	5.4	10.2	1.27	1.31	1.61	16.37	18.13	81.52	2.13	30.45
5.	Panicles hill ⁻¹	6.01	4.67	9.07	1.1	0.89	1.2	15.69	18.23	74.03	1.67	27.8
6.	Main panicle length (cm)	23.71	18.4	27.93	2.53	3	6.42	7.31	10.69	46.71	2.44	10.28
7.	Peduncle length (cm)	30.59	26.33	39.66	3.65	9.54	13.32	10.1	11.93	71.59	5.38	17.6
8.	Grains main panicle ⁻¹	196.79	123.07	327.6	46.22	1846.95	2136.3	21.84	23.49	86.46	82.32	41.83
9.	1000 grain weight (g)	19.52	8.53	29.25	5.55	26.55	30.81	26.4	28.44	86.18	9.85	50.49
10.	Biological yield (q ha ⁻¹)	90.44	56.67	146.67	20.64	317.13	426.2	19.69	22.83	74.41	31.65	34.99
11.	Harvest index (%)	39.52	28.59	54.95	9.12	38.48	83.24	15.7	23.08	46.23	8.69	21.99
12.	Grain length (mm)	8.04	5.53	10.65	1.31	1.44	1.73	14.91	16.35	83.17	2.25	28.02
13.	Grain width (mm)	2.72	2.15	3.3	0.37	0.1	0.14	11.4	13.49	71.48	0.54	19.86
14.	L/B Ratio of grain	3.03	1.88	4.39	0.78	0.47	0.6	22.53	25.55	77.71	1.24	40.9
15.	Grain yield(q ha ⁻¹)	35.39	21	57.33	10.3	87.24	106.06	26.39	29.1	82.26	17.45	49.31

genetic advancement as a percentage of mean was documented for namely; tillers hill⁻¹, plant height (cm), panicles hill⁻¹, 1000 grain weight (g), grains per main panicle, harvest index (%), L/B ratio of grain, biological yield (q ha⁻¹), grain yield (q ha⁻¹) and grain length (mm) (Table-2) which suggested potency of selection from these characteristics as they showed additive gene effect. As more additive gene accumulate, simple selection method based on direct selection of phenotypic expression for these traits would be rewarding for further improvement. A similar set of claims were made by "Kumar *et al.* (2020), Bhattacharya *et al.* (2019), Kumar (2018) and Islam *et al.* (2016)".

Conclusions

All of the characters under consideration showed a significant difference. Genotypic coefficient of variation and phenotypic coefficient of variation values estimated, ascertained to be greatest for traits 1000 grain weight followed by grain yield (q ha⁻¹), of grain's length breadth ratio and number of grains main panicle⁻¹ in the study of variability parameters. Furthermore, high heritability in combination with higher genetic advancement of character as a percentage of mean was obtained for 1000 grain weight, number of grains per main panicle, grain yield (q ha⁻¹) and plant height; implying that environmental variation has less of an impact on the inheritance of these attributes, that can be enhanced further over with the method of simple selection.

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Growth Performance of Wheat Varieties under Shaded and Open Condition in Agri-Horticulture System in Central India

Baban Kodle¹, N.K. Kushwaha^{2*}, Vijay Bagare³, Mukesh Rajak³, Madhuri Thakur³, Vishnu Solanki¹ and Anshu Dhaka⁴

¹Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P.

²RVSKVV, Gwalior, M.P.

³Mangalayatan University, Jabalpur, M.P.

⁴D.N (P.G) College, Meerut, U.P.

*Corresponding Author Email : neerajkushwaha07@gmail.com

Abstract

Wheat (*Triticum aestivum*) a member of Poaceae family, is the world's second most important staple food crop after rice, and plays an important role in global trade. Wheat make up as about 35 percent to the national food basket and is critical for food and nutritional security. It includes around 12 percent protein, 70 percent carbohydrate, 2.7 percent minerals, 1.7 percent fats, 2 percent fiber and 12 percent moisture. Highest plant population 60 DAS was recorded in (sole GW 322) i.e. 59.15 per m², which was at par with (Sole JW-3288) i.e. 58.12. Lowest was recorded in (Guava +JW-3382) i.e. 55.22 per m². Significantly highest plant population at harvest was recorded in (Sole GW-322) i.e. 58.37 per m², which was at par with (Sole JW-3288) i.e. 57.25 and lowest in (Guava +JW-3382) i.e. 55.20 per m².

Key words : Agroforestry, Agri-horticulture, system.

Introduction

Wheat (*Triticum aestivum*) a member of Poaceae family, is the world's second most important staple food crop after rice, and plays an important role in global trade. Wheat makes up as about 35 percent to the national food basket and is critical for food and nutritional security. It includes around 12 percent protein, 70 percent carbohydrate, 2.7 percent minerals, 1.7 percent fats, 2 percent fiber and 12 percent moisture (Sharma and Jain, 2004). Wheat farming has also been associated with the green revolution, food security and long term productivity. India ranks second among wheat producing countries in the world after China. (Kurrar, 2012). In India, wheat was shown on an area of around 30.6 million hectares with a yielding of 98.4 million tons with an average productivity of 3216 kg/ha during 2016-17 (Anonymous, 2017). It is cultivated under a wide range of climatic condition favored by cool moist weather followed by dry warm weather. It is a cereal crop. It produces about 20% food resources of the world. In Madhya Pradesh, it is cultivated in 5.73 million ha land with an annual production of 16.32 million tones with productivity of 2843 kg/ha (Anonymous, 2019). The stagnation in the production of this crop is now all-apparent. But there is still a wide gap in the potential productivity and actual production of wheat crop in real farming situation. There are many caused responsible for lower yield, such as delayed planting, selection of unsuitable varieties, insufficient seeding rates, improper planting geometry and soil type etc. Sustainable increase

in grain production of wheat varieties can be achieved by sowing the wheat crop at the optimum time period, which varies according to variety or genotype, climatic conditions and availability of resources. Among various factors responsible for lower yield of wheat crop in the country, sowing time and varietal selection are of primary importance (Dhaka et al., 2006).

World having 121 million peoples live in 329 million ha geographical area with population density of 382 persons per sq. km. Overall per capita land availability is about 0.37 ha. Due to increasing population there is heavy pressure on land for food, fodder and timber / fuel wood etc. Agroforestry may be one of the solutions to increase forest area to one third of the total geographical area of our country. Increasing wood, Food and fuel wood requirement as well as reduce the pressure on forest for Food, fuel and wood consumption. *Psidium guajava* is a member of the Myrtaceae family native to Southern Mexico and Central America, has gained economic importance in the tropical and subtropical regions of the world because of its wide adoptability to varied soil and climatic condition. In the India Guava is considered one of the most popular and important fruit crop grown on small scale in different parts of the country for fresh consumption. Guava is one of the most common fruit in India and most popular fruit in Madhya Pradesh. The total area, production and productivity of Guava in India is about 2.60 Million hector and Madhya Pradesh, total area,

production and productivity of Guava is 28.44 thousand hectares (Anonymous 2017).

Materials and Methods

The experiment was laid down in Rabi season during the year 2020-21 on new Forestry Research Farm, Department of Forestry, JNKVV, Jabalpur Seasonal variation prevailing during the growth period play an important role not in the growth and development of the crop which ultimately influence the final yield of crop. The weekly metrological data during the cause of investigation recorded during crop season at metrological observatory, College of Agriculture Engineering, JNKVV Jabalpur. It is evident from the data that weather condition almost favorable for the growth and development of wheat. During the growing season of crop (Nov 2020 to April 2021). Maximum temperature 33.4°C was recorded in Nov and minimum temperature 4.8°C in Feb, relative humidity range between 82-91% in morning and 20 to 75% in evening. The total rainfall received during the crop season was 206.1 mm. which was obtained in 18 rainy days. The wind velocity varies between 1.6 to 4.8 km per hours. The mean sunshine hour ranged between 2.4 to 9.8 hours per day.

Experimental Detail

Technical Programmed of Work :

Location	:	Forestry Research Farm JNKVV, Jabalpur
Crop	:	Wheat
Variety of crop	:	GW-322, JW-3211, JW-3288, JW-3382.
Seedrate	:	80-100 kg ha ⁻¹
Row to row spacing	:	20 cm
Design	:	Randomized Block Design (RBD)
Year of experiment	:	2020-2021
Number of replications	:	04
Number of treatment	:	09
Number of plot	:	36
Gross plot size	:	5m x 5m
Net plot size	:	4.2m x 4.2m
Total experimental area	:	500 m ² (guava)
Total experimental area	:	400 m ² (Wheat alone)
Total experimental net	:	282.24 m ² area wheat
Distance between plots	:	0.8m
Fertilizer dose (recommended)	:	120:60:60 NPK kg ha ⁻¹
Tree species	:	Guava
Variety of guava	:	Lucknow-49
Tree spacing	:	5.0 m x 5.0 m
Year of plantation	:	1997

(A) Crop :

(a) Pre-harvest

1. Plant Population (m⁻²)
2. Plant height (cm)
3. Days to 50% flowering
4. Total number of tillers in one-meter row length

(B) Post-harvest

1. Plant Height
2. Effective tillers per meter row length
3. Length of earhead
4. Number of filled grain/earhead
5. 1000 grain weight (test weight)
6. Grain yield (kg/plot)
7. Straw yield (kg/plot)
8. Harvest index (%)
9. Grain: straw ratio

Observation Recorded : All the pre harvest observations of plants at different critical stages were recorded. Post-harvest observations were recorded at the time of harvesting and after the threshing of crop.

Pre-harvest observations : To record various observations to be places (1-meter row length) in each plot were randomly selected, tagged 15 days after sowing of the crop marked both end by putting wooden sticks. Observations were taken from marked areas.

Germination percentage : The number of plant/MRL (meter row length) was counted 15 days after sowing in marked area in each plot. Then germination percentage was worked out on the basis of number of plant comes out /MRL. This seed is 90% germination of the open condition and 88-90% of shaded condition.

Plant population : Plant Population per meter row length was recorded 15 days after sowing at three randomly selected spots in each plot.

Height of the Plant (cm) : Height of 5 randomly marked plants were measured in centimeter from the ground level up to the auricle of the upper most fully opened leaf at the stage of crown root initiation(CRI), late storing(LT), late jointing(LJ), flowering(F), milking(M), dough(D) stage. The mean height was calculated by dividing the summation with five.

Numbers of tillers per meter row length : Total number of tillers per meter row length at all growth stages of the crop (i.e. CRI, LT, LJ, F, M and Dough) and at harvest

were recorded by counting from five marked row in each plot and the mean values were calculated.

At and Post-Harvest Studies

Number of effective tillers per meter row length : Effective tillers per meter row length (tillers which produce ear head) were counted from already marked one-meter row length plants at maturity stage. The average was worked out.

Length of ear head (cm) : This site of field is five ear head from each plot were selected randomly at the time of harvesting and length of each ear head was measured from the base to tip of the ear head. There-after, mean length of ear head was calculated and expressed in centimeter.

Number of grains per ear head : Randomly selected five ear head were crushed by hand manually then removed the straw and count the total number of grains. Finally, total number of grains counted and divided by five to find out the number of filled grain/ear head.

Number of filled grain / ear head : All the filled grains from the total number of grains counted manually. Then the mean numbers of grains per ear head were computed.

Number of unfilled grain /ear head : This deducting the number of filled grains per ear head from total numbers of grains per ear head the number of unfilled grains per ear head were computed.

Harvesting : Harvesting of crop was done manually with the help of sickle on 27 March 2021 to 30 March 2021 when it attained maturity. One row (20 cm) from other side of each plots and at same distance from both the ends were harvested separately to remove the border effect and then net plots were harvested. It was left in the field for sun drying. After 2-3 days of drying, the bundles were made out of the harvested produce and tagged.

Threshing and winnowing : After sun drying the produce was bind to bundles and weighed plot wise. Threshing was done on the tarpaulin by manual labours with the help of wooden sticks. The material threshed from each plot was kept separately from the straw by winnowing with the help of hand pan (supa). After this the clean grains were weighed plot wise, deduct grain yield from bundle weight to find out straw yield per plot.

Test weight (1000 grain weight) : Samples of grains were randomly drawn from the produce of each plot and thousand grains were carefully counted. The counted grains were weighed on an electric balance and weight was recorded in grams.

Grain yield (kg ha⁻¹) : After winnowing and cleaning the grain from each net plot, the produce of the net plot was

tied in bundles and their weights were recorded by using spring balance. After threshing the grain from each bundle, the weight of clean grain per plot was recorded accurately. The grain yield per hectare was obtained by multiplying the net plot yield by converting factor (10,000 divided by net area (m²) of plot). The yield was expressed in kilograms per hectare.

Straw yield (kg ha⁻¹) : The straw yield of each plot was obtained by subtracting the grain yield from (Biological yield) total weight of the bundles per plot. The straw yield per hectare was obtained by multiplying the net plot yield by the converting factor (10,000 divided by net area (m²) of plot). The yield was expressed in kilograms per hectare.

Harvest Index : Harvest index is expressed as the ratio of economic yield (grain yield) to the total biological yield (grain yield + straw yield) and expressed in percentage. It was calculated as per the formula proposed by Nichiporovich (1967).

$$\text{Harvest Index} = \frac{\text{Economic Yield}}{\text{Biological Yield}} \times 100$$

Results

Germination percentage : The observation on plant Germination percentage was recorded and furnished in below table-1. The germination percentage is one of the most important factors which contribute towards crop growth and ultimately crop yield. The number of seeds germinates/MRL were recorded 15 days after sowing and the data were statistically analyzed. Maximum germination percentage of 15 DAS was recorded in T₇ (Sole GW-322) i.e. 93%. Whereas minimum germination percentage was recorded in T₁(Guava +JW-3211) i.e. 87%.

Table-1 : Germination percentage of wheat under Guava based Agri-Horticulture practices of Agroforestry.

Treatment	Germination % 15 DAS
T-1 Guava + JW-3211	87.000
T-2 Guava + GW-322	88.000
T-3 Guava + JW-3288	87.750
T-4 Guava + JW-3382	87.500
T-5 Guava sole	—
T-6 Sole JW-3211	92.250
T-7 Sole GW-322	93.000
T-8 Sole JW-3288	92.500
T-9 Sole JW-3382	92.000
SE ±	0.6792
CD @ 5%	1.9975

Plant population : The observation on plant population was recorded and furnished in table-2. Among all the treatments, significantly highest plant population 60 DAS was recorded in T₇ (sole GW 322) i.e. 59.15 per m², which was at par with T₈ (Sole JW-3288) i.e 58.12. Lowest was

recorded in T₄ (Guava +JW-3382) *i.e.* 55.22 per m². Significantly highest plant population at harvest was recorded in T₇ (Sole GW-322) *i.e.* 58.37 per m², which was at par with T₈ (Sole JW-3288) *i.e.* 57.25 and lowest in T₄ (Guava +JW-3382) *i.e.* 55.20 per m².

Table-2 : Plant population of wheat under Guava based Agri-Horticulture practice of Agroforestry.

Treatments	Plant population (per m ²) 60 DAS	Plant population (m ²) at harvest
T-1 Guava + JW-3211	56.97	55.90
T-2 Guava + GW-322	57.07	56.97
T-3 Guava + JW-3288	56.70	56.62
T-4 Guava + JW-3382	55.22	55.20
T-5 Guava sole	—	—
T-6 Sole JW-3211	57.02	56.70
T-7 Sole GW-322	59.15	58.37
T-8 Sole JW-3288	58.12	57.25
T-9 Sole JW-3382	56.47	56.35
SE ±	0.53	0.46
CD @ 5%	1.57	1.37

Plant height : The observation on plant height was recorded and furnished in table-3. The Maximum plant height (cm) was recorded in the T₂ (Guava+GW-322) at 30, 60, 90 DAS and harvest time (33.93,64.52,84.72 and 83.40 cm respectively) which was at par with treatments T₃(Guava +JW-3288)& T₄(Guava +JW-3382) at 30 days, T₃(Guava +JW-3288) at 60 days, T₇(Sole GW-322)at 90 days and at harvest T₇(Sole GW-322) and T₃(Guava +JW-3288).The minimum plant height was recorded in T₆(Sole JW-3211)at 30, 60, 90 and harvest time.

Table-3 : Plant height (cm) of wheat under Guava based Agri-Horticulture practice of Agroforestry.

Treatments	30 days	60 days	90 days	At harvest
T-1 Guava + JW-3211	31.71	63.00	80.05	79.80
T-2 Guava + GW-322	33.93	64.52	84.72	83.40
T-3 Guava + JW-3288	32.18	64.22	82.15	81.61
T-4 Guava + JW-3382	32.42	63.75	81.15	80.90
T-5 Guava sole	—	—	—	—
T-6 Sole JW-3211	26.25	59.05	78.85	78.17
T-7 Sole GW-322	28.77	60.45	83.62	81.75
T-8 Sole JW-3288	27.08	59.75	82.15	80.30
T-9 Sole JW-3382	26.84	59.15	81.12	80.01
SE ±	0.63	0.37	0.80	0.69
CD @ 5%	1.85	1.10	2.35	2.03

Total number of tillers in one-meter row length : The observation on total number of tillers and effective tillers in one-meter row length was recorded and furnished in table-4. Significantly maximum total number of tillers in one-meter row length at 60 DAS were recorded in treatment T₇ (sole GW 322) *i.e.* 263.50 per m⁻¹, which was at par with T₂(Guava+GW-322) *i.e.* 260.25, whereas minimum number of tiller were recorded under T₄ (Guava +JW-3382) *i.e.* 252.75 per m⁻¹.

Effective tillers in one meter row length : The data on the total number of effective in one-meter row length are presented in table-4. Highest number of effective tiller in one-meter row length at 90 DAS was found in highest T₇ (sole GW- 322) *i.e.* 246.50 per m⁻¹, which was at par with T₈ (sole JW-3288) (244.0). However lowest total number of effective tiller in at 90 DAS was recorded in T₃ (Guava+ JW 3288) *i.e.* 240 per m⁻¹.

Table-4 : Total number of tillers and effective tillers in one-meter row length of wheat under Guava based Agri-Horticulture practice of Agroforestry.

Treatments	Total number of tillers in one meter row length (m ⁻¹)	Effective tillers in one meter row length(m ⁻¹)
T-1 Guava + JW-3211	256.25	242.00
T-2 Guava + GW-322	260.25	243.00
T-3 Guava + JW-3288	256.25	240.00
T-4 Guava + JW-3382	252.75	240.75
T-5 Guava sole	—	—
T-6 Sole JW-3211	257.50	243.75
T-7 Sole GW-322	263.50	246.50
T-8 Sole JW-3288	257.75	244.00
T-9 Sole JW-3382	258.00	243.75
SE ±	1.33	0.91
CD @ 5%	3.92	2.68

Days to 50% flowering : The data on the 50% flowering and length of ear head are presented in table-5. Highest 50% flowering was recorded under T₄ (Guava+JW-3282) *i.e.* 60.75 which was at par with T₁ (Guava+JW-3211) whereas minimum 50% flowering was recorded in T₇(Sole GW-322) *i.e.* 58.75.

Length of ear head (cm) : The observation on length of ear head was recorded and furnished in table 5. Wheat under Guava based Agri-Horticulture practice produced longest length of ear head (9.92 cm) in treatment T₇ (Sole GW-322) which was at par with treatment T₈ (sole JW-3288) *i.e.* 9.47 cm. The shortest length of ear head was found (8.17 cm) in treatment T₁ (Guava+ JW-3211).

Table-5 : Days to 50% flowering and Length of ear head (cm) of wheat under Guava based Agri-Horticulture practice of Agroforestry.

Treatments	Days to 50% flowering	Length of ear head (cm)
T-1 Guava + JW-3211	60.50	8.17
T-2 Guava + GW-322	60.25	8.97
T-3 Guava + JW-3288	59.75	8.75
T-4 Guava + JW-3382	60.75	8.67
T-5 Guava sole	—	—
T-6 Sole JW-3211	58.25	8.97
T-7 Sole GW-322	58.75	9.92
T-8 Sole JW-3288	57.75	9.47
T-9 Sole JW-3382	59.75	9.10
SE ±	0.22	0.18
CD @ 5%	0.65	0.53

Grain yield ($q\ ha^{-1}$) : The observation on grain yield $q\ ha^{-1}$ was recorded and furnished in table-6. The significantly maximum grain yield $q\ ha^{-1}$ was recorded in the treatment T_7 (Sole GW-322) *i.e.* 42.79 $q\ ha^{-1}$, which was at par with treatment T_8 (Sole JW-3288) *i.e.* 42.37 $q\ ha^{-1}$ and minimum grain yield $q\ ha^{-1}$ was found in the treatment T_1 (Guava +JW-3211) *i.e.* 23.37 $q\ ha^{-1}$.

Straw yield ($q\ ha^{-1}$) : The data on the straw yield are presented in table-6. The significantly highest straw yield was found under T_7 (Sole GW-322) *i.e.* 60.30 $q\ ha^{-1}$ which was at par with T_8 (Sole JW-3288) *i.e.* 57.65 $q\ ha^{-1}$. However minimum straw yield $q\ ha^{-1}$ was recorded in T_1 (Guava +JW-3211) *i.e.* 33.07 $q\ ha^{-1}$.

Table-6 : Grain yield ($q\ ha^{-1}$) and straw yield ($q\ ha^{-1}$) of wheat under Guava based Agri-Horticulture practice of Agroforestry.

Treatments	Grain yield ($q\ ha^{-1}$)	Straw yield ($q\ ha^{-1}$)
T-1 Guava + JW-3211	23.37	33.07
T-2 Guava + GW-322	24.95	35.60
T-3 Guava + JW-3288	23.60	35.95
T-4 Guava + JW-3382	23.40	34.00
T-5 Guava sole	—	—
T-6 Sole JW-3211	39.96	56.07
T-7 Sole GW-322	42.79	60.30
T-8 Sole JW-3288	42.37	57.65
T-9 Sole JW-3382	40.24	56.80
SE $\pm$	0.51	0.97
CD @ 5%	1.51	2.87

Test weight : The data on the test weight are presented in table-7. Significantly maximum test weight was recorded in T_7 (sole GW 322) *i.e.* 41.15 GM. which was at par with T_8 (sole JW-3288) (39.72 GM). However minimum test weight was recorded in T_1 (Guava +JW-3211) *i.e.* 33.67 GM.

Number of filled grain / ear head : The observation on number of filled grain / ear head was recorded and furnished in table-7. The significantly maximum number of filled grain per ear head was recorded in the treatment T_7 (Sole GW-322) *i.e.* 52.75, which was at par with treatment T_8 (sole JW-3288) *i.e.* 50.0 and minimum filled grain per ear head was found in the treatment T_1 (Guava +JW-3211) *i.e.* 29.75.

Table-7 : Test weight and Number of filled grain / ear head of wheat under Guava based Agri-Horticulture practice of Agroforestry.

Treatments	1000 grain weight (test weight)	Number of filled grain / ear head
T-1 Guava + JW-3211	33.67	29.75
T-2 Guava + GW-322	36.20	34.87
T-3 Guava + JW-3288	34.15	30.25
T-4 Guava + JW-3382	33.77	31.25

T-5 Guava sole	—	—
T-6 Sole JW-3211	38.45	47.50
T-7 Sole GW-322	41.15	52.75
T-8 Sole JW-3288	39.72	50.00
T-9 Sole JW-3382	38.55	47.75
SE $\pm$	0.53	0.99
CD @ 5%	1.57	2.93

Grain: Straw yield ratio : It can be elucidated from the data depicted in table-8 that the grain & straw yield ratio was non- significant under Guava & sole crops of wheat.

Harvest index : The observation on harvest index was recorded and furnished in table-8. The maximum harvest index was recorded in the treatment T_8 (Sole JW-3288) *i.e.* 42.40%, which was followed by treatment *i.e.* T_6 (sole GW-3211) (41.60%), whereas minimum harvest index was found in the treatment T_3 (Guava +JW-3288) *i.e.* 39.60%.

Table-8 : Grain: Straw yield ratio and harvest index of wheat under Guava based Agri-Horticulture practice of Agroforestry.

Treatments	Grain : Straw ratio	Harvest index
T-1 Guava + JW-3211	0.70	41.40
T-2 Guava + GW-322	0.70	41.20
T-3 Guava + JW-3288	0.65	39.60
T-4 Guava + JW-3382	0.68	40.80
T-5 Guava sole	—	—
T-6 Sole JW-3211	0.71	41.60
T-7 Sole GW-322	0.71	41.50
T-8 Sole JW-3288	0.73	42.40
T-9 Sole JW-3382	0.70	41.51
SE $\pm$	0.01	0.005
CD @ 5%	NS	0.014

Discussion

Germination count : Maximum germination percentage of 15 DAS was recorded in T_7 (sole Gw-322) (93%). Whereas minimum germination percentage was recorded in T_1 (Guava + JW- 3211) (87%). Similarly result was found in wheat under poplar because of the reduced germination due to presence of various inhibiting substance phenolic in the leaf leachates of the poplar decrease the germination count of wheat by Singh *et al.*, (2012).

Plant population : Among all the treatments, significantly highest plant population at 60 DAS was recorded in T_7 (sole GW-322) (59.15 per m^2) and lowest was recorded in T_4 (Guava +JW-3382) (55.2 per m^2). Highest significantly plant population at harvest was recorded in T_7 (sole GW-322) (58.37 per m^2) and lowest in T_4 (Guava +JW-3382) (55.2 per m^2), similar results were found in plant population among different varieties of wheat under poplar by Mukherjee (2012).

Plant height : The Maximum plant height (cm) was recorded in the T_2 (Guava+GW-322) at 30, 60, 90 DAS and harvest time. The minimum plant height was recorded in T_6 (sole JW-3211) at 30, 60, 90 and harvest time, Mukherjee, (2012) found similar results in plant height of wheat crop among different varieties. The competitive effect between popular tree and wheat crop for light, nutrients and water effect of popular tree. Observed height was reported among different varieties of wheat crop. The significant difference in height of the wheat in open farming system as well as under Agroforestry system were also reported by Chauhan *et al.* (2010), Kaur *et al.* (2010).

Number of tiller and effective tiller/MRL : Significantly maximum number of tillers in one-meter row length at 60 DAS were recorded in treatment T_7 (sole Gw-322) (263.50 per m^{-1}) whereas minimum number of tiller were recorded under T_4 (Guava +JW-3382) (252.75 per m^{-1}).

Highest number of effective tillers in one-meter row length at 90 DAS were found in T_7 (sole GW 322) (246.50 per m^{-1}). However, the lowest total number of effective tillers at 90 DAS was recorded in T_3 (Guava+ JW-3288) (240 per m^{-1}). Variability during the varieties with respect to number of tillers exploit be due to their genetic makeup (Mukherjee, 2012 and Mumtaj *et al.*, 2015). Similar results were also reported by Gaill *et al.*, (2009). Observed that shading (50% of ambient light form booting caused maximum tillers mortality and different sowing time. Lesser number of tillers under popular Agroforestry system due to shading effect.

Days of 50% flowering : Highest 50% flowering was recorded under T_1 (Guava+ JW-321)(60.50) and whereas minimum 50% flowering was recorded in T_7 (sole GW-322) (58.75). Similar result was also found by Metwally *et al* (2003). Salicylic acid induces flowering, retards senescence and increases cell metabolic rate, enzyme activities in barley (*Hordeum vulgare*) seedlings and in wheat and flowering increased the grain yield by 24 percent (Sahu and Singh, 1995).

Length of ear head : Wheat under Guava based Agri-Horticulture practice produced longest length of ear head (9.92 cm) in T_7 (Sole GW-322). The shortest length of ear head was found (8.17) in treatment T_1 (Guava + JW-3211). Due to the fact that timely sowing condition of wheat provided better adaptability of weather parameter like lower gap between minimum and maximum relative humidity, temperature lower evaporation transpiration leading to better availability of soil moisture and nutrient (Tyagi *et al.*, (2003), Zende *et al.*, (2005), and Man (2010). This was because of fact that the variety GW 322 have more utilization of power of fertilizer and other nutrient with late maturity characteristic leading to higher dry matter

accumulation and translocation in plant parts in terms of length of spike and number of grains per spike resulting obtained the higher values than other varieties (Patel *et al.*, 2018).

Grain and straw yield : The significantly maximum grain yield $q\ ha^{-1}$ was recorded in the treatment T_7 (Sole GW-322) ($42.79q\ ha^{-1}$) and minimum grain yield $q\ ha^{-1}$ was found in the treatment T_1 (Guava+JW-3211). The significantly highest straw yield was found under T_7 (Sole GW-322) ($60.30q\ ha^{-1}$). However minimum straw yield $q\ ha^{-1}$ was recorded in T_1 (Guava+JW-3211) ($33.07q\ ha^{-1}$). Similar results were reported by Mishra *et.al.* (2000), Jadhav and karanjikar (2001). Light, nutrients and moisture are the most important limiting component which influences the overall growth and yield of Agroforestry system. Significant yield reduction by tree species could be due to their shading effect and below ground completion for resources (Bisht *et al.* 2017). This was because of fact that the variety GW 322 have unique genetic makeup and other nutrient with late maturity characteristic leading to higher dry matter accumulation and translocation in plant parts in terms of length of spike and number of grains per spike resulting obtained the higher values than other varieties by Patel *et al.* (2018). The performance of wheat under popular based Agroforestry system and study revealed that grain and straw yield of wheat was better in sole cropping than under popular based Agroforestry system. (Rani *et al.* 2015).

Test weight : Significantly maximum test weight was recorded in T_7 (sole+GW-322) (41.15 GM). However minimum test weight was recorded in T_1 (Guava +JW-3211) (33.67 GM). Reduction in test weight due to contest for various factor like water, light and nutrient between tree and crop under guava based agroforestry system. (Jiang *et al.*, (1994), similar results were also found by Lakshama and Raomma, 1996 and Rao *et al.* (2006). Patel *et al.* (2018) found that in respect of 1000-grain weight this was because of better and congenial weather parameter enjoyed by wheat varieties.

Total number of filled grain per ear head : The significantly maximum number of filled grain per ear head was recorded in the treatment T_7 (Sole GW-322) (52.75) and minimum filled grain per ear head was found in the treatment T_1 (Guava+JW-3211) (29.75). Similar results were also found by Patel *et al.* (2018). Light, nutrients and moisture are the most important limiting component which influences the overall growth and yield of agroforestry system. Significant yield reduction by tree species could be due to their shading effect and below ground completion for resources (Patel *et al.* 2018). Studied the performance of wheat under popular based agroforestry system and study revealed that number of grain per ear

head of wheat was better in sole cropping than under popular based Agroforestry system (Rani *et al.* 2015).

Grain: straw ratio : It can be elucidated from the data depicted in table 8.that the grain & straw yield ratio was non- significant under Agri-Horticulture system and open farming system. This may be due to light, nutrients and moisture are the most important limiting component which influences the overall growth and yield of Agroforestry system.

Harvest index : The maximum harvest index was recorded in the treatment T₈(sole JW-3288) (42.40%) and whereas minimum harvest index was found in the treatment T₃ (Guava +JW-3288) (39.60 %). Similar results were also found by Sarvade *et al.* (2014), Bisht *et al.* (2017), Bijalwan (2012),. Harvest index of different wheat varieties showed the increasing trend under poplar based agroforestry system as compared to open farming system (Kumar, 2015).

Conclusions

It may be concluded that based on different plant parameters, yield and yield attributes, the performance of different wheat varieties under Guava based Agri-Horticulture was lower as compare to open farming system. The yield was found maximum in Guava based Agri-horticulture system as compared to open farming system in all the treatment. But the comparison among different wheat varieties studies that the performance of wheat varieties GW-322 in germination, plant population, plant height, length of ear head, effective tiller, test weight, grain and straw yield, gross and net monetary return was better as compared to other wheat varieties studies. Significantly higher economic returns were observed under Guava based Agri- Horticulture system as compared to open farming system.

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Correlation Study on Morphological and Yield Parameters of Horsegram (*Macrotyloma uniflorum* L.)

Rakesh Kumar*, LT. Roshan Parihar, A.P. Agrawal, D.J. Sharma and Anant Kumar Pandey

Department of Genetics and Plant Breeding B.T.C. College of Agriculture and Research Station, IGKV, Bilaspur, C.G.

*Corresponding Author Email : rakeshtkam120@gmail.com

Abstract

The present study was conducted to determine the correlation coefficient analysis with 64 genotype including four checks Indira kulthi-1, Bilasakulthi, Chhattisgarh kulthi-2 and Chhattisgarh kulthi-3. The genotype was grown in (ABD) design with 6 Block during late Kharif 2020 at BTC College of Agriculture and Research station Bilaspur, (CG). The correlation coefficient analysis for seed yield plot⁻¹ was highly significant and positively correlated with 1000-seed weight (g), pod width (mm), biological yield plot⁻¹ (g), harvest index (%), number of pods plant⁻¹ and pod length (cm) while non-significant positive correlation with days to maturity, branches plant⁻¹. Days to 50% flowering and plant height (cm) had non-significant negative correlation with seed yield plant⁻¹.

Key words : Horsegram, correlation.

Introduction

Horsegram (*Macrotyloma uniflorum* L.) is a legume crop family is leguminosae. It is commonly known as kulthi and hirwa, horsegram generally called as a poor man's crop. Native to south-east Asia and tropical Africa but the center of origin of cultivated species is considered to be south India (Vavilov, 1951 and Zohary, 1970). It is a true diploid having chromosome number ($2n=2x=20$). Horsegram is a self fertilized crop, also known poor man's pulse crop. Horsegram is extremely drought-resistant crop. Moderately warm, dry climatic conditions are suitable for its optimum growth. The temperature range of 25-30°C and relative humidity between 50-80% is optimum, 300 mm of precipitation for its growth. The crop can be grown on wide range of soils from light to heavy soils which are free from alkalinity. The main season for sowing horsegram is late August-November. (DPD, Publication 2017).

In Chhattisgarh, horsegram occupies an area of 40.15 (000 ha), with production of 15.20 (000 Mt), with an average productivity 379 kg/ha. In India, horsegram occupies an area of 460.40 (000 ha), with a production of 181.29 (000 tonnes) with an average national productivity of 394 kg/ha (Anonymous, 2019). Horsegram is an important crop of south India. It is grown in Karnataka, Odisha, Chhattisgarh, Bihar, West Bengal, Jharkhand, Kerala, Tamil Nadu, Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Maharashtra, Uttaranchal, and in India, With regard of area and production, Karnataka is on the first position on all India.

Materials and Methods

The experiment was conducted at Research cum

Instructional Farm at BTC College of Agriculture and Research Station, Bilaspur, a constituent college of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), during late Kharif 2020-21. The experiment was laid out in augmented block design with 6 blocks following 64 genotypes including 4 checks.

Sowing was done in 1st week of September 2020, keeping plant to plant distance of 10 cm and row to row distance of 30 cm with 3 rows and 1 m row length with plot size of 1m². Data was collected on days to 50% flowering, days to maturity, number of branches plant⁻¹, number of pods plant⁻¹, number of seeds pod⁻¹, plant height (cm), pod length (cm), pod width (mm), test weight (g), biological yield plot⁻¹ (g), seed yield plot⁻¹ (g), harvest index. The data were statistically analyzed using analysis of variance technique appropriate for Augmented Block design. Means, range, variance standard deviations and standard error were calculated and correlation was worked out.

Results and Discussion

Days to 50% flowering : Significant differences were found in the mean values for days to 50% flowering among the horsegram genotypes (Table-1). The earliest flowering was noted in the genotype OLD-GPM-58 (40 days), while flowering was found most delayed in the genotype GPM-422 (60 days). Correlation was worked out for the trait with other parameters revealed that days to 50% flowering was positively associated with days to maturity, number of seeds pod⁻¹, pod length (cm), pod width (mm), test weight (g) and harvest index (%) while it had negative association with biological yield plot⁻¹ (g), seed yield plot⁻¹ (g), number of pods plant⁻¹, branches plant⁻¹ and plant

Table-1 : Adjusted mean of twelve quantitative characters in horsegram.

Sl. No.	Genotype	Character	DF	DM	PH (cm)	NBP	NPP	PL (cm)	PW (mm)	NSP	TW (g)	BY (g)	HI (%)	SY (g)
1.	Indira kulthi-1 (Check)		47	95	62.43	4	20	3.85	4.58	4	27.58	260.50	25.79	67.58
2.	Bilasakulthi (Check)		47	96	60.51	3	17	4.05	4.67	4	27.76	286.17	29.87	85.65
3.	Chhattisgarh kulthi-2 (Check)		48	97	47.95	3	14	4.08	4.82	4	27.60	224.67	27.57	62.28
4.	Chhattisgarh kulthi-3 (Check)		49	97	48.06	3	18	3.65	4.32	4	33.15	199.17	28.93	57.76
5.	GPM-66		47	94	51.09	5	21	4.80	4.45	4	27.27	331.38	24.94	83.07
6.	TCR-1617(D)		45	96	47.59	4	19	3.90	4.45	3	31.07	317.38	22.45	72.47
7.	50-32 B-P6		48	100	33.09	3	14	3.60	4.53	4	26.27	269.38	35.81	96.37
8.	GPM-30 (D)		52	102	38.89	3	19	4.00	4.33	5	29.67	285.38	29.73	84.97
9.	BSP-GP-(A)		50	97	37.29	4	17	3.50	4.33	4	30.37	296.38	28.98	86.07
10.	LATA-A-P		48	98	38.59	4	17	4.10	4.57	5	26.37	267.38	35.74	95.47
11.	BS17-1		55	107	40.29	3	14	4.60	4.85	5	28.07	270.38	29.81	81.27
12.	CG-Kulthi-2PHG-9		46	95	42.09	4	19	3.40	4.21	4	26.07	377.38	22.58	85.87
13.	TCR-1590-(D)		46	99	52.09	5	20	4.50	4.79	4	27.17	387.38	22.45	88.07
14.	GPM-93 (D)		50	98	45.09	4	19	4.20	4.75	4	29.17	275.38	24.13	66.87
15.	Amoridas		45	95	37.39	2	12	4.05	4.84	4	26.65	311.63	25.33	79.72
16.	Bastar Kulthi×BHG-1316(D)		49	102	35.29	3	12	4.35	4.80	4	30.35	328.63	25.50	84.52
17.	Chamansing (C)		48	98	41.49	3	16	3.65	4.44	4	31.55	253.63	28.60	72.32
18.	New GPM (C)		46	99	34.09	3	9	3.85	4.68	4	27.35	286.63	31.37	90.92
19.	THG-15		50	97	36.59	3	11	3.65	4.34	5	29.05	266.63	25.60	68.72
20.	GH-2 A		47	101	45.29	3	14	3.65	4.44	4	26.65	314.63	25.72	81.52
21.	TCR-1781 (D)		53	102	35.79	2	13	3.75	4.56	4	30.75	278.63	22.00	62.52
22.	TCR-1746 (D)		44	98	41.09	2	16	3.55	4.50	4	29.35	231.63	32.92	76.62
23.	GPM-58(D)		49	103	49.59	4	23	3.45	4.34	5	27.95	374.63	23.64	89.82
24.	TCR-1493		47	96	52.89	4	18	3.85	4.68	4	28.25	332.63	27.28	91.62
25.	GPM-61		49	98	37.61	4	15	3.98	4.79	5	32.3	239.13	34.41	81.62
26.	GPM-19		47	98	39.81	4	17	4.08	4.91	4	26.1	315.13	31.53	99.02
27.	GPM-32		49	96	54.41	5	26	4.08	4.67	5	26	389.13	26.50	102.72
28.	TCR-1517		51	105	49.61	4	23	4.18	4.86	6	28.2	401.13	25.44	101.52
29.	OLD-GPM-58		40	94	37.01	5	18	3.58	4.62	4	29	308.13	33.96	103.92
30.	TCR-1755(D)		49	97	50.01	4	15	3.38	4.47	4	28.5	239.13	27.65	65.82
31.	Chamansing (D)		47	93	44.91	4	16	3.38	4.61	5	30.3	281.13	29.21	81.62
32.	Motinagoi (B)		49	105	56.51	5	25	3.68	4.64	4	26.9	342.13	25.33	86.32
33.	TCR-1635(D)		49	93	42.81	3	15	3.88	4.43	5	27.8	273.13	29.97	82.12
34.	Motinagoi (A)		54	102	50.41	5	27	3.78	4.25	4	27.4	407.13	26.84	108.32
35.	GPM-54		50	105	51.14	4	18	3.15	4.38	4	29.35	398.13	25.18	100.57
36.	Dholising Netam (D)		47	97	42.04	3	13	3.45	4.69	4	31.75	248.13	38.33	95.47
37.	Deshram		45	92	41.44	3	14	3.55	4.83	4	28.35	203.13	30.27	61.97

Table-1 : Contd.....

Sl. No.	Character	DF	DM	PH (cm)	NBP	NPP	PL (cm)	PW (mm)	NSP	TW (g)	BY (g)	HI (%)	SY (g)
	Genotype												
38.	GPM-49	44	93	34.84	2	13	4.25	4.84	5	30.65	363.13	27.43	99.57
39.	GPM-65	51	101	44.04	3	14	3.75	4.69	5	30.75	246.13	27.53	68.37
40.	GPM-18	47	104	48.44	4	22	3.55	4.75	4	30.35	405.13	22.51	91.771
41.	GH-6(B)	46	98	41.44	2	10	3.55	4.77	4	30.55	288.13	29.14	84.671
42.	TCR-1734(D)	50	102	52.04	3	21	3.25	4.29	4	29.15	303.13	29.04	88.571
43.	GPM-2(D)	45	93	45.54	3	18	3.45	4.53	3	29.95	257.13	36.59	94.471
44.	GPM-26(D)	47	103	49.44	3	15	3.55	4.67	4	28.25	240.13	40.03	96.87
45.	TCR-1503	50	96	47.04	4	21	3.88	4.74	5	30.05	242.13	38.71	94.77
46.	TCR-1503(D)	49	97	43.64	2	18	4.08	4.70	5	28.85	279.13	35.94	101.27
47.	GPM-(C)	45	91	47.24	2	14	3.98	4.84	5	28.45	348.13	29.46	103.27
48.	TCR-1488 (D)	45	98	46.64	3	12	3.98	5.72	3	26.65	242.13	25.61	62.87
49.	BSP-GP-(D)	54	99	52.04	4	16	3.98	4.34	4	27.45	259.13	29.23	76.57
50.	GPM-22(D)	44	89	42.74	4	14	3.48	4.32	3	32.65	243.13	24.10	58.77
51.	GPM-4(D)	50	93	44.24	3	18	3.38	4.12	4	29.85	356.13	26.045	93.97
52.	Dholsing Netam	46	96	36.64	2	15	3.58	4.40	4	31.55	288.13	24.43	70.67
53.	Lata-(A)	43	86	45.14	4	18	3.98	4.74	4	30.35	244.13	35.80	88.57
54.	Punitram (D)	49	91	48.34	4	23	3.88	4.44	3	34.05	381.13	24.61	94.47
55.	GPM-171	54	98	51.11	5	23	3.80	4.64	4	28.67	353.63	27.20	95.64
56.	GPM-48	48	101	50.51	5	21	3.80	4.17	4	28.37	364.63	27.48	99.54
57.	TCR-1593	45	94	49.31	4	20	4.30	4.50	5	30.97	259.63	36.95	97.04
58.	GPM-422	60	107	45.11	4	17	3.70	4.30	4	29.37	209.63	34.83	73.94
59.	Tiharidas	48	94	39.51	3	19	3.80	4.82	3	30.87	318.63	30.07	96.34
60.	HIRAWA-14	52	99	47.01	4	18	3.90	4.64	3	31.97	268.63	33.83	91.14
61.	Mohansing (A)	49	95	40.91	3	20	4.10	4.72	4	26.37	247.63	37.57	93.74
62.	Ishwarlal (A)	50	100	43.11	4	15	3.50	4.54	3	31.67	254.63	28.20	71.74
63.	Karichapra (A)	49	94	45.51	4	17	4.30	4.16	4	27.67	225.63	24.86	55.94
64.	Badekapapali	46	98	40.31	3	17	3.20	4.16	5	31.07	201.63	27.83	56.14
Average		48.25	97.60	44.90	3.51	17.23	3.81	4.57	4.15	29.12	293.16	29.00	84.12
Min		40	86	33.03	2	9	3.15	4.12	3	26	199.17	22	55.94
Max		60	107	62.43	5	27	4.8	5.72	6	34.05	407.13	40.03	108.32
CD values of ABD Design													
Checks		2.885	1.963	4.044	0.777	3.375	0.306	0.149	0.647	1.222	16.24	2.461	7.558
Within the block		7.067	4.809	9.905	1.903	8.267	0.75	0.364	1.585	2.994	39.781	6.028	18.514
Among the block		7.901	5.377	11.075	2.128	9.242	0.839	0.408	1.772	3.347	44.476	6.74	20.699
Checks and entries		6.035	4.106	8.458	1.625	7.059	0.64	0.311	1.354	2.557	33.969	5.147	15.809

DF=Days to 50% flowering, DM=Days to maturity, PH=Plant height, NBP=Number of branches per plant, NPP=Number of pods per plant, PL=Pod length, PW=Pod width, NSP=Number of seeds per pod, TW=Test weight, BY=Biological yield per plot, HI=Harvest index, SY=Seed yield per plot.

Table-2 : Phenotypic correlation co-efficient between different traits in germplasm lines of horsegram.

Traits	Days to 50% Flowering	Days to Maturity	Plant height (cm)	Branches per plant	Number of pods per plant	Pod length (cm)	Pod width (mm)	Number of seeds per pod	Test weight (g)	Biological yield per plot (g)	Harvest index (%)	Seed yield per plot (g)
Days to 50% flowering	1.000	0.590**	-0.027	-0.179	-0.027	0.212	0.130	0.375**	0.243	-0.456**	0.240	-0.217
Days to maturity		1.000	-0.328**	-0.279*	-0.354**	0.303**	0.396**	0.092	0.254*	-0.170	0.190	0.009
Plant height (cm)			1.000	0.570**	0.806**	-0.099	-0.085	0.040	-0.342**	0.007	-0.117	-0.095
No. branches per plant				1.000	0.713**	-0.054	-0.211	0.100	-0.382**	0.177	-0.178	0.002
No. of pods per Plant					1.000	-0.314**	-0.372**	0.144	-0.140	-0.073	-0.231	0.312**
Pod length (cm)						1.000	0.775**	0.378**	-0.235	0.280*	-0.045	0.283**
Pod width (mm)							1.000	0.302**	-0.457**	0.387**	0.144	0.586**
No. of seeds per pod								1.000	-0.068	-0.215	0.036	-0.156
1000-seed weight (g)									1.000	-0.494**	-0.118	0.637**
Biological yield per plot (g)										1.000	-0.525**	0.562**
Harvest index (%)											1.000	0.403**

* & ** Significant at 5% & 1% respectively.

height (cm) (Table II). The results are in conformity with the finding of Birari *et al.* (1987) for days to maturity and number of seeds pod⁻¹.

Days to maturity : Highly significant differences were recorded among the genotypes for days to maturity ranging from 86 days for genotype Lata A to 107 days for genotype BS17-1 and GPM-422 (Table-1). Correlation analysis revealed that days to maturity had significantly positive correlation with pod width (mm), pod length (cm), 1000-seed weight (g) and

Number of pods plant⁻¹, plant height (cm) and branches plant⁻¹ were recorded to be negatively correlated (Table-2). Present results confirm the finding of previous workers Agarwal and Kang (1976) for pod length (cm) and 1000-seed weight (g), Ganeshian (1978) for pod width (mm), Reddy and Saxena (1983) for 1000 seed weight (g), seed yield plot⁻¹ (g).

Plant height (cm) : Indira kulthi-1 was the tallest genotype having maximum plant height of 62.43 cm. The genotype 50-32 B-P6 was dwarfest with only 33.09 cm height. The plant height (cm) exhibited highly positive significant association with number of pods plant⁻¹, branches plant⁻¹. 1000-seed weight (g) exhibited highly negative significant association with plant height (cm). This is in conformity to the finding of Reddy and Saxena (1983), Nehru *et al.* (2000) for number of pods plant⁻¹, Lad *et al.* (1999) for number of seed pod⁻¹, Prakash and Khanure (2000) for number of pods plant⁻¹ and number of branches plant⁻¹.

Branches plant⁻¹ : It varied from 2 (TCR-1746 D) to 5 (TCR-1590-D). The branches plant⁻¹ exhibited highly positive significant association with number of pods plant⁻¹ and positive non-significant association with number of seeds pod⁻¹, biological yield plot⁻¹ (g), seed yield plot⁻¹ (g). 1000-seed weight (g) exhibited highly negative significant association with branches plant⁻¹ and harvest index (%), pod width (mm) pod length (cm) was non-significant negative association. Similar results were reported by Nehru *et al.* (2000), Prakash, Khanure (2000) and Roopdevi *et al.* (2002) for number of pods per plant.

Number of pods plant⁻¹ : The variation in number of pods plant⁻¹ ranged between 9 (NEW GPM C) to 27 (Motinagoi A). The number of pods plant⁻¹ positive association with seed yield plot⁻¹ (g) and number of seeds pod⁻¹. The number of pods plant⁻¹ negative association with pod width (mm), pod length (cm), test weight (g), biological yield plot⁻¹ (g) and harvest index (%). The result obtained in the present studies are supported by the finding of Patil (1981) for number of pods plant⁻¹, Prabha et al. (2010) for Seed yield plot⁻¹ (g), Reddy and Saxena (1983) for number of pods plant⁻¹.

Pod length (cm)

The variation in plant spread ranged between 4.8 (GPM -66) to 3.15 cm (GPM-54). The pod length (cm) exhibited highly positive significant association with pod width (mm), number of seeds pod⁻¹, seed yield plot⁻¹ (g), and biological yield plot⁻¹ (g). Pod length was negative association with test weight (g) and harvest index (%). Similar results were reported by prabha et al. (2010) for pod length (cm) and seed yield plot⁻¹ (g), Lad et al. (1999) for pod length (cm) and pods plant⁻¹.

Pod width (mm) : The genotype GPM-19 showed the highest plant spread (4.91 mm) and lowest 4.12 mm (GPM-4 D) was observed. The pod width (mm) exhibited highly positive significant association with seed yield plot⁻¹ (g), biological yield plot⁻¹ (g) and number of seeds pod⁻¹. 1000-seed weight (g) exhibited highly negative significant association with pod width. Corresponding results were found by Ganeshian (1978) for pod width (mm), Prabha et al. (2010) for seed yield plot⁻¹ (g), Raina et al. (2007) for biological yield plot⁻¹ (g).

Number of seeds pod⁻¹ : The strains TCR-1517 (6) was maximum while minimum number of seeds pod⁻¹ were recorded in Tiharidas (3). The number of seeds pod⁻¹ is shown non-significant positive association with harvest index and non significant negative association with biological yield plot⁻¹ (g), seed yield plot⁻¹ and 1000-seed weight. Similar results were reported by Roopdeviet al. (2002) and Rama et al. (2007) for number of seeds pod⁻¹.

1000-seed weight (g) : The variation in 1000 seeds weight ranged between 26 g (GPM-32) to 34.05 g (Punitram-D). The 1000-seed weight (g) exhibited highly positive significant association with seed yield plot⁻¹ (g) and negative significant association with biological yield plot⁻¹ (g) and harvest index (%). The result obtained in the present studies are supported by the finding of Prabha et al. (2010) for seed yield plot⁻¹ (g), Raina et al. (2007) for biological yield plot⁻¹ (g), Ghorpade (1985) for test weight (%), Reddy and Saxena (1983) for 1000 seed weight (g).

Biological yield plot⁻¹ (g) : The biological yield plot⁻¹ varied from 199.17 g (Chhattisgarh kulthi-3) to 407.13 g (Motinagoi-A). The biological yield plot⁻¹ (g) exhibited highly positive significant association with seed yield plot⁻¹

(g) and highly negative significant association with harvest index (%). Similar results were reported by Raina et al. (2007) and Rama et al. (2007) for biological yield plot⁻¹ (g), Prabha et al. (2010) and Sunil et al. (2014) for yield plot⁻¹ (g).

Harvest index (%) : The minimum and maximum harvest index was found in the accessions TCR-1781 (D) (22.00g) to GPM-26 (D) (40.03g). The harvest index (%) exhibited highly positive significant association with seed yield plot⁻¹ (g). This is in conformity to the finding of Prabha et al. (2010) and Sunil et al. (2014) for seed yield plot⁻¹ (g).

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Utilizing Underutilized Fruit Crops in Subtropical Climates : A Path to Biodiversity, Resilience and Sustainability

Shubham Jain¹, Manjunath Rathod², Deepak. S. Kore³, Lalit Dhurve⁴, Rimpika⁵, Rohit Sharma⁶, Shivani⁷ and Anushi⁸

¹Department of Fruit Science, College of Horticulture and Forestry, ANDUAT, Kumarganj, Ayodhya, U.P.

²Department of Post Harvest Technology, University of Horticultural Sciences, Bagalkot, Karnataka

³Department of Fruit Science, College of Horticulture Bengaluru, University of Horticultural Sciences, Bagalkot, Karnataka

⁴Defence Institute of Bio-Energy Research, DRDO, Haldwani, Uttarakhand

⁵Department of Fruit Science College of Horticulture and Forestry Thunag Mandi, H.P.

⁶Department of Fruit Science, YSP UH&F Nauni, Solan, H.P.

⁷Department of Horticulture, College of Agriculture, CCSHAU, Hisar, Haryana

⁸Department of Fruit Science, CSAUAT, Kanpur, U.P.

*Corresponding Author Email : anushiyadav25@gmail.com

Abstract

Subtropical climates offer unique opportunities for the cultivation of underutilized fruit crops, which are often overlooked but possess great potential for enhancing biodiversity, promoting sustainability, and improving food security. Subtropical climates, characterized by their moderate to warm temperatures, diverse landscapes, and distinct precipitation patterns, are ideal for cultivating a wide range of fruit crops. In these regions, a plethora of underutilized fruit species thrive, offering a valuable alternative to more commonly grown fruits. Examples of underutilized fruit crops that have found a place in subtropical climates include the loquat, carambola, Barbados cherry, kiwifruit, jackfruit, persimmon etc. The introduction of these underutilized fruits into subtropical climates not only expands the diversity of available fruits but also fosters resilience in agriculture. These crops are often hardier, requiring fewer synthetic inputs, and can contribute to sustainable and organic farming practices. Their cultivation aids in preserving biodiversity and ensures a steady food supply in regions susceptible to climate fluctuations. The utilization of underutilized fruit crops in subtropical climates holds promise for enhancing agricultural diversity, resilience, and sustainability. These fruits provide unique flavors, nutritional benefits, and adaptability to local conditions. By recognizing and promoting underutilized crops, we can harness their potential to address the challenges of food security and promote sustainable, resilient agriculture in subtropical regions.

Key words : underutilized, diversity, moderate climate, food security, valuable

Introduction

The utilization of underutilized fruit crops in subtropical climates represents an exciting opportunity to diversify agricultural practices, enhance food security, and promote sustainable farming. Subtropical regions are often characterized by a diverse range of climates and conditions, making them suitable for the cultivation of a wide variety of fruit crops. Many of these regions have unique climatic advantages that allow for the growth of less common or underutilized fruit species that may not thrive in other areas. Introducing underutilized fruit crops to subtropical climates not only contributes to the preservation of biodiversity but also offers a wealth of economic and nutritional benefits. These lesser-known fruits often possess unique flavors, nutritional profiles, and adaptability to the specific climatic challenges of subtropical regions. By integrating these crops into local farming systems, communities can access a broader range of dietary options, thereby improving nutrition and

reducing their reliance on a limited selection of common fruits. Moreover, the cultivation of underutilized fruit crops can also have positive environmental impacts. Many of these crops are well-suited to sustainable and organic farming practices. They can contribute to soil health, reduce the need for chemical inputs, and promote agroecological approaches that benefit both the environment and local farmers [7, 9, 20].

Loquat

The subtropical evergreen fruit tree known as locust (*Eriobotrya japonica* L.) has been farmed for more than 2,000 years and is grown for commercial purposes in more than 20 nations. The loquat is valued highly on the market and regarded as a functional fruit due to its unique nutritional compounds, which include α -ionone, phenylacetaldehyde, hexanal, (E)-2-hexenal, and hexanoic acid [1]. A loquat fruit of superior quality has low flesh firmness, an acidity range of 0.3–0.6%, and a total soluble solids content of more than 12%. High

concentrations of pharmacologically active ingredients like kaempferol, ursolic acid, oleanolic acid, tartaric acid, and quercetin are found in loquat fruit and leaves, along with ascorbic acid, calcium, iron, manganese, and potassium. Additionally, it has a number of pharmacological qualities, including anti-inflammatory, antitumor, antioxidant, antimutagenic, and antidiabetic effects. The fruit has a limited shelf life and is very vulnerable to a number of physiological conditions as well as postharvest decay. It needs to be stored properly and receive physical, chemical, and biological post-harvest treatments [2]. The three most significant cultivars are Golden Nugget, Tanaka, and Algerie. In the various nations where the species is grown, there are also cultivars that are chosen [3]. Loquat marketing should maintain a good distribution while considering the fruit quality of the cultivar. It seems paradoxical that instances of fruit rejection have been documented, accompanied by unfavourable remarks about their flavour, and that these instances stem from inadequate fruit ripeness conditions at the point of sale to the customer [4]. In terms of rootstocks, loquat seedlings, which are derived from seeds, are used 90–95% of the time in the three productive areas. After this is grafted with the selected variety, three years later production starts. This combination results in a fairly large, lime-tolerant tree with an extremely long productive season. In any case, because of the type of pruning that is done, a tree's size no longer poses as many handling challenges [5]. In regions where citrus was grown, the species spread easily; nevertheless, loquat has more stringent environmental requirements than citrus. The winter months are when flowers and fruits develop, indicating an average temperature of more than 15°C. The tree is rustic, but wind and frost can harm the fruits. Open flowers and small fruits are harmed by temperatures below –2°C, and recently set fruits can be harmed by temperatures as low as –1°C [6].



Carambola

Due to its unusual shape, *Averrhoa carambola* (Oxalidaceae), formerly known as “kamrakh,” is also referred to as “star fruit” in general. It is widely used in Ayurveda; preparations made from its fruit and leaves are used to treat skin conditions, worm infestations, diarrhoea, vomiting, haemorrhoids, intermittent fever, excessive perspiration, and general debility [10]. It also helps to

pacify impaired kapha and pitta. Additionally, it is utilised in traditional medicine for a variety of illnesses in nations like Brazil, China, India, and the Philippines [11]. When the fruits are young and unripe, they are green; as they get older and riper, they become yellow or orange [12]. The fruits are juicy and oblong in shape, measuring up to 9 cm in width, 5 to 6 angles longitudinally, and 5 to 15 cm in length [13]. The fruits are crisp and crunchy, and their cross-sectional shape resembles a star, hence the name. Saponins, alkaloids, flavonoids, and tannins were detected in the fruit of the cambola plant based on preliminary phytochemical analysis [14]. Proanthocyanidins, epicatechin, gallic acid in gallotannin form, and L-ascorbic acid were also discovered to be present in the fruit. The four main plant fatty acids—palmitic, oleic, linoleic, and linolenic acid—as well as the major sterols—sitosterol, campesterol, lupeol, and isofucosterol—were found in carambola fruits, according to reports [15]. Ripe fruits or their juice have various medicinal uses in India, including antipyretic, laxative, appetite stimulant, sialogogue, astringent, and antiscorbutic effects [16]. Though star fruit has been cultivated for hundreds of years in Malaysia and Southeast Asia, it is thought to have originated in Ceylon and the Moluccas [17]. The antibacterial activity of *Averrhoa carambola* stem extracts was demonstrated by their inhibition of *Staphylococcus aureus* and *Klebsiella* sp., as demonstrated by their respective minimal bactericidal concentrations (MBC) of 15.62 mg/ml and 125 mg/ml [18].



Barbados cherry

The Malpighiaceae family includes the Barbados cherry (*Malpighia glabra* L.) [22]. It is a small fruit-bearing tree or shrub that grows in tropical and subtropical regions. While young plants die even in brief exposure to temperatures below 1.11°C, mature trees can withstand brief exposure to 2.22°C [23]. It can withstand protracted droughts and has a medium to low rainfall requirement, but it won't produce anything until there is rainfall. With 1000–4000 mg of ascorbic acid per 100 g of edible portion, fruits are the richest known sources of this vitamin [24]. Fruit-derived vitamin C is being marketed in a variety of forms, including juice, syrup, pills, powder, and capsules. Fruit-derived vitamin C is being marketed in a variety of forms, including juice, syrup, pills, powder, and capsules

[25]. The evergreen bushy shrub or small tree known as the Barbados cherry can grow up to 6 meters tall. It is made up of tiny, hairy branches that are either drooping or spreading somewhat erect [26]. Fruits can be produced in pairs or threes in the leaf axils. Fruits have three lobes and are oblate to round. Fruit has a diameter of 1-3 cm and a weight of 3-5 g [27]. The fruit is similar to a real cherry, but it is a three-carpellate drupe with a glossy, thin peel that is bright red and orange in colour. Fruit has a lot of juice [28]. The pulp has an acidic to slightly acidic flavour and is soft. From floral anthesis to fruit maturity, it takes about three weeks [29]. Approximately forty-five species of small trees or shrubs belong to the genus *Malpighia*, which is one of the 55 genera in the family *Malpighiaceae* [30]. Compared to other fruit crops, Barbados cherries are produced very infrequently worldwide. Enhancing its cultivation and production potential will require coordinated efforts involving all stakeholders in the development of participatory technologies and crop improvement [31]. It is necessary to spread awareness of the crops in their appropriate locations across the globe [32].



Kiwifruit

Grown all over the world, kiwifruit (*Actinidia* spp.) is a relatively new but significant crop in terms of economic value. The creation of new cultivars with unique consumer attributes, such as flavour, appearance, nutritious components, and convenience, is what propels commercial success [33]. It is thought that the kiwifruit (*Actinidia deliciosa* A. Chev.), the most remarkable fruit of the previous century, originated in China. It has since replaced the old English names “Chinese gooseberry,” “China’s miracle fruit,” and “Horticultural wonder of New Zealand” [34]. The kiwifruit, a deciduous dioecious vine that is a member of the *Actinidiaceae* family, has a hairy, rusty-brown fruit. Fruit pulp has a light green colour and a decorative pattern of lighter-colored rays radiating from the centre [35]. Many small, soft, dark seeds are embedded in the pulp. It needs a strong structural support because it is a perennial climber or scrambling vine. Actinidin, an enzyme found in kiwifruit that dissolves proteins, is known to cause allergies in certain people.

A raw kiwifruit’s actinidin quickly breaks down milk

proteins, which is why it should not be used in desserts containing milk or any dairy products. There are a lot of seeds in the pulp that are rich in omega-3 fatty acids and vitamin E, which act as natural blood thinners [36]. *Actinidia* Lindl. is a large genus of climbing plants that primarily originates from southern China and contains between 50 and 70 species [37]. Kiwifruit is propagated using a variety of stem cuttings, including hardwood, semi-hardwood, and softwood stem cuttings. Hardwood and semi-hardwood cuttings are both commonly favoured due to their ease of handling and superior rooting. The optimal cutting has a thickness of between 0.5 and 1.0 cm, comparatively short internodes measuring between 10 and 15 cm, and at least 4–5 buds [38]. Commercial kiwifruit propagation involves grafting and budding on a rootstock of seedlings. This is a widely used, commercial propagation technique. When the stem diameter is between 8 and 10 mm at the end of the first growing season, the seedling is typically ready for grafting and budding [39]. Since kiwifruit is a deciduous vine, it can tolerate a wider range of climates. However, the crop needs particular climatic conditions in order to produce fruit of high quality [40]. In order to break the dormant state of buds during the winter, 700–800 chilling hours below 7°C are needed. Frost in the spring and autumn can harm the crop. Leaves get scorched in the summer due to high temperatures above 35°C, high insulation, and low humidity [41]. The training of kiwifruit vines is a crucial process that needs ongoing care. A vine can be trained using a variety of structures, but T-bar trellis and pergola systems are the most widely used, with the pergola system being a more costly structure [42].



Jackfruit

The jackfruit tree (*Artocarpus heterophyllus* Lam), commonly referred to as “Jaca” in Brazil, is thought to have originated in India. It grows in African nations such as Uganda, Kenya, and Tanzania [43]. The tree is medium-sized, reaching heights of 8 to 25 meters, and it bears one of the largest edible fruits in the world, weighing up to 80 kg. Depending on the variety, cultural practices, and environmental factors, the tree can yield 50–80 tonnes of fruit per hectare annually, which is higher than any other tree species [44]. The tree adapts well to a variety of conditions, even marginal soils and harsh

climates. Jackfruit bulbs are eaten in a variety of ways when they are young and fully grown. You can either cook the seeds whole or grind them into flour for baking [45]. The tree is renowned for its robust and sturdy wood. Additionally, a dye that can be used to colour clothing is produced by the wood chips. Goats, pigs, and cattle can be fed the leftover fruit and leaves [46]. The potential uses of jackfruit's inedible parts for pectin extraction, briquette and biochar production, and biogas generation have also been investigated. Compared to other tropical fruits like avocado, pineapple, mango, watermelon, and banana, mature jackfruit flesh and seeds have higher levels of protein, calcium, iron, and thiamine [47]. Significant amounts of B vitamins, vitamin C, potassium, calcium, iron, proteins, and carbohydrates are present in the fruit. extremely popular fruit tree that has the potential to reduce food insecurity, particularly in developing nations because of its extreme resilience and low maintenance needs. By utilizing the wide range of products this fruit tree offers, consumers can take advantage of its benefits [48]. One of the primary uses of jackfruit is its role as a meat substitute for vegetarians and vegans. The flesh of unripe jackfruit has a fibrous, meat-like texture, making it an excellent ingredient for plant-based dishes, particularly as a replacement for pulled pork or shredded chicken [49]. Jackfruit is also known for its sustainability. The trees are hardy and require minimal care, and the fruit itself is often considered a food security crop. The trees produce a high yield of fruit, and the seeds can be roasted and consumed, reducing waste and increasing the overall utility of the plant [50]. As awareness of its benefits grows, jackfruit's presence in global markets continues to expand, making it a valuable addition to our efforts to promote sustainable and healthy food choices [51].



Persimmon

The persimmon, or *Diospyros kaki*, 1782, is an ancient fruit tree belonging to the Ebenaceae family and one of the earliest that humans cultivated. It originated in China and later travelled to the Far East, passing through Korea and Japan, where it is also referred to as the Loto of Japan [54]. The fruit of *Diospyros kaki* is a bright orange berry that is harvested between October and November. The trees can grow up to 15 meters tall, have thick foliage,

wood-leaved, gray-dark, wrinkled bark, and large, enlarged oval leaves [55]. The vanilla species has a more compact pulp, but the most common variety of khaki has a very creamy pulp. The fibrous, fleshy, tropical persimmon has recently attracted a lot of attention due to its potential health advantages. Numerous diseases can be prevented in large part by the presence of bioactive molecules like proanthocyanidine, tannins, and flavonoids, as well as antioxidant substances like polyphenols, carotenoids, and tocopherols [56]. Fruit naturally contains carotenoids, fat-soluble substances that give fruits their characteristic orange, red, yellow, and purple hues. Due to their inherent ability to impart colour, fruits can be used as quality indicators since colour is the primary qualitative parameter that indicates the fruit's freshness [57].

Additionally, they contain a wealth of bioactive properties that can help prevent chronic illnesses like cancer, atherosclerosis, and cardiovascular disease. They can also strengthen the immune system and shield the epithelium from UV rays, protecting the health of the eyes and cornea [58]. Extracts from kaki leaves, which are added to tea in some countries, are also rich in compounds that help prevent atherosclerosis, hypertension, oxidative stress, and diabetes mellitus and its complications [59]. Because of the anti-inflammatory qualities of tannic acid, an extract made from the stems of leaves of a wild variety of *Diospyros kaki* is used as a medication to treat nocturnal enuresis, vomiting, and hiccups [60].

One popular way to add value to persimmons is by processing them into jams, jellies, and preserves. These preserves capture the natural sweetness of persimmons and create delightful spreads that can be enjoyed on bread, crackers, or as accompaniments to various dishes [61]. Dried persimmons are another valuable product. The natural sugars in persimmons caramelize during the drying process, resulting in a sweet and chewy snack [62]. Dried persimmons are not only delicious but also have a longer shelf life, making them an ideal option for preserving the fruit. Moreover, the extracted juice from persimmons can be processed into beverages like nectar, juice blends, or even alcoholic drinks. This not only diversifies the product range but also allows for creative combinations with other fruits and flavors [63].



Conclusions

In conclusion, the introduction and utilization of underutilized fruit crops in subtropical climates hold great promise for enhancing food diversity, sustainability, and economic opportunities. By harnessing the potential of these fruits, we can foster agricultural resilience, promote local food cultures, and address the challenges of climate change and food security in a rapidly changing world.

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Effect of Organic Manures on Growth, Yield and Quality of Vegetable Crops — A Review

Sumit Kumar^{1*}, Ajay Sharma², Rahul³ and Rahul⁴

¹Department of Vegetable Science, CCS Haryana Agricultural University, Hisar

²Department of Mathematics and Statistics, CCS Haryana Agricultural University, Hisar

³Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar

⁴CCS Haryana Agricultural University, Hisar

*Email : sumitbidlan2@gmail.com

Abstract

By improving soil fertility and encouraging healthy plant growth, organic manures play an essential role in sustainable agriculture. The use of organic manures is becoming more significant as synthetic fertilisers raise environmental and health issues. Organic manures, generated from both plant and animal sources, provide a balanced nutritional composition that enhances soil structure, water-holding capacity, and microbial activity. They release nutrients gradually, lowering the possibility of nutrient leaching and ensuring that crops have access to nutrients for a longer period of time. Additionally, organic manures encourage the growth of advantageous soil microbes that help with nutrient cycling and disease prevention. Additionally, they improve soil ability to exchange cations, which helps retain and exchange nutrients between soil and plants. This encourages the sustainability and long-term soil fertility of agricultural systems. Due to better nutrient availability and soil structure, there is an increase in vegetative growth, flower initiation, and fruit setting. Additionally, organic manures can increase a crop resistance to abiotic stresses like drought and extremely high temperatures, resulting in steady yields even under difficult circumstances.

Key words : Plant growth, organic manures, soil fertility.

Introduction

Vegetables help to ensure that people have access to healthy food. There has been a remarkable transformation in the production and accessibility of vegetables because of the sector focused attention (Dibsdall *et al.* 2003). With a contribution of roughly 14.45% to global production, India is currently the second-largest producer of vegetables (90.8 million tonnes) after China. Agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, are promoted and enhanced by the organic production management approach known as organic agriculture (Raut *et al.* 2018). The use of synthetic pesticides, conventional fertilisers, chemicals and genetically engineered plants and animals are prohibited in organic agriculture. (Roitner-Schobesberger *et al.*, 2008). Organic fertilizers can be made from fresh/ dried plant/ plant material, animal manure etc (Nxumalo *et al.*, 2019). Vegetable demand is rising as a result of urbanisation, globalisation, and rising income levels. Because of the population increased and concern for their health and the environment, the issue of food quality is receiving more attention. Vegetable cultivation has a high labour intensity, which offers considerable potential to provide jobs for small and marginal farmers. Additionally, these organic sources aid in reducing the prevalence of secondary and micronutrient deficiencies (Chhonkar, 2003). Organic farming is

regarded as a trustworthy method for raising vegetables with supply of nutrients, particularly micronutrients, lowering nitrate levels and pesticide exposure through food (Rempelos *et al.* 2021). For the growth, yield and quality of horticultural crop production, organic manures provides both macro and micronutrients in enough amount. Due to the nutritional support for crops and preservation of the physical and chemical features of the soil, organic manures have also become sufficiently important in crop production practises. (kota *et al.*, 2022). Vermicompost is a nutritive “organic fertilizer” rich in NPK and micronutrients such as Calcium (Ca), Magnesium (Mg), Zinc (Zn) and Manganese (Mn) (Jamir *et al.* 2017). It also contains enzymes like amylase, lipase, cellulase, and chitinase that continue to break down organic materials in the soil long after they have been voided (to release the nutrients and make it accessible to the plant roots). By encouraging the growth of bacterial biomass, natural fertilisers encourage secondary production. (Reganold and Wachter, 2016). Organic farming is a measure to prevent pests from entering pesticides and synthetic fertilizers and maintains a well needed natural balance (Ramakrishnan *et al.*, 2021). The physical, chemical and biological characteristics of soil and crop growth are the main factors that govern how organic manures functions as an inducer in nature. Combining bio-fertilizers with organic manures improves plant growth by increasing root biomass; total root surface promotes higher nutrient

Different type of organic manures and their compositions (Kumar and Rani 2023).

Manures	N%	P ₂ O ₅ %	K ₂ O%
FYM	0.5	0.25	0.5
Vermicompost	3.0	1.5	1.0
Sheep and goat manure	3.0	1.0	2.0
Poultry manure	3.03	2.63	1.4

Bulky organic manures

Manures	N%	P ₂ O ₅ %	K ₂ O%
Cotton seed cake	3.9	1.8	1.6
Sesamum cake	6.2	2.0	1.2
Ground nut cake	7.3	1.5	1.3
Coconut cake	3.0	1.9	1.8
Castor cake	4.3	1.8	1.3
Blood meal	10-12	1-2	1.0

Concentrated organic manures

absorption and increases output by lowering consumption of natural resources. By increasing the biomass and productivity of a variety of crops, organic fertilisers have shown their potential (Agamy *et al.* 2013).

Organic manures : Manures are animal and plant wastes that are used as plant nutrient sources. As they break down, they release nutrients. Different types of manure are used to increase the soil fertility and productivity. Two types of manure *i.e.*, bulky organic manures and concentrated organic manures are widely used (agritech.tnau.ac.in).

Effect of organic sources/manures on the growth attributes of vegetable crops : When nutrients are readily available to plants, cell growth and division is supported which promotes plant growth. Due to diverse organic manures/fertilizers management practices, growth parameters such as plant height, fresh weight of root and shoot, dry weight of root significantly increased. Organically grown foods are perceived as better quality, healthier and more nutritious than conventional cultivation (Warman and Havard, 1997). On the other hand, the relatively slow mineralization of the composts and other organic fertilizers limits the effective nitrogen utilization (Hartz *et al.*, 2000). Silva *et al.*, (2006) investigated the effect of earthworm humus and cattle manure on growth of radish (*Raphanus sativus*). According to the findings, total dry matter of plants continuously increased from 9 to 30 DAS with the addition of humus (30 and 45 t ha⁻¹) and manure (45 t ha⁻¹). Both root volume and diameter increased when treatment, cattle manure and earthworm humus was applied. Mulani *et al.*, (2007) found in that the average vine length (5.38 m), fruit weight (84.80 g), fruit length (26.94 cm), fruit girth (3.48 cm), numbers of fruits per vine (63.11) were improved by applying 25% nitrogen through neem cake and 75% nitrogen through poultry manure. Singh *et al.*, (2007) examined the effect of supplementing chemical fertilisers with organic and biofertilizers such as FYM (20 t ha⁻¹), vermicompost (4 t ha⁻¹), green manure (5 t ha⁻¹) and *Azotobacter* and PSB (5 kg ha⁻¹) with half recommended doses of NPK on growth and yield of carrot and reported that the plant height

(61.39 cm), leaf length (45 cm), fresh weight of leaves (25.92 g), leaves per plant, root length (16.37 cm) and root diameter (2.85 cm) were increased with application of half dose of NPK + green leaf manure + *azotobacter* + PSB. According to research findings of Jayaraman *et al.*, (2008), treatment that received a combined application of FYM at 25 t ha⁻¹) along with 100% of the recommended dose of inorganic fertiliser (60:50:40 Kg NPK ha⁻¹) and vermicompost at 5 t ha⁻¹ recorded the maximum vine length (8.96 cm), whereas number of laterals (9.22), internode length (21.63 cm) and number of leaves (91.40) were more with the application of FYM at 25 t ha⁻¹ combined with 75% recommended dose of inorganic fertiliser @ 60:50:40 Kg NPK ha⁻¹. Kameswari and Narayanamma (2011) examined the effect of integrated nutrient management on ridge gourd and found that the application of 75% vermicompost with 25% recommended dose of fertiliser significantly recorded maximum vine length (9.23 cm), 50% flowering in 47.67 days after sowing and the first early picking was recorded at 66.33 days after sowing which was at par with the treatment 75% FYM + 25% RDF. However, 25% poultry manure and 75% of the recommended fertiliser dose resulted in the shortest vine length (6.37cm). Ali *et al.*, (2016) examines three different organic manures (control, cow dung and vermicompost) and three different neem products (control, neem leaf powder and neem oil cake) and their findings showed that the use of neem products and organic manures had a significant impact on the factors that contributed to growth and production. Chatterjee *et al.*, (2016) concluded in their investigation that among the application of organic manure, vermicompost and earthworm biomass, application of vermicompost treatment recorded highest root length (19.26 cm), root volume (73 cm³), root weight (68.43 g) of carrot. Nayak *et al.*, (2016) recorded that the application of lime, biofertilizer and vermicompost at 5 t ha⁻¹ + RDF (100%) recorded maximum vine length (234.27 cm), vine girth (3.72 cm) and number of branches per plant (12.45) which was at par with the treatment of lime and vermicompost @ 5 t ha⁻¹ + RDF (75%). Ahmad *et al.*, (2017) studied the effect of organic fertilizers on growth of coriander and reported that plants under poultry manure

treatment recorded the highest number of leaves (6.24), leaf area (14.95 cm²) and shortest number of days needed to harvest (40.75 days). Singh *et al.*, (2017) concluded that application of 1.75 kg/ha PSB, 1.5 t/ha vermicompost, 12.5:10:12.5 kg/ha RDF and 3 t/ha FYM significantly increase the plant height (53.05 cm), leaves length (42.55 cm), root length (15.25 cm) as compared to control. Kurrey *et al.*, (2018) studied *Azotobacter* as a nitrogen fixation bacterium and its affect shown on soil and plant growth, yield, bio-chemical properties of soil. The results show significant increase in germination percent (85%), plant height (57.3 cm), number of leaves (11.4), bulb weight (120.7 g), maximum diameter of bulb (6.2 cm), bulb dry weight (23.9 g), plant dry weight (28.2 g) and harvest index (69.35%) and in onion when treated with the dose of *azotobacter* 1.66 g m⁻² as compare to control. Kumawat *et al.*, (2018) concluded in her studies that application of organic manure, *i.e.*, vermicompost and poultry manure recoded maximum fresh weight of plant, top root ratio, average weight of root per plant, diameter of root, length of edible root, core diameter, percentage of core to flesh, weight of core, weight of flesh and root yield in carrot. Yadav *et al.*, (2022) concluded in their study that carrot growth attributes *i.e.*, plant height (54.13 cm), root diameter (3.18 cm) and yield (35776 kg ha⁻¹) increased when vermicompost was applied @ 20 t ha⁻¹ in comparison to the control. Tiwari and Prasad (2022) investigated an experiment to evaluate the effect of organic manures on growth, yield and quality of beetroot (*Beta vulgaris* L.) cv. Lali. According to the results, application of poultry manure (100%) led to higher plant height at 25 DAS (20.18 cm), 50 DAS (32.10 cm) and at harvest (36.52 cm) when compared to other organic manures treatments. Kota *et al.*, (2022) results revealed that maximum plant height (110.93 cm), days for first flowering (33.13 days), 50% flowering (38.67 days), number of pods per plant (20.69 pods), pod length (12.93 cm), pod weight (9.17 g), pod width (1.69 g) of okra were recorded with the application of vermicompost + poultry manure (50%) + goat manure (50%). Patel *et al.*, (2022) carried out a study on the effect of organic manures and biofertilizers on growth, production and quality of potato (*Solanum tuberosum* L.) and concluded that RDF (135:60:90 kg/ha) + (2.5 t/ha) vermicompost + *Azotobacter* + PSB has a significant impact on morphological trait of potato, *i.e.*, height (48 cm), fresh wight of shoot (188 g), whereas the lowest were recorded under application of (90:40:60 kg/ha) RDF + (6.25 t/ha) FYM + (2.5 t/ha) vermicompost. Rohith *et al.*, (2022) conducted study on chilli and concluded in their study that the application of Neem cake @ 250 kg ha⁻¹ along with the recommended fertiliser doses of 100:50:50 kg NPK ha⁻¹ produced the highest average plant height (86.28 cm) and

average fruit weight (4.36 g) whereas, the maximum average number of fruits/plant (113.08) was obtained in treatment where vermicompost applied @ 1 t/ha. Yadav *et al.*, (2022) studied the effect of vermicompost and biochar on growth, yield and economics of chilli. cv Kashi Anmol-2. This study concluded that the treatment with 100 kg N + 80 kg P + 100 kg K+ 1 t ha⁻¹ vermicompost + 80 kg ha⁻¹ biochar was recorded significant treatment for the growth attributes *i.e.*, height (62.83 cm), number of leaves per plant (96.24), number of flowers per plant (294) as compared to other treatments.

Effect of organic sources on the yield attributes of vegetable crops :

Due to favourable soil conditions, increased photosynthesis rates and adequate availability of major and micronutrients, improved yield attributes from organic manures may also result in increased vegetative growth and yield by supplying more sites for the translocation of photosynthates. Kannan *et al.* (2006) reported that the application of nitrogen through different organic sources significantly influenced the tomato growth and yield. Among the different organic sources, substitution of 100 per cent N through FYM recorded higher plant height, number of branches plant⁻¹ and yield comparable with that of 100 per cent RDN through urea. Mulani *et al.*, (2007) investigated the effects of organic manures and biofertilizers on the yield of bitter gourd and reported that bitter gourd fruit yield (263.33 kg/ha) was significantly increased by applying 25% nitrogen through neem cake and 75% nitrogen through poultry manure as compared to control. Singh *et al.*, (2007) studied the effects of supplementing chemical fertilisers with organic and biofertilizers such as FYM (20 t ha⁻¹), vermicompost (4 t ha⁻¹), green manure (5 t ha⁻¹), *Azotobacter* + PSB (5 kg ha⁻¹) and half recommended doses of NPK on growth and yield of carrot. Out of these treatments, the application of (40:30:30 kg/ha) NPK + green leaf manure + *Azotobacter* + PSB, recorded the highest yield (242.85 q ha⁻¹) of carrot as compare to other treatments. Chatterjee *et al.*, (2016) found in their study that among the application of organic manure, vermicompost and earthworm biomass, vermicompost recorded highest yield (16.07 Mg ha⁻¹) of carrot. Singh *et al.*, (2017) was concluded that application of 25% PSB, 25% vermicompost, 25% RDF and 25% FYM to carrot significantly increased the yield of carrot (280.33 q ha⁻¹). Bijjula and Somasundram (2019) conducted a field study to know the effect of organic manures on yield and quality of onion and concluded that application of FYM @ 25 t ha⁻¹ along with panchagavya @ 3% had the significant increases in bulb yield (15.9 t ha⁻¹), bulb weight per clump (70 g), followed by the recommended dose of NPK and TNAU pulse wonder @ 5 kg ha⁻¹. Chaudhary *et al.*, (2019) studied the growth and yield of bottle gourd as affected by both complementary and sole applications of organic and

Yield of different vegetable under organic farming (Singh et al. 2017).

	Cabbage	Tomato	Okra	Cowpea	Pea
Conventional yield (t/ha)	41.00	37.5	9.26	8.00	7.3
Organic farming					
First year yield (t/ha)	25.42	23.63	5.27	4.64	4.964
Second year	29.54	27.75	6.57	5.76	6.278
Third year	34.75	33	8.23	7.04	7.154
Fourth year	38.83	36.84	9.16	7.84	

inorganic fertilisers. Results showed that application of (60: 30 :20 kg NPK) NPK through inorganic fertilizer + 50% N through FYM recorded 238.9 q ha⁻¹ fruit yield. Tiwari and Prasad (2022) conducted an experiment to evaluate the effect of organic manures on growth, yield and quality of beetroot (*Beta vulgaris* L.) cv. Lali and resulted that application of poultry manure (100%) led to higher root yield (18.85 t ha⁻¹) as compared to other organic manures used under study. Kota *et al.*, (2022) reported that maximum fruit yield per plant (189.83 g), yield per plot (3.03 kg) and yield per hectare (10.68 t ha⁻¹) were recorded with the application of vermicompost + poultry manure (50%) + goat manure (50%) in okra. Rohith *et al.*, (2022) was found that the highest fruit yield (465.73 g plant⁻¹ and 172.46 q ha⁻¹) was recorded with the application vermicompost applied @ 1 tonne ha⁻¹ with neem cake applied @ 250 kg ha⁻¹ respectively in chilli. Patel *et al.*, (2022) carried out a study on the effect of organic manures and biofertilizers on growth, production and quality of potato (*Solanum tuberosum* L.) and concluded that 75% RDF + 25% vermicompost + Azotobacter + PSB has a significant impact on tuber yield of potato (383.20 q ha⁻¹) whereas the lowest yield was recorded in application of 50% RDF + 25% FYM + 25% vermicompost.

Effect of organic sources on the quality attributes of vegetable crops : With the application of various organic manures, especially FYM and vermicompost, quality attributes improve because these manures contain significant amounts of micronutrients, particularly ferrous (Khachi *et al.* 2015). It is a crucial component of the various respiratory enzymes, including catalase and the cytochromes A, B, and C that are involved in cellular respiration. Reserve food materials will be transformed into simple, soluble components through this respiration in the plant system, which might be used for growth or maintenance. Ravindran and Bala (1987) reported that the starch content of potato increased with the increased rate of application of organics viz., FYM @ 5 t ha⁻¹ (72.50 per cent) and FYM @ 10 t ha⁻¹ (75 per cent). Santoshkumar and Shashidhara (2006) found in their study that the application of FYM @ 10 t ha⁻¹ along with RDF increased yield by 16.97 % and 124.23 kg ha⁻¹,

respectively over 100 per cent RDF alone (14.53 and 87.50 kg/ha, respectively). Mulani *et al.*, (2007) conducted an experiment to investigate the effects of organic manures and biofertilizers on the quality of bitter gourd and concluded that the pulp thickness (1.03 cm) and shelf life (7.33 days) were significantly improved by applying 25% nitrogen through neem cake and 75% nitrogen through poultry manure. Shankar *et al.*, (2012) investigated the impact of organic and inorganic farming on, quality traits of tomatoes and concluded that the application of organic manures had a significant impact on TSS (11.50° Brix) and lycopene content (6.41 %) of tomato as compared to the application of inorganic fertilisers. Chatterjee *et al.*, (2013) investigated the effect of various nutrient sources on shelf life and qualitative characteristics of tomatoes and the research showed that the use of various nutrient sources had a substantial impact on the shelf life, total soluble solids, total sugar, vitamin-A and vitamin-C levels. Vermicompost produced a better growth medium and produced superior results. Kumar *et al.*, (2014) found that higher level of N substitution (*i.e.*, for 100% and 75%) through compost or vermicompost significantly increased carrot quality attributes like reducing sugar, total sugars and ascorbic acid content as compared to control. Umuhoza *et al.*, (2014) carried out an experiment to find out the impact of FYM on nutritional quality of carrot and found that the application of FYM (20 t ha⁻¹) had the lowest TSS and a favourable impact on β -carotene and vitamin-C as compared to the control treatment. Chatterjee *et al.*, (2016) found in their study that, among the application of organic manure, vermicompost and earthworm biomass, the use of vermicompost recorded highest quality of the carrot root on the basis of beta carotene and TSS observations. Thongney *et al.*, (2018) found in their study on cucumber that the maximum TSS (4.10°Brix), Vitamin-C (8.39 mg/100 g of fruit pulp) and acidity (0.90 %) were observed in the treatment of vermicompost @ 2 t ha⁻¹ + FYM @ 15 t ha⁻¹ as quality parameters. Yadav *et al.*, (2022) concluded that the carrot quality attributes *i.e.*, TSS (8.17° Brix), beta-carotene (23.07 μ g g⁻¹) and total chlorophyll content (2.61 mg g⁻¹) increased when vermicompost was applied @ 20 t ha⁻¹ comparison to the control.

Conclusions

In conclusion, using organic manures in vegetable crop production provides an environmentally friendly approach that has a beneficial effect on the health of the soil, the growth, yield, and nutritional quality of the crops. Farmers can reduce the damaging effects of synthetic fertilisers on the environment while ensuring the production of high-quality, nutrient-rich vegetables by embracing organic manures. Further study is necessary, however, to maximise the advantages of organic manures in various agricultural systems by finding out the best management strategies and doses for various vegetable crops and agro-climatic situations.

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A Review on Bahar Regulation in Pomegranate

Manmohan Singh Bhooriya, Dinesh Kumar Kuldeep*, Maneesh Kumar and N.R. Rangare

Department of Horticulture, JNKVV, Jabalpur, M.P., India

*Corresponding Author Email : dineshkuldeep88@gmail.com

Abstract

Pomegranate bears different flowering flushes throughout the year if left without any treatment. It primarily shows three distinct flowering seasons i.e. February-March (AmbeBahar), June-July (MrigBahar) and October-November (Hasta Bahar) with the corresponding harvest period during rainy (June – July), winter (November- December) and spring season (February- March), respectively. Secondly, Three types of flowers namely male, hermaphrodite and intermediate are borne on new and old branches in pomegranate once, two or three times a year that are influenced by germplasm, climate management practices etc. It gives poor quality and low yield at different times and is not commercially profitable. Good quality production can be ensured by regulating the crop in such a way that they can produce only one crop instead of two or three in a year. Plants are forced to produce only one crop instead of two or three crops with good quality production. The main objective of crop regulation is to force the tree to rest and produce profuse blossoms and fruits during any one of the two or three flushes. It can be achieved through holding irrigation water, shoot pruning, debossing, spraying chemicals and other plant growth regulators. The selection of bahar at a location is mainly determined by prevailing production constraints like availability of irrigation water, quality production, occurrence and extent of the damage by the disease and pests and several market factors. Crop regulation planning is about identifying, selecting, implementing and monitoring methods to control the yield and quality of pomegranate crops.

Key words : Pomegranate, Bahar, regulation, yield and quality.

Introduction

Pomegranate (*Punicagranatum* L.) is one of the oldest known edible fruits and is capable of growing in different agro-climatic conditions ranging from tropical to sub-tropical (Levin, 2006; Jalikop, 2007). It belongs to the genus *Punica* and family *Punicaceae* (Chatterjee and Randhawa, 1952). It is grown for its delicious and juicy pink aril (outer growth of seed) which is eaten fresh (Keskar et al., 1993). The pomegranate is an ancient fruit that originated in South-west Asia, probably in Iran and some adjoining countries (De Candolle, 1967).

In India, it is grown commercially in Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Telangana, Tamil Nadu, Madhya Pradesh and Rajasthan states. The area under pomegranate cultivation in India is increasing at a faster rate owing to its high demand, hardy nature, better storage quality and nutritional value (Saroj and Kumar, 2019). Due to its hardy nature, high yield and low input requirements it has emerged as a potential fruit crop for resource-poor farmers under harsh conditions (Rajkumar et al., 2017). It covers 273 thousand ha area with an annual production of 3068 thousand t and a productivity of 11.24 t ha⁻¹ in India (Anonymous, 2021). Pomegranate flowers continuously throughout the year under tropical climates. In subtropical central and western India, there are three distinct seasons for flowering but yield and quality is not so well in all crop harvest. It is vital to identify

the flowering and fruiting behaviors of crops and which bahar will give a good crop while considering all the factors related to a particular bahar. There is Ambebahar-February to March flowering and fruit ripens in July–August, Mrigbahar–June to July flowering and fruit ripens from October to December and Hast bahar–October to November flowering and fruit ripens in February to April (Shukla et al. 2008). Continuous bearing results in a reduction of yield with small-size fruits. Hence, for commercial production, it is advisable to take only one crop in the main season during which the quality of fruits is also good.

In pomegranate fruit development, water stress causes an asymmetric increase in fruit turgor pressure, because aril turgor increased to a much greater extent than peel turgor, the pressure of the arils on the peel favoring fruit splitting (Galindo et al., 2014), which is a major problem in hot arid climate. In pomegranate crop regulation, water stress, plant growth regulators, defoliants, and nutrient and plant architectural engineering are major horticultural innovations that influence flowering induction, alter sex ratio and improve fruit quality (Kumar et al., 2019b). Crop regulation in pomegranate is done keeping in mind the availability of irrigation, pest and disease infestation and market prices (Shivran et al., 2020). In pomegranates, 1-2 month stress is imposed by the withholding irrigation depending upon soil and climatic conditions. Pruning and flower/bud

thinning are performed to modify the natural growth habits of pomegranate plant and to make a balance between vegetative and reproductive growth which regulate flowering and fruiting for quality yield. Withholding of irrigation during June+pruning and thinning+ethrel 2 ml l⁻¹+DAP 5 g l⁻¹ treatment induced flowering during optimal climatic conditions and significantly improved sex ratio and fruit set of pomegranate (Kumar *et al.*, 2020).

Goell *et al.*, (1981) reported that moisture stress followed by alleviation was effective in initiating and promoting vegetative flushing. The flowering is delayed under longer periods of stress which may be due to conditions like high and low temperature and low humidity conditions. Singh and Chadha (1988) advocated that imposition of stress caused uniformity in flushing and intensity depending on the amount of stress as measured by relative water content (RWC) in the plant before alleviation. Several methods have been tried to induce new vegetative growth during the rainy season so that bumper crop is obtained in the subsequent winter season (Shigeura and Bullock, 1976, Singh *et al.*, 2000). Coordination of the fruiting cycle can help in maintaining fruit supplies during most months (Lopez *et al.*, 1982, Manica *et al.*, 1982, Lopez and Perez, 1977 and Shatat, 1993).

Why bahar regulation : Pomegranate crops that bloom more than once a year do not produce good yield and quality of the fruit throughout the year. The yield and quality depend on the bahar. For example, the rainy season crop of pomegranate is poor in quality and the crop is affected by many biotic and abiotic stresses as compared to the winter season crop. The winter season crops (mrigbahar) which ripen from the second fortnight of October to the first fortnight of January are superior in quality, free from diseases and pests and fetch higher income. This requires regulation of flowering (from ambebahar to mrighbahar) to obtain the most profitable crop by several methods. In different regions, various methods of crop regulations are followed depending on climatic factors, cropping patterns, cultivars etc. Winter season crop is superior in quality which fetches higher prices than rainy season crop. In the rainy season, there is a serious attack of pomegranate butterfly (most severe during July) which deteriorates its quality. So far getting quality fruits in the pomegranate winter season and summer season crop should be taken and rainy season crops should be avoided. Water availability is a big issue in Maharashtra, Rajasthan and Gujrat during the summer season for pomegranate growers. They always avoid taking the ambebahar crop and regulating this crop into mrighbahar with the onset of monsoon and crop is harvested during winter and some farmers prefer hastbahar with less availability of water.

Principle of bahar regulation : The basic principle of bahar regulation is to manipulate the natural flowering of the guava plant in a desired season that contributes to increased fruit yield, quality and profitability. This concept is based on the fact that most of the crops' flowers are borne only on new, succulent, vigorously emerging vegetative growths. These new growth flushes can be either on new emergences of lateral bud on older stems or extensions of already established terminals of various sizes and vigor.

Objectives of Bahar regulation : The main objective of crop regulation is to force the tree to rest and produce prolific blossoms and fruits during any one of the two or three flushes. Besides, some objectives are as under:

1. To obtain suitable crop at a desired season
2. To regulate a uniform and good quality of fruits
3. To maximize the production as well as profit to the grower.
4. To reduce the cost of cultivation because uninterrupted continuous blossom would produce light crops over the whole year and require a high cost for monitoring and marketing.

The selection of bahar at a location is mainly determined by : Selection of bahar depends upon the location and some prevailing production constraints like availability of irrigation water, fruit quality, market prices and occurrence and infestations of the diseases and pests. Water availability is a vast concern in arid and semi-arid regions during the summer season for pomegranate growers. They always avoid taking the ambebahar crop and regulate this crop into mrighbahar with the onset of monsoon and the crop is harvested during winter. Some farmers prefer hasta bahar with less availability of water.

Table-1 : Flowering and fruiting season in pomegranate.

Bahar	Flowering time	Fruiting
Ambe	Feb.- March	July-August
Mirg	Jun.-July	March-April
Hasth	Sep.-Oct.	November-December

Methods of bahar regulation in pomegranate : Several methods have been tried to induce new vegetative growth during the rainy season so that bumper crop is obtained in the subsequent winter season (Singh *et al.*, 2000). To get only the appropriate season crop it is necessary to manipulate the flowering. The following practices can be adopted :

1. **Withholding of irrigation :** In northern plains, mrighbahar is preferred over ambe and hast-bahars, therefore, it becomes necessary to regulate flowering, so that Mrighbahar can produce heavy flowering and fruits

are available in winter. The practices followed for taking Mrig-bahar are: Restricting irrigation water: The trees should not be given irrigation from February to the middle of May. Doing so, the tree sheds its leaves during the hot season (April-May) and goes to rest. During this rest period, the tree can conserve food material in its branches (Pedapati, 2015).

The main principle of withholding irrigation is to provide rest to the plant. It increases the number of flowers and accumulates large amounts of food to increase growth in the coming season. Withholding of irrigation is done for one month in light sandy soils and for one and half months in loamy soils. The ideal condition for crop regulation is practiced when pomegranate plants get the desired leaf fall (50 to 70 %). Under water stress conditions, plants produce osmatin, proline and arginine protein. Proteogenic amino acids like prolines etc. accumulates under stress and non-stress conditions as a beneficial solute in plants and provide the high capacity for tolerance to stress condition and these amino acids helps stimulate the flowering in the plants under water stress condition. Therefore, plants produce more flowering, a good sex ratio and more fruits (Shiran *et al.*, 2020). Induction of water stress by withholding irrigation from December to June or until the beginning of the monsoon depending upon the prevailing conditions has been recommended (Cheema *et al.*, 1954).

2. Use of plant growth regulator and chemicals : In recent times, the foliar spray of ethrel (1-2 ml per liter) has been extensively practiced for crop regulation in pomegranate crops. Ethrel hormone stimulates the enzymes i.e. cellulase and polygalacturonase for cell smelting. This condition is considered good for achieving more flowering, a good sex ratio and a high yield (Shiran *et al.*, 2020). Growth regulators and certain chemicals have been found very effective in thinning flowers and manipulating the cropping season NAA, NAD, 2, 4-D carbaryl and ethrel were found successful in reducing the rainy season and increasing the winter crop under different agroclimatic conditions (Chundawat *et al.*, 1975). Similar findings were reported by Singh *et al.*, (1993) that deblossoming can be carried out by spraying 10 percent urea or naphthalene acetic acid (NAA) @ 600 ppm of water during May, when maximum flowers have opened. Each tree requires about 10-12 liters of solution i.e. about 1000 liters per acre. For preparing the NAA solution, dissolve 600 g of NAA in 1500-2000 ml alcohol, then make the volume of 1000 liters.

3. Bahar regulation by cultural practices : Canopy management practices viz. training, pruning and nutrient management (carbon-nitrogen ratio) are best for achieving higher flowering percent and quality fruit

production in pomegranate. Pomegranates may be trained as multi-stemmed trees or single-stemmed trees. Generally, 3 to 4 stems are retained to avoid damage due to stem borer and the remaining shoots are removed, this will give a bush-form look to the tree. In the initial years, pomegranate plants are generally trained by an open center system. Light pruning is done after withholding of irrigation and 15 -20 days before starting of new growth. Use of 10 percent Bordeaux paste is done on pruned parts of plants to avoid fungal attack. In dry areas, mrighbahar is regulated for qualitative crop production. For regulating crops in dry areas, withholding of irrigation is done in April-May. Subsequently, light pruning and spraying the mixer of 1000-2000 ppm ethrel and 0.5 percent diammonium phosphate is followed. Flowering takes place in June - July. This gives good quality fruits in November-December. To get a good quality yield 60 to 80 fruits should be retained on a single plant (Shiran *et al.*, 2020) in pomegranate and Singh and Bal (2006) reported that pruning help in reducing the tree size and improving the fruit quality in guava. Similar observations were also made by Bajpai *et al.*, (1977). The minimum flower drop was recorded on severely pruned trees (100 cm) and the maximum flower drop was obtained on lightly pruned trees (30 cm) of guava during the rainy season.

4. Nutrition application : To increase the quantum of winter crops the fertilizer schedule should be changed from April-May to May-June which will induce more vegetative growth that subsequently increases the winter cropping (Boora *et al.*, 2016). Gupta and Nijjar (1978) advocated the application of a combination of NPK@ 40,100, and 40 g, respectively. Application of 100 % RDF + 20ppm NAA + fertigation at 15-day intervals in ambehahar significantly affected fruit retention (%), number of fruit/plant, yield kg/plant, TSS, total sugar, and reducing sugar (Bhooriya *et al.*, 2021). Singh and Singh, 1994 recommended 10 % urea for a better crop of Sardar guava and Allahabad safeda during winter under Lucknow and Punjab conditions in guava crops.

5. Insect-pests and diseases management : Bahar regulation is a good system to manage insect pests and diseases. Use of defoliant induces leaf falls from 50 to 100 percent depending upon the concentration of defoliant used for bahar regulation. The fallen leaves should be collected and burnt so that insect pests and diseases may be destroyed up to some extent. Therefore, it helps to escape the crop from the outbreak of insect pests and diseases and also reduces the usage of insecticides.

Conclusions

Bahar regulation is an effective and advanced management practice for obtaining higher yields with good quality fruit production. Availability of irrigation, pests

and diseases infestation, market demand, use of germplasm and climatic conditions play major roles in bahar regulation. It requires intensive care and work for its operation. In addition to this, bahar regulation is more effective in controlling physiological disorders i.e. fruit cracking, sun scorching, and browning of arils.

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Influence of Storage Media and Period on Seed Germination and Seedling Growth in Acid Lime (*Citrus aurantifolia* Swingle) cv. Kagzi

Nitu Nilwanshi, S.K. Pandey, Manmohan Singh Bhooriya*, Maneesh Kumar and Dinesh Kumar Kuldeep

Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalyaya, Jabalpur, M.P.

*Corresponding Author Email : monubhooriya903@gmail.com

Abstract

The present investigation entitled "Influence of storage media and period on seed germination and seedling growth in acid lime (*Citrus aurantifolia* Swingle) cv. Kagzi." The experiment was conducted at Fruit Research Station Imalia Farm, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalyaya, Jabalpur (M.P.) to study the influence of storage media on germination and growth of acid lime to find out the effect of storage period on seed germination and growth of acid lime and also to find out the combined effect of storage media and storage period on seed germination and seedling growth of Acid lime, during 15 december 2017 to 15 Feb. 2018. The experiment was laid out in randomized block design with nineteen treatments combination consisting of three main storage media Charcoal dust, cow dung ash and neem leaf powder and different dates of sowing (seven) of first seed sown just after extraction without storage (T1 Control) and second seed sown 10, 20, 30, 40, 50, and 60 days after seed extraction respectively. All growth and vigour parameter were found significantly superior under T5 Storage media which comprising (Charcoal+20 days) followed by different treatments at 10, 20, 30, 40, 50 and 60 DAS respectively. As regards, to seed storage period and storage media, the treatment (T5 Charcoal+ 20 days) after seed extractions observed superior in germination, days taken to start germination, days taken to 50% germination, percentage of germination, height of seedlings (cm), number of leaves/seedling, fresh weight of shoots (g), dry weight of shoots (g), fresh weight of root (g), dry weight of root (g), at 120 days after sowing.

Key words : Storage period, storage media, germination parameters, growth parameters.

Introduction

Citrus belongs to Rutaceae family and third most important crop of India after mango and banana. Important species of acid lime (*Citrus aurantifolia* Swingle) is belongs to citrus group. India is the largest producer of acid lime in world. Acid lime seeds are recalcitrant in nature. The recalcitrant seeds impose serious storage problems due to their desiccation and chilling sensitivity (Chin and Roberts, 1980).

Citrus fruits are extensively grown in tropical and sub-tropical regions throughout the world. The Kagzi lime (*Citrus aurantifolia* Swingle) is probably originated in India and then spread to the Middle East and other tropical and subtropical countries (Salunkhe and Desai, 1984). Limes are a good source of vitamin C, and are often used to accent the flavors of foods and beverages. The peel contains volatile oil, which is used in the production of perfumes and different kinds of sweets. Also lime has medicinal uses like citric acid, which is used in a drug (Sumaya, 2005). The plants of acid lime are small and bushy having fine twigs; thorns conspicuous and sharp; flowers are small, pure white in colour and borne in clusters. The fruits are small to medium in size; pulp is greenish and adherence to the skin is strong. The seeds are small and smooth; skin yellowish green, thin or papery and shiny. The juice sacs are slender with solid core.

It is successfully grown in state of Andhra Pradesh, Maharashtra, Tamil Nadu, and Madhya Pradesh. Citrus is grown in 248000 ha with the production of 2484000 metric tonnes having productivity 9.70 metric tonnes/ha and lime is grown in 219000 ha with the production of 2108000 metric tonnes having productivity 9.6 tonnes/ha in (Anonymous, 2018-2019).

Kagzi lime is commercially propagated through seeds in India (Naik, 1949) as it comes true to type, because of high degree (39-60%) of nucellar embryony. In seed propagated plants better and quicker germination of seeds and production of maximum number of seedlings are highly essential to meet the increasing demand of the cultivars in shortest possible time. In Kagzi lime germination percentage is low and it varies between 27-58 per cent (Anandam and Singh, 1969) and Kagzi lime takes about 3 weeks to germinate (Naik, 1949 and Cheema et al., 1954). The growth of acid lime seedling is very slow in nursery as well as in the field, In fact many complaints from cultivators for slow growth of seedlings under field conditions are being reported (Shant and Rao, 1973). The Acid lime seeds are recalcitrant in nature therefore, nursery men faces the problem of poor germination of acid lime seed which having very short storage period. For overcoming such type of problems at nursery stage, investigation is important to find out the

influence of storage period by using storage media on seed germination and growth of acid lime seedlings.

Materials and Methods

The experiment was conducted at Fruit Research Station, Imalia, Department of Horticulture, JNKVV, Jabalpur (M.P.). The details of the experiments and methods followed during course of present investigation i.e. September 2017 to February 2018 are described under following heads. Seeds of fully ripe kagzi lime fruits were extracted manually and rubbed in ash to remove sticky material on seed. Seeds were sown immediately while remained seeds were stored different storage media (charcoal, neem ash and cow dung) at ambient condition. The seeds were stored in different lots for different sowing dates. The media were used to grow seedling in poly bag comprising Soil + Vermi-compost - the ratio 3:1 of soil and vermi-compost was taken and mixed thoroughly for making the desired quantity. Poly bags length of 20 cm and diameter of 30 cm with 200 gauge thickness were used and filled with the media comprise soil + vermi-compost in the ratio of 3:1 respectively. One seed of acid lime was dibbled at about 2 to 3 cm depth in each polythene bag. For each replication 190 polythene bags were filled and kept in net house having 75% green shed net. Data on number of days taken first germination, days required for 50 percent germination. Growth parameters viz., seedling height (cm), number of leaves per plant, root, fresh weight of shoot, dry weight of shoot (g), fresh weight of root and dry weight of root (g) was recorded from five randomly selected plants and statically analysed.

Results and Discussion

Initiation of seed germination : The findings showed in Table-1 show that the analysis of seed germination data was significantly impacted by the use of Storage Media and Period. The data revealed that T5 is recorded significantly minimum days taken to start germination under seed stored up to 20 days in Charcoal powder (9.21) followed by T7 (10.2), T8 (10.3), and T18 (10.3) and maximum days taken (21.2) under recorded T1 which is sowing of these seed. Low temperature discourage early germination may be the possibility of late germination of seeds were sown during Dec. to January month. On the other hand seeds were sown in the 1st week of Jan. 2017 after 20 days of storage in charcoal dust, took minimum (9.21 days) days for initiation germination and 50% seed germination. This might be due to high level of carbohydrate and protein reserve in the seed which responsible for early initiation and germination percentage of seed. similar result were also recorded by abbas *et al.* (2003) in jamun and khopkar *et al.* (2014).

Days taken to 50% germination : The data pertaining to 50 per cent germination were presented in table 1. The result clearly show that treatments of storage media significantly influenced the days taken to 50% germination. Data indicate that the storage media T5 Charcoal+20 days has taken minimum days of (16.2) followed by T6 (16.3) and T7 (18.2). The maximum days (27.2) were noted for 50 per cent germination under T1 control. Storage period of seed had significant effect on days taken for 50 per cent germination. Treatment T5 has taken minimum days to 50 per cent germination i.e. 16.2 days which is significantly superior. The significant effect of 20 days seed storage period was recorded to days taken for 50 per cent germination. This might be due to high level of carbohydrate and protein reserve in the seed which responsible for early initiation and germination percentage of seed. similar result were also recorded by abbas *et al.* (2003) in jamun and khopkar *et al.* (2014).

Seedling Height (cm) : The data pertaining height of seedlings at 30, 60 and days after sowing presented in the table-1. The data recorded at 30 days after sowing was found significant, maximum mean height of plant T5 (3.33, 6.55 and 5.68 cm) was recorded. while in T1 treatment took significantly minimum height was recorded of plant 2.33, 4.40 and 4.17 cm. The maximum plant height was recorded under storage period and growing media T5 (Charcoal+20 days), recorded and minimum seedling height recorded under T1 (Control). The higher height and of stored seed in charcoal dust could be due to higher germination capacity, optimum moisture content, food and nutrient reserve resulted maximum height. On the other hand optimum temperature facilitate better germination under the suitable seed moisture level responsible for nutrient mobilization in the seedlings and cell multiplication resulted higher height and stem girth. Dhakad and pandey (2001), Singh and Singh (1981), Vanitha *et al.* (2005) reported freshly extracted seed gave higher plant height due to more water / moisture content in the seeds looking to the references it is proved that if the seed moisture is maintain / retain could be helpful for faster growth of the seedlings. Better growth of seedlings the seed moisture might be retain for long period of time due to storage in charcoal dust.

Number of leaves/seedling : Data on number of leaves per seedling 30, 60 and 90 days was presented in Table-2. As regards, the storage period of seeds had also showed significant effect on number of leaves per seedlings and higher number of leaves recorded in T5 (3.90, 6.55 and 9.60). The treatment T1 (Control) recorded the minimum number of leaves per seedling (3.00, 4.40 and 7.77). If various viz. 30, 60 and 90 DAS stage of growth period the

Table-1 : Influence of storage period and storage media on initiation of seed germination, 50% seed germination (in days) and height of seedling (cm).

Treatment	Days taken initiation of germination	Days taken 50% seed germination	Height of seedling (cm)		
			30 DAS	60 DAS	90 DAS
T1 (Control)	21.17	27.2	2.33	4.40	4.17
T2 (Charcoal+10 Days)	14.22	25.3	3.07	6.40	5.17
T3 (Cow dung Ash+10 Days)	19.87	26.2	2.60	5.33	4.53
T4 (Neem leaf powder+10Days)	20.16	26.2	2.36	4.42	4.18
T5 (Charcoal+20Days)	9.21	16.2	3.33	6.55	5.68
T6 (Cow dung Ash+20Days)	11.16	16.3	2.47	4.93	4.47
T7 (Neem leaf powder+20Days)	11.23	18.2	2.40	4.80	4.33
T8 (Charcoal+30Days)	10.25	21.2	3.10	5.93	5.03
T9 (Cow dung Ash+30Days)	10.27	22.2	2.63	4.93	4.77
T10 (Neem leaf powder+30Days)	11.33	22.4	2.40	4.87	4.70
T11 (Charcoal+40Days)	12.25	22.3	3.20	5.67	5.23
T12 (Cow dung Ash+40Days)	13.25	23.0	2.40	4.80	4.30
T13 (Neem leaf powder+40Days)	14.21	25.3	2.37	4.77	4.17
T14 (Charcoal+50Days)	11.27	22.2	3.10	5.47	4.90
T15 (Cow dung Ash+50Days)	11.29	23.2	2.53	4.60	4.30
T16 (Neem leaf powder+50Days)	12.60	23.2	2.43	4.57	4.23
T17 (Charcoal+60Days)	10.17	21.2	3.10	6.17	5.33
T18 (Cow dung Ash+60Days)	10.28	21.2	2.53	6.07	4.33
T19 (Neem leaf powder+60Days)	11.20	22.2	2.47	5.13	4.30
SEm $\pm$	0.17	0.1	0.09	0.31	0.13
CD at 5% level	0.49	0.3	0.27	0.90	0.38

Table-2 : Influence of storage media and period on number of leaves per seedlings dry and fresh weight of shoot and root.

Treatment	Number of leaves per seedling			Fresh weight of shoot	Dry weight of shoot	Fresh weight root	Dry weight of root
	30 DAS	60 DAS	90 DAS				
T1 (Control)	3.00	4.40	7.77	1.25	0.71	0.96	0.25
T2 (Charcoal+10 Days)	3.87	6.40	9.53	1.54	0.94	1.20	0.54
T3 (Cow dung Ash+10 Days)	3.27	5.33	8.37	1.26	0.74	1.00	0.45
T4 (Neem leaf powder+10Days)	3.13	4.42	7.83	1.45	0.73	1.01	0.29
T5 (Charcoal+20Days)	3.90	6.55	9.60	2.38	0.98	1.31	0.62
T6 (Cow dung Ash+20Days)	3.80	4.93	8.33	1.41	0.85	1.16	0.35
T7 (Neem leaf powder+20Days)	3.27	4.80	8.27	2.14	0.83	1.02	0.34
T8 (Charcoal+30Days)	3.77	5.93	8.43	2.21	0.94	1.21	0.56
T9 (Cow dung Ash+30Days)	3.37	4.93	8.23	1.30	0.84	1.19	0.51
T10 (Neem leaf powder+30Days)	3.27	4.87	8.10	1.27	0.81	1.02	0.33
T11 (Charcoal+40Days)	3.80	5.67	9.30	2.33	0.90	1.29	0.56
T12 (Cow dung Ash+40Days)	3.33	4.80	9.13	1.52	0.83	1.13	0.41
T13 (Neem leaf powder+40Days)	3.20	4.77	8.30	1.47	0.82	1.04	0.33
T14 (Charcoal+50Days)	3.50	5.47	8.90	2.34	0.95	1.21	0.44
T15 (Cow dung Ash+50Days)	3.27	4.60	8.20	1.48	0.93	1.04	0.33
T16 (Neem leaf powder+50Days)	3.23	4.57	7.86	1.43	0.90	1.03	0.30
T17 (Charcoal+60Days)	3.53	6.17	9.17	2.35	0.96	1.18	0.43
T18 (Cow dung Ash+60Days)	3.30	6.07	8.40	1.60	0.82	1.06	0.31
T19 (Neem leaf powder+60Days)	3.20	5.13	8.23	1.31	0.80	1.02	0.30
SEm $\pm$	0.16	0.31	0.22	0.17	0.04	0.04	0.04
CD at 5% level	0.46	0.90	0.63	0.48	0.10	0.11	0.10

more number of leaves and was found in Charcoal dust storage media while seeds were storage and sown after 20 days of the storage period. This might be due to the mobilization of reserve nutrient encourage better germination and emergence of root support to the feeding process so that the combined activities. Accelerator plant growth parameters like number of leaves. The gradual increase in storage period resulted gradual decline in number of leaves (Priya and Rao 2008). It is clear from the findings of various that the decrease in moisture content by storing in bags etc at ambient conditions resulted poor germination and growth (Pangou et al. 2011 and vasudevan *et al.* 2012). On the other hand if seed moisture is optimum resulted better germination and growth of seedlings. Therefore, number of leaves was more in T5 (Charcoal+20 days) at different storage period. these results were also accordance with the findings of Doijode (1993) verma *et al.* (2008) and Vinitha *at al.* (2005).

Fresh and dry weight of shoot and roots of seedling

(g) : Storage period of seed had shown significant effect on fresh and dry weight which accumulates maximum fresh weight of seedling shoot and roots presented in table-2. The maximum fresh weight of 2.38 g and 1.31 g of shoots and roots were obtained at 90 days, and minimum fresh weight of shoots and roots (1.25 g and 0.96 g) was observed under T1 (Control). The maximum dry weight of 0.98 g and 0.62 g of shoots and roots were obtained at 90 days, and minimum dry weight of shoots and roots (0.71 g and 0.25 g) was observed under T1 (Control). Due to better growth of seedling under the treatment might be the cause of maximum fresh and dry weight of shoot and roots. The accumulations of more sink due to higher growth rate, more number of leaves etc. The finding is supported by the findings of Krishna et al. (2008) in medicinal plants.

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Response of Cutting Frequency on Seed Quality Parameters of Beet Leaf (*Beta vulgaris* var. *bengalensis*) Intercropped in Onion (*Allium cepa* L.) Seed Crop

K.S. Saini* and S.K. Dhankhar

Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, Haryana

*Corresponding Authors Email : sainik656@gmail.com

Abstract

A field study was conducted at Vegetable Research Farm, CCS Haryana Agricultural University, Hisar for two years, 2018-19 and 2019-20. Additive series inter-cropping pattern was implemented and the onion was grown as the main seed crop and beet leaf seed crop as an intercrop. Seven intercropping patterns considered as treatment and replicated three times. Plant to plant and row to row spacing for onion crop was 60 × 30 cm and the intercrop beet leaf seed crop was maintained at 15 × 5 cm spacing. In all the treatments, 3 leaf cuttings were common (except sole beet leaf) and after subsequent leaf cuttings beet leaf crop was left for seed as per the experimental objectives. The superior seed quality parameters were recorded from the sole beet leaf seed crop treatment (test weight 14.0, germination 76.4%, vigour-I 1505.4, vigour-II 136.9, Tz. test 91.4%, AAT 59.4% & ECe 0.57 S/cm/50 seeds) in which there was no leaf cutting. Whereas, the highest seed quality parameters in intercropping treatment were recorded in the treatment, onion + Beet leaf (1 row) with 3 cuttings & left for seed (test wt. 13.7, standard germination 71.0%, vigour-I 1320.4, vigour-II 120.8, Tz. test 87.40%, AAT 53.7% & ECe 0.68 iS/cm/50 seeds). While, the minimum seed quality parameters of beet leaf were recorded from the intercropping treatment, Onion + Beet leaf (2 rows) 5 cuttings & left for seed crop (test wt. 12.1g, standard germination 57.0%, vigour-I 985.5, vigour-II 83.1, Tz test 72.7%, AAT 36.7.0% & ECe 0.96 S/cm/50 seeds). Hence, growing the beet leaf as the sole crop was found better in terms of seed quality parameters for both main and intercrop and for the economic net returns than growing in intercropping.

Key words : *Allium cepa*, *Beta vulgaris* var. *bengalensis*, cutting frequency, intercropping, seed quality, row pattern.

Introduction

Beet leaf (*Beta vulgaris* var. *bengalensis* Hort.) also known as Indian *Palak* or Spinach beet or beet leaf spinach or Saag or Desi Palak. It belongs to the family Chenopodiaceae with Chromosome numbers 2n=18 and is native to the Indo-Chinese region. Beet leaf is grown for its nutritive leafy foliage which is rich in vitamins and minerals and contains a high quantity of ascorbic acid and iron (Naresh *et al.* 2022). The leafy vegetables have a very high protective food value among all the vegetables called mines of minerals and are rich in vitamin A, vitamin C, and minerals. Beet leaf contains 30 mg of phosphorus, 380 mg of calcium, 16.2 mg of iron, 3.4 g of protein, 46 kcal of energy, 0.8 g of fat, 6.5 g of carbohydrates, 0.26 mg of thiamine and 0.56 mg of riboflavin per 100 g of edible part (Singh *et al.* 2015). Besides this, they contain soft fibrous matter; provide necessary roughage to the diet. Beet leaf is one of the green vegetables most commonly grown in tropical and subtropical regions of India, it is commonly grown in Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan, West Bengal, Delhi, Haryana and Punjab are some of the most well-known growing states in India (Shah *et al.* 2023). It is cultivated for its fresh green leaves, which are ready for harvest in about 30 to 35 days after sowing (Mishra *et al.*, 2003).

Onion (*Allium cepa* L.) belongs to the family

Alliaceae and belongs to the genus *Allium*, originated from Central Asia between Turkmenistan and Afghanistan (Bagali *et al.* 2012), which is one of the most important monocotyledonous spices as well as Vegetable crops grown for its pungent bulbs and flavorful leaves in the world (Welbaum, 2015). With an average productivity of 18.10 metric tonnes per hectare, India is the second-largest producer of onion bulbs after China, producing 19.4 mt of onion bulbs from an area of 14.34 lakh hectares (Anonymous, 2019) which is low compared to the world average. Along with increasing global demand for food, the relationship between production and food security, and the need for natural resource preservation, improving the diversity of planting systems seems necessary. More natural resources can be used more effectively with intercropping, which also benefits marginal and small farmers by providing ground cover for longer periods of time than monocropping (Naresh *et al.* 2022). Intercropping provides insurance against yield and crop reduction (Zhang *et al.* 2013).

Materials and Methods

Experimental site and cultural practices : The field experiment was conducted at the Research Farm, Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, which is situated at 29° 10' latitude north, 75° 46' longitude east, and 215.2 m above

mean sea level. To fulfil the requirements of the objectives of the investigation, a field experiment was conducted during the *Rabi* seasons 2018–19 and 2019–20. The experiment was based on a randomized block design (RBD) and 7 intercropping treatments replicated three times. Spacing for the beet leaf seed crop was 15 × 5 cm which was intercropped in between the onion crop spacing (60 × 30) in one and two row patterns. In each replication, the treatments were distributed at random. Recommended package of practices were followed for optimum growth and development of both main crop and intercrops. The produced beet leaf seed was prepared for different laboratory analyses to test its seed quality. Different seed quality parameters like; test weight, standard germination test (%), tetrazolium test (%), seed vigour index-I & II, accelerated ageing test or AAT (%) and electric conductivity test or ECe were analyzed in the seed laboratory.

Experimental test procedures : Test weight (g) is the weight of the thousand seeds for this one thousand seeds were randomly counted from the seed lot of each treatment per replication and weighed in grams. To test standard germination (%) fifty seeds from every treatment of each crop in a replicated manner were placed in germination papers inside the germination chambers set at 25± 1°C. On the 14th day, germination was counted, and normal seedlings were used to calculate the percentage of germination. Standard germination percentage is equal to (=) the number of seeds germinated and divided by the total number of seeds placed for germination multiplied (×) by 100. Seedling vigour indices were calculated according to the method suggested by Abdul-Baki and Anderson, 1973.

$$\text{Seed Vigour Index-I} = \text{Seed germination (\%)} \times \text{Average seedling length (cm)}.$$

$$\text{Seed vigour Index-II} = \text{Seed germination (\%)} \times \text{Average dry seedling weight (mg)}.$$

For testing the accelerated ageing test or AAT (%) 2 grams of freshly harvested seeds from all replications were taken. Seeds were put on the stainless steel mesh into a plastic box (having distilled water at the bottom) and placed in an accelerated ageing chamber at 40 ± 1 °C and about 100% RH for 48 h. After the incubation, 50 randomly selected seeds were tested for germination and normal seedlings were used to calculate the percentage of germination. Electrical conductivity or ECe Test (µS/cm/50 seed) is concerned to seed leachates, the electrical conductivity (ECe) was measured to know the current status of membrane permeability as per ISTA (1999). In the method, fifty randomly selected seeds from each treatment in every replication were soaked in beakers contain seventy five (75) ml distilled water. The

seeds were completely immersed in the water. The beakers were covered with foil up to next procedure. Later, the seed samples were shifted to the germinator (25±1°C) for 24 h. The ECe was measured by 60-direct reading conductivity meter having unit, µS/cm/seed. The gathered data were analyzed statistically and the recommended methodology outlined by Panse and Sukhatme (1978). The ANOVA table and randomized block design were employed to test for significant differences among the treatments using both MS Excel and OPSTAT software.

Results and Discussion

Beet leaf seed yield per plant (g) : The cutting frequency of beet leaf influenced the seed yield per plant was affected by the intercropping patterns. Significantly higher yield per plant (4.15 g) was reported in the treatment combination, Onion + Beet leaf (1 row) 3 cuttings and left for seed crop followed by the treatment, Onion + Beet leaf (1 row) 4 cuttings and left for seed crop (3.63 g plant⁻¹). The minimum seed yield per plant was recorded (1.51 g plant⁻¹) in the sole beet leaf crop. Lowest seed yield per plant in sole beet leaf might be due to the more plants per unit area. An increase in plant population with closer spacing decreased seed yield per plant but increased seed yield per hectare. Similar results were also reported by Chakraborty *et al.* (2015) in the yield of *Palak* crop.

Seedyield of beet leaf per hectare (q ha⁻¹): Data revealed that the seed yield was significantly influenced by the cutting frequency of beet leaf crop in the onion-beet leaf intercropping patterns. The maximum seed yield was recorded (17.97 q ha⁻¹) in the sole beet leaf seed crop followed by the treatment, Onion + Beet leaf (2 rows) 3 cuttings and left for seed crop (12.38 q ha⁻¹). The minimum seed yield was recorded (5.79 q ha⁻¹) in the treatment, Onion + Beet leaf (1 row) 5 cuttings and left for seed crop. Plant population density and cutting frequency of beet leaf increase or decrease the beet leaf seed yield. This might be due to the more cuttings though increased the number of branches/plant and total green leaf yield but the seed yield and quality in terms of germination and seedling dry weight were considerably reduced due to less absorption and storage of photosynthates. Confirming results were also reported by Singh *et al.* (2013) studied the yield of *Palak* crop.

Test weight (g): The test weight of the beet leaf was influenced by the cutting frequency and row patterns of the beet leaf in the intercropping patterns. The maximum mean test weight (wt. of 1000 seeds) was recorded (14.0 g) in the treatment, Beet leaf seed crop (sole crop) during both years. The maximum seed yield might be due to more photosynthesis accumulation in seeds responsible for higher seed weight. It was followed by the treatment,

Table-1 : Effect of cutting frequency of beet leaf on the seed yield (g/plant) and the seed yield (q/ha) of beet leaf under different onion-beet leaf intercropping patterns.

Treatments	Beet leaf seed yield (g/plant)			Beet leaf seed yield (q/ha)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T1 : Beet leaf seed crop (sole crop)	1.50	1.51	1.51	17.85	18.09	17.97
T2 : Onion + Beet leaf (1 row) 3 cuttings and left for seed crop	4.00	4.29	4.15	8.94	9.65	9.30
T3 : Onion + Beet leaf (1 row) 4 cuttings and left for seed crop	3.60	3.65	3.63	8.08	8.22	8.15
T4 : Onion + Beet leaf (1 row) 5 cuttings and left for seed crop	2.57	2.59	2.58	5.76	5.82	5.79
T5 : Onion + Beet leaf (2 rows) 3 cuttings and left for seed crop	2.73	2.77	2.75	12.28	12.48	12.38
T6 : Onion + Beet leaf (2 rows) 4 cuttings and left for seed crop	2.60	2.63	2.62	11.71	11.81	11.76
T7 : Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop	1.73	1.78	1.76	7.90	7.99	7.95
SEm ±	0.07	0.05	-	0.20	0.17	-
C.D. at 5%	0.20	0.16	-	0.64	0.54	-

Table-2 : Effect of cutting frequency of beet leaf on the test weight (g/1000 seeds) and the standard germination (%) of beet leaf under different onion-beet leaf intercropping patterns.

Treatments	Test weight (g/1000 seeds)			Standard germination test (%)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T1 : Beet leaf seed crop (sole crop)	13.9	14.1	14.0	76.0	76.7	76.4
T2 : Onion + Beet leaf (1 row) 3 cuttings and left for seed crop	13.6	13.8	13.7	70.7	71.3	71.0
T3 : Onion + Beet leaf (1 row) 4 cuttings and left for seed crop	13.5	13.7	13.6	66.0	67.3	66.7
T4 : Onion + Beet leaf (1 row) 5 cuttings and left for seed crop	13.2	13.2	13.2	58.7	59.3	59.0
T5 : Onion + Beet leaf (2 rows) 3 cuttings and left for seed crop	13.0	13.3	13.2	68.7	68.7	68.7
T6 : Onion + Beet leaf (2 rows) 4 cuttings and left for seed crop	12.4	12.5	12.5	62.7	64.0	63.4
T7 : Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop	12.0	12.1	12.1	56.0	58.0	57.0
SEm ±	0.1	0.1	-	1	0.8	-
C.D. at 5%	0.3	0.4	-	3.2	2.5	-

Onion + Beet leaf (1 row) 3 cuttings and left for seed crop (13.7 g) test weight because treatment was left for seed just after 3 leaf cuttings and stand in the field for maximum time. The minimum test weight (12.1 g) was recorded in the treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop. This minimum test wt. might be due to the more number of leaf cuttings (5 cuttings) and higher temperature during the growth stage induced earlier seed maturity and lowest test weight of the beet leaf seed.

Standard germination (%): The standard germination of beet leaf was affected by the cutting frequency and row patterns of beet leaf under different onion-beet leaf intercropping patterns. The maximum germination per cent was recorded from the treatment, Beet leaf seed crop (sole crop) without leaf cuttings (76.4%). It was followed

by the treatment, Onion + Beet leaf (1 row) 3 cuttings and left for seed crop (71.0%). The minimum germination (57.0%) was recorded in the treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop. The higher plant population (2 rows) and maximum leaf cuttings and after that taking seed crop of beet leaf reduces the quality of the crop under the field conditions, its lowest seed vigor and germination might be due to more competition for nutrients, water and space and ultimately reduced the seed vigour and germination. Confined results of the above study were also observed by Gowda *et al.* (2020), and Oshone *et al.* (2014).

Seed vigour index-I: The seed vigour index-I was influenced by the cutting frequency and row patterns of beet leaf under different onion-beet leaf intercropping

Table-3 : Effect of cutting frequency of beet leaf on the seed vigour index-I and the seed vigour index-II of beet leaf under different onion-beet leaf intercropping patterns.

Treatments	Seeds vigour index-I			Vigour index-II		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T ₁ : Beet leaf seed crop (sole crop)	1492.0	1518.7	1505.4	135.7	138.0	136.9
T ₂ : Onion + Beet leaf (1 row) 3 cuttings and left for seed crop	1313.0	1327.8	1320.4	120.3	121.2	120.8
T ₃ : Onion + Beet leaf (1 row) 4 cuttings and left for seed crop	1205.3	1232.9	1219.1	106.7	106.6	106.7
T ₄ : Onion + Beet leaf (1 row) 5 cuttings and left for seed crop	1044.0	1057.7	1050.9	91.0	89.0	90.0
T ₅ : Onion + Beet leaf (2 rows) 3 cuttings and left for seed crop	1261.0	1263.4	1262.2	109.0	113.3	111.2
T ₆ : Onion + Beet leaf (2 rows) 4 cuttings and left for seed crop	1129.7	1158.0	1143.9	98.0	99.2	98.6
T ₇ : Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop	959.0	1011.9	985.5	82.0	84.1	83.1
SEm ±	21.7	15.7	-	4.6	2.4	-
C.D. at 5%	67.7	49.1	-	14.2	7.3	-

Table-4 : Effect of cutting frequency of beet leaf on Tetrazolium test (Tz) of beet leaf under different onion-beet leaf intercropping patterns.

Treatments	Tetrazolium test (%)			Accelerated ageing test (%)			Electric conductivity test (µS/cm/50 seed)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T ₁ : Beet leaf seed crop (sole crop)	90.7	92.0	91.4	58.0	60.7	59.4	0.60	0.54	0.57
T ₂ : Onion + Beet leaf (1 row) 3 cuttings and left for seed crop	86.7	88.0	87.4	53.3	54.0	53.7	0.71	0.64	0.68
T ₃ : Onion + Beet leaf (1 row) 4 cuttings and left for seed crop	80.0	82.7	81.4	45.3	45.3	45.3	0.83	0.75	0.79
T ₄ : Onion + Beet leaf (1 row) 5 cuttings and left for seed crop	73.3	74.7	74.0	38.7	38.7	38.7	0.91	0.94	0.93
T ₅ : Onion + Beet leaf (2 rows) 3 cuttings and left for seed crop	85.3	86.7	86.0	52.0	52.7	52.4	0.73	0.72	0.73
T ₆ : Onion + Beet leaf (2 rows) 4 cuttings and left for seed crop	77.3	81.3	79.3	42.7	43.3	43.0	0.84	0.83	0.84
T ₇ : Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop	72.0	73.3	72.7	37.3	36.0	36.7	0.94	0.98	0.96
SEm ±	1.8	1.8	-	1.1	0.8	-	0.02	0.01	-
C.D. at 5%	5.6	5.5	-	3.4	2.5	-	0.06	0.04	-

patterns. Significantly higher (1505.4) was recorded in the treatment, Sole beet leaf (seed crop). Among intercropping treatments maximum vigour index was founded in the the treatment, Onion + Beet leaf (1 row) 3 cuttings and left for seed crop (1320.4). The minimum vigour index-I (985.5) was recorded in the treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop.

Seed vigour index-II: The seed vigour index-II was affected by the cutting frequency and row patterns of beet leaf crop under different onion-beet leaf intercropping patterns. The maximum vigour index-II was observed (136.9) in the sole beet leaf seed crop. Whereas, among the intercropping treatments maximum seed vigour index -II was recorded (120.8) in the treatment, Onion + Beet leaf (1 row) 3 cuttings and left for seed crop. While the minimum vigour index-II (83.1) was recorded in the

treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for seed crop. Less test results might be due to less vigor and unhealthy seeds more number of leaf cuttings leads the less time for growth and development in the field conditions and onion seed crop was also there in the plot which also required nutrition for its growth & seed development that's why the competition under field conditions reduced seed quality and seed vigour also. The confined results of the above study were also observed by Gowda *et al.* (2020) and Singh *et al.* (2013) reported that late sown crop coupled with more cuttings though the number of branches/plants and total green leaf yield the seed yield and quality in terms of germination, seedling dry weight, and vigour indices I and II were considerably reduced due to less absorption and storage of photosynthates.

Tetrazolium (Tz) test : Data indicated that the tetrazolium test was affected by the cutting frequency and row patterns of beet leaf crop under different onion-beet leaf intercropping systems. The highest tetrazolium test percent was recorded (91.4%) in the treatment, Beet leaf seed crop (sole crop), followed by the treatment, Onion + Beet leaf (1 row) 3 cuttings and left for seed crop (87.4%). The minimum test results of tz, (72.7%) was recorded in treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for a seed crop, that might be due to more number of leaf cuttings and left for seed reduce the seed quality and then test results as the seed vigour test.

Accelerated ageing test : The accelerated ageing test per cent was recorded maximum (59.4%) in the treatment, Beet leaf seed crop (sole crop), followed by the treatment, Onion + Beet leaf (1 row) 3 cuttings and left for seed crop (53.7%). The minimum accelerated ageing test per cent (36.7%) was recorded from the treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for a seed crop, during both years 2018-19 and 2019-20, respectively. The maximum test results might be due to the healthy seed and good quality seed produced in this plot among the treatments. However, the minimum accelerated ageing test percent and the highest ageing rate were recorded from the treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for a seed crop, that was a poor quality seed and could not satisfied the minimum seed quality standard as its seed storage ability might deteriorated with in the year.

Electric conductivity test ($\mu\text{S}/\text{cm}/50$ seed) : The electrical conductivity is negatively correlated with quality and seed vigour *i.e.*, the most vigorous seeds have minimum electrical conductivity and the lowest vigorous seeds have maximum electrical conductivity. The minimum electrical conductivity was recorded (0.57) in the treatment, Beet leaf seed crop (sole crop), followed by the treatment, Onion + Beet leaf (1 row) 3 cuttings and left for seed crop (0.68). The maximum electrical conductivity (0.96) was recorded in the treatment, Onion + Beet leaf (2 rows) 5 cuttings and left for a seed crop. Seed produced in the higher planting density and followed by maximum number of leaf cuttings might be responsible for increased EC test results. The poor seed quality might be due to the less food reserved storage or photosynthetes accumulation in the seeds reserves and when testing its EC to check the quality it founded the highest. The EC test measures the conditions of the cell membranes and he low quality seeds have poor membrane structure which allow amino acids and inorganic ions to leak through. The seed produced in sole beet leaf or in wider spacing with fewer leaf cuttings was found in lower EC which indicates the best quality seed. Confined results of the above study were also observed by Gowda et al. (2020) and Oshone et al. (2014).

Conclusions

Seed quality point of view in the case of beet leaf seed the lowest or zero cutting frequency resulted in the highest seed quality parameters. Sole beet leaf without leaf cutting recorded the maximum seed quality parameters and good quality seed among the treatments. The inter-cropping patterns seed produced after 3rd leaf cutting (with single row) the seed performed highest quality parameters among the inter-cropping treatments. At the higher leaf cutting frequency (4-5 cuttings) and left for seed crop the seed quality parameters gradually reduced as the cutting frequency was increased. Beet leaf crop after the 5th leaf cutting recorded the lowest seed quality parameters. The number of row patterns (1 row and 2 rows) also slightly influenced the seed quality parameter but no more than the frequency of beet leaf cuttings.

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Underutilized Arid and Semi-arid Fruit Crops : Potential, Challenges and Opportunities

Shubham Jain¹, Rajat Sharma², Varsha Minz³, Hari Baksh⁴, Lalit Dhurve⁵, Rakesh Meena⁶, Rutuja Narendra Deshmukh⁷ and Anushi⁸

¹Department of FRUIT SCIENCE, College of Horticulture and Forestry, ANDUAT, Ayodhya (U.P.).

²Department of Horticulture, GBPUAT, Pantnagar, Uttarakhand, Now, Serving as District Horticulture Officer or Equivalent, Govt. of Haryana

³Department of Fruit Science, Indira Gandhi Krishi Vishwavidyalaya, Raipur, C.G.

⁴Department of Horticulture Tilak Dhari PG College, Jaunpur (222002), Uttar Pradesh

⁵Defence Institute of Bio-Energy Research, DRDO, Haldwani, Uttarakhand

⁶Department of Fruit Science, College of Horticulture and Forestry, Jhalawar, Agriculture University, Kota, Rajasthan

⁷Department of Fruit Science, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra

⁸Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh

*Corresponding Author Email : anushiyadav25@gmail.com

Abstract

Arid and semi-arid regions are often seen as challenging environments for agriculture due to their harsh climatic conditions, including limited water resources and high temperatures. However, these regions are home to a wide variety of underutilized fruit-bearing plants that have adapted to thrive in such conditions. This abstract explores the potential, challenges, and opportunities associated with these underutilized arid and semi-arid fruit crops. The cultivation of underutilized arid and semi-arid fruit crops offers substantial potential for enhancing food security and economic development. These crops have the ability to diversify agricultural production, increase food availability, and provide an additional source of income for local communities, particularly small-scale farmers. Furthermore, the nutritional value of many of these fruits is often underestimated, making them important contributors to a healthy diet. However, several challenges hinder the adoption and commercialization of these crops. Limited awareness and knowledge about these fruits among both producers and consumers, as well as a lack of research and development efforts, are significant barriers. Additionally, the unpredictable climate in these regions, marked by droughts and extreme weather events, poses risks to crop yields, necessitating the development of resilient crop varieties and sustainable farming practices. Addressing these challenges requires a concerted effort involving research, development, and awareness-building initiatives. By doing so, the potential of underutilized arid and semi-arid fruit crops can be harnessed, leading to greater food security, improved livelihoods for local communities, and a more diversified and nutritious food supply. Ultimately, these crops can play a pivotal role in the sustainable development of arid and semi-arid regions, benefiting both local communities and the broader agricultural sector.

Key words: semi-arid, diversify, underutilized, economic, water.

Introduction

Underutilized arid and semi-arid fruit crops hold great potential as valuable resources for both food security and economic development. These regions are often characterized by harsh environmental conditions, such as limited water availability and high temperatures, which can make traditional agriculture challenging. However, a diverse range of fruit-bearing plants have adapted to thrive in these conditions, offering a unique opportunity to harness their untapped potential. One of the most significant obstacles is the lack of awareness and knowledge about these crops among both farmers and consumers. Many of these fruits are not well-known or readily available in mainstream markets, which can hinder their commercialization. Crops such as Ber, phalsa, Bael, karonda, jamun, aonla can be grown as arid and semi-arid crops. Additionally, there may be limited research and

development efforts dedicated to improving the production and post-harvest handling of these crops.

Ber

Indian jujube, also known as ber (*Ziziphus mauritiana* Lamk.), is a fruit that is commonly consumed fresh and is significant in arid regions. Ber fruit is very nutrient-dense; it contains high levels of provitamin A, vitamin C, and vitamin B complex, as well as calcium, potassium, br, rb, and la [1]. Ber fruit's main sugars are galactose, fructose, and glucose. Fruits are a great source of ascorbic acid and carotenoids, and their pulp has a spongy, sweet flavour. The fruits are drupes with a fleshy mesocarp (pulp), a thin pericarp (skin), and a highly lignified, pointed endocarp (stone) [2]. Ber fruit exhibits a respiratory climacteric behaviour. Although there are other maturity indices in use, colour is the most trustworthy. In terms of distribution and economic importance, the two most significant

species are *Z. jujuba* Mill. and *Z. mauritiana* Lamk [3]. Native to China, the former is referred to as the Chinese date or Chinese jujube. Among the two species, it is deciduous and less tropical, able to withstand temperatures as low as approximately 29 degree C. *Z. mauritiana* is an evergreen or semideciduous tree that is most significant to the Indian economy, where it is referred to as Indian jujube or Ber. Ber fruit is an edible drupe that is glabrous, globose, or oval [4]. Its diameter ranges widely from 1 to 2 cm, though some oval cultivars can reach 6 to 4 cm. The fruit is greenish-yellow or occasionally reddish, with a sweet and acidic pulp [5].

Chinese jujube fruits are oval-oblong, 1.5–2.3 cm long, dark reddish-brown to black, with a pulp that is naturally sweet. Each fruit has a short stalk and may be pendulous [6]. Although ber is typically consumed as a dessert fruit, it has good potential for use in processed goods like syrup, candy, and squash. Numerous studies have been conducted to prepare different processed products from ber fruit, including wine and juice, candy, dehydrated products, shreds, and powder [7]. The fruit of *Z. nummularia* is dried, powdered, and mixed with spices in western India to make a dish called churn. In Malawi and throughout West Africa, the fruit is also used to make an alcoholic beverage [8]. At room temperature (15–25 degree C), a two–four-day shelf life is typical. A significant amount of fruit is wasted, leading to significant postharvest losses, as a result of the abundance of fruits in the local markets during peak season [9]. Ber's respiratory activity pattern, in which the peak of respiration occurs one day before the ethylene burst, designates it as a climacteric fruit. Fruit drop, peel discoloration, and cracking are examples of preharvest physiological disorders that cause a significant reduction in ber fruit yield and quality [10].



Phalsa

One such promising, but little-used berry fruit is the phalsa (*Grewia asiatica* L.), which grows in tropical South Asia (Pakistan and India). It is rich in different bioactive compounds, including flavonoids, anthocyanins, tannins, and phenols [11]. Additionally, the fruit pulp has proteins, amino acids, and flavonoids—all of which are excellent sources of nutrition. Moreover, other plant parts have been utilized in herbal medicine to treat a variety of

illnesses, including diabetes, rheumatism, fever, cancer, and ageing [12]. The berry fruit has enormous nutritional value, but the industry has not given its commercial cultivation and production the attention it deserves. Recent berry fruit research and development has shown that these fruits are a rich source of bioactive food ingredients that can be used to create nutritious food products that are often referred to as functional foods [13]. Under limited water climate conditions, where temperatures range from 3? 65 C to 45? C, phalsa yields better results. This plant needs protection from extremely low temperatures, such as <3? 66 C, but it can withstand light frost [14]. Growing well at elevations greater than 1,000 meters above sea level is these 67 plants. Its fruit must be exposed to enough sunlight and high temperatures in order to ripen, or develop the proper colour and flavour. Although phalsa doesn't have exacting requirements for soil, well-drained loam soils are ideal for growing it [15]. The hardest part of the process is turning the raw berry fruit into functional foods and beverages with added value, like juices and jams. It has been reported that unless it is refrigerated, mature berry fruit cannot be stored for longer than 48 hours. The phalsa plant experiences multiple fruiting periods and an unpredictable growth pattern. Fruits ripen unevenly and steadily, so harvesting takes place over the course of a month [16]. Pest attacks, such as leaf-cutting caterpillars that severely harm plant foliage, are another related issue that has a negative impact on the quantity and quality of phalsa berry fruit. Phalsa is a very perishable, non-climacteric fruit [17].

Phalsa fruits are rich in fiber, vitamins, and important minerals but low in calories and fat. Different phytochemicals found in phalsa varieties are concentrated in the fruits, leaves, stem, bark, flowers, and even pomace [18]. The various alkaloids, glycosides, saponins, functional acids, various steroids, and flavonoids make up the phytochemicals. Phalsa fruit has been used in traditional medicine; it has been shown to be useful in treating blood, heart, and respiratory conditions as well as inflammation [19]. Phalsa juice has also been used medicinally to treat stomach pain; one such formulation includes 25–30 mL of phalsa juice combined with 3 g of carom seeds. Similarly, phalsa sherbet, a drink made with sugar and lemon, helps to relieve chest and stomach burns [20]. Phalsa berries are available in the market for a brief period of time and are primarily grown as wild shrubs. Cultivating these berries in a more organized way is necessary for their industrial-scale commercial processing. By using this technique, phalsa berry postharvest losses can be decreased and fruits of the right quality can be obtained based on their intended use [20].



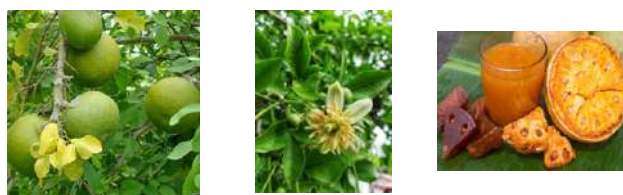
Bael

The Indian fruit Bael (*Aegle marmelos* Correa) is underappreciated. It is a member of the Rutaceous family of citrus fruits, and in India it is also referred to as the maredo, bel, belwa, sriphal, Indian quince, golden apple, holy fruit, and Bengal quince. In 1759, it was brought from India to Europe [21]. The tree, also known as “Shivaduma” (The Tree of Shiva), is revered in Hinduism and is offered in the prayers of the Hindu deities Lord Shiva and Parvati. Its therapeutic qualities have been documented in age-old texts such as the Yajur Veda, Upvana Vinod, and Charaka Samhita [22]. It has also been depicted in paintings found in the Ajanta Caves. Despite being a subtropical tree, Bael is highly adaptable and thrives in tropical, arid, and semi-arid environments [23]. Astringent, antidycentric, antipyretic, antiulcer, antidiabetic, antibacterial, antiviral, antifungal, anticancer, analgesic, radioprotective, antiviral, antimicrobial, and anti-helminthic properties have all been applied to various plant parts in ethnomedicine [24]. The Bael fruit has a lot of nutrients. The fruit's analysis reveals the following values: Per 100 g of edible portion, there are 61.5 g of moisture, 1.8 g of protein, 0.39 g of fat, 31.8 g of carbohydrates, 1.7 g of minerals, 55 mg of carotene, 0.13 mg of thiamine, 1.19 mg of riboflavin, 1.1 mg of niacin, and 8.0 mg of vitamin C [25].

Wood is used to make small agricultural tools, and pulp from seed and stem locules is used to make wrapping paper. Gum from these sources is used to stabilize drilling fluids, prepare adhesive, and waterproof and emulsion coat surfaces. Bael is a medium-sized tree with slow growth that can reach heights of 25 to 30 feet [26]. The short, thick, soft stem has spreading, occasionally spiny branches that are 2 to 5 cm long, with the lower branches drooping. The bark is flaking. The leaves are trifoliate, compound, and alternate. The opposite pair of leaves is short stalked and has an ovate or ovate lanceolate leaflet that is crenate, acuminate, and membranous, with a prominent midrib underneath [27].

It was discovered that softwood grafting and patch budding worked best in May and June (before the rain started). June, right after the monsoon's first rains, is the best month to plant in rainy conditions. Bael grafts are planted anywhere between five and eight meters apart, depending on the variety and agroclimatic circumstances [28]. It has been discovered that pruning 25% of the yearly

growth during the leafless stage promotes the emergence of new shoots and the formation of a dense canopy to protect against sunburn, particularly in dryland environments [29]. Fruit ripening can be determined by separating the fruit from the stalk, though this method isn't suitable for all genotypes and varieties. To prevent infection, mature Bael fruits are plucked off the tree one at a time, along with a 2-3 cm section of the fruit stalk. Serious diseases do not afflict Bael trees [30]. However, it has been reported that fusarium rot, fruit rot, leaf spots, powdery mildew, shot hole and fruit canker, and stalk end rot can all be easily controlled with chemical sprays. The caterpillars of lemon butterflies consume foliage and result in financial loss [31]. Other insect pests, such as spiraling whiteflies (*Aleuriodicus dispersus* Russell), brown scale, and citrus leaf miners (*Phyllocnistis citrella* Stainton), are either locally restricted or sporadic in their occurrence, making them of little concern [32].



Karonda

The plant known as Karonda (*Carissa carandas* L.) is a member of the Apocynaceae family, which also includes shrubs and even herbs. This hardy, prickly, deciduous shrub has a socioeconomic importance for the tribal communities of India. It grows naturally at elevations between 300 and 1800 meters in the western ghats and the Himalayas [33]. The fruit is a berry, and it usually grows in clusters of three to ten fruits. The fruit has an ovoid to ellipsoid shape and is coloured lighter near the seed and reddish on the skin. Karonda fruit can be either pinkish red or pinkish white depending on the stage of growth. Cultivated varieties are categorized into three groups: cultivars with dark purple fruits, white fruits with a pink blush, and green-fruited varieties [34]. Karonda is a tiny fruit that is grown on a very small scale. Because of its axillary spine, it can make an excellent bio-fence. *Carissa carandas* is a small to large evergreen deciduous shrub that can grow up to 2-4 meters tall [35]. The branches have sharp spines, and the stem is rich in white latex. The tiny, white flowers have a diameter of three to five centimeters. The fruit is a berry, and it grows in clusters of three to ten fruits. When ripe, fruits are pinkish white and turn red to dark purple. Depending on the genotype, ripe fruit can be pinkish red, green, or white in colour. Jan-Feb is flowering month, and May-June is fruit maturity month [36]. Fruits are typically picked when they are still immature for use as vegetables; fully ripe fruits are either

eaten raw or processed. The leaves are brown below and green above, with an oblong, conical shape that measures 4-6 inches long and 2-3 inches wide. Due to its hardness, this crop can withstand temperatures as high as 44°C and is resistant to saline, sodic soils with high pH levels. It is advised to harvest vegetables at the immature stage, and to harvest fruits at the fully ripened stage [37]. Karonda is also divided into pickle, spice, ornamental, and table-purpose varieties based on how they are used; these varieties are called Pant Manohar, Pant Sudarshan, Pant Suvarna, and Konkan bold, CHES K-II-7, CHESK-35, respectively [38].

Karonda fruits have a tart, delicately sweet, and astringent flavour. They also contain a significant amount of vitamin C, which boosts immunity, and iron, making them a great source of both nutrients. It also contains calcium, vitamin A, and phosphorus. Fruits can be consumed raw or used in recipes, pickles, jams, jellies, and chutneys. The fruit also has hepatoprotective, anti-microbial, and cardiogenic properties [39]. The 1.5 percent digestive fibers in karonda fruits help to reduce inflammation and increase the production of collagen. The levels of anthocyanin, flavanols, and phenols are thought to play a significant role in fruits' antioxidant activity. Additionally, this fruit qualifies as a protective food because it boosts immunity to illnesses and is a great source of bioactive compounds, nutraceuticals, and pharmaceuticals that lessen human suffering [40]. In the commercial world, karonda is propagated asexually by layering, budding, and hardwood cuttings, and sexually by seed propagation. Because seedlings are heterozygous, their growth rate slows down and they typically take two years to mature enough for transplantation. Hardwood cuttings have been used for asexual propagation of Karonda. After separating from the parent plant, the basal section of 1.5–2.0 cm cuttings were submerged in the growth regulator formulation at varying concentrations. Captan (0.1%) was applied to Karonda cuttings in order to prevent fungal infection [41].



Jamun

The Myrtaceae family member *Syzygium cumini* is also referred to as *Eugenia cumini* and *Syzygium jamunum*. Indian blackberries are also known by the names Jambul, Black Plum, Java Plum, Jamblang, and Jamun [42]. Berries from the tree bear fruit only once a year, and they

have a sweet-sour flavour. Ripe fruits are used to make health drinks, wine, squash, and jellies [43]. All parts of the tree, but the seeds most importantly, are used in conjunction with its nutritional use to treat diabetes mellitus. Jamun possesses various health benefits such as antioxidant, anti-inflammatory, anti-HIV, anti-tileishmanial and antifungal, scavenging of free radicals, nitric oxide, gastroprotective, anti-ulcerogenic, and radioprotective properties. Indian blackberry pulp contains the phytochemicals malic acid, oxalic acid, gallic acid, tannins, cynidin glycoside, oleanolic acid, flavonoids, essential oils, and betulinic acid [44]. The pulp of the jamun contains anthocyanins, delphinidin, petunidin, and malvidin-diglucosides. Fruits contain high concentrations of glucose, fructose, citric, malic, gallic, delphinidin-3-gentiobioside, malvidin-3-laminaribioside, petunidin-3-gentiobioside, and cyaniding diglycoside [45].

Fruit weights range from 83.70 to 85.80 grammes, with protein content between 0.70 and 0.13 grammes, crude fibre content between 0.15 and 0.30 grammes, carbohydrates between 14 grammes, and ash between 0.32 and 0.40 grammes. 8.30 to 15.00 mg of calcium, 35.00 mg of magnesium, 15.00 to 16.20 mg of phosphorus, 1.20 to 1.62 mg of iron, 26.20 mg of sodium, 55.00 mg of potassium, 0.23 mg of copper, 13.00 mg of sulphur, 8 I.U. of vitamin A, 0.01 to 0.03 mg of thiamine, 0.009 to 0.01 mg of vitamin B12, and 0.20 mg to 29 mg of niacin are present in every 100 g of edible portion [46].

Premium jamun juice works wonders for “squash,” syrup, and sherbet. The latter is a bottled beverage made in India that is made by heating crushed fruits to 140°F for five to ten minutes, then pressing out the juice and mixing it with water and sugar. Sodium benzoate and citric acid are then added as preservatives [47]. The bark's long-standing use as an astringent to treat conditions like dysentery can be attributed to its tannin and carbohydrate content. Jamun, a glycoside found in the seed, is thought to have anti-diabetic qualities [48]. Jamun fruit pulp and seeds have been shown to have a number of benefits for diabetic patients, including lowering blood sugar levels and postponing the development of cataracts and neuropathy. The most common use of jamun is as an adjuvant treatment for type-2 diabetes [49]. Jamun fruit is excellent for controlling diabetes because it lowers blood sugar levels. Its seeds contain glucoside, jamboline, and ellagic acid, which, in the event of an excess of glucose production, are said to be able to inhibit the conversion of starch into sugar [50]. An average dosage of 1-3 g of seed powder per day is recommended by ayurvedic texts. Furthermore, it has been suggested that diabetics consume ripe fruit juice in the amount of 0.5-2 tsp (2.5-10 ml) at least three times a day [51].



Aonla

The Indian gooseberry, or aonla (*Emblica officinalis*), is a significant fruit crop native to India that is farmed throughout the nation under a variety of agroclimatic conditions. With the exception of the Barbados cherry, it is the fruit with the highest vitamin C content, containing 500–1800 mg of ascorbic acid per 100g of fruit pulp [52]. Its therapeutic and medicinal qualities date back thousands of years to India, where the fruit's high vitamin C and pectin content led to its widespread use in Ayurvedic medicine to make remedies like triphala and chyavanprash [53]. Aonla has emerged as a significant fruit of the twenty-first century due to its hardy nature, capacity to thrive in a variety of wastelands, high productivity per unit area, nutritional and therapeutic qualities, and suitability for processing a wide range of value-added products [54]. The fruit helps treat cough, bronchitis, jaundice, diarrhea, dysentery, and anemia. Fruits can be used to make herbal jam, jellies, pickles, candy, shreds, murabba, and more. Aonla powder, which is better than synthetic vitamin C in treating deficiencies, is also made from fruit. Approximately 350 species, primarily shrubs, a few herbs, and some trees make up the new genus *Emblica* (formerly *Phyllanthus*), which Aonla belongs to in the family Euphorbiaceae and order Euphorbiales. Of the different aonla species, *E. officinalis* is the most widely cultivated for commercial purposes. Aonla varieties with distinct limitations include Banarasi, Francis, and Chakaiya. Francis is prone to necrosis, Banarasi is a shy bearer, and Chakaiya produces tiny, fibrous fruits [55].

Significant aonla cultivars that are being commercially cultivated in the nation under various edephoclimatic conditions include Anand-1, Anand-2, BSR-1, BSR-2, Goma Aishwarya, and Laxmi 52. According to Bajpai (1965), the aonla tree has a phyllanthoid branching habit with both determinate (short shoots) and indeterminate (long shoots) shoots [56]. The longer indeterminate shoots keep the season fresh with growth. These shoots do not fall from the tree or bear flowers; in contrast, determinate shoots develop on the nodes of indeterminate shoots, and depending on the cultivar, there may be three to five of these shoots at each node when springtime flowering occurs. Nonetheless, there are two flowering seasons in south India: February–March and June–July [57]. Aonla seeds take

two weeks to sprout. For best results, scion of desired varieties is patch budded on to six- to one-year-old seedlings that are used as rootstock between May and September. In general, seeds sown in the first week of March in 40 x 15 cm perforated polythene bags are ready for budding in July, saving approximately six months and aiding in more efficient nursery management than traditional methods. Additionally, seeds should be soaked in 500 ppm GA3 overnight for optimal germination and healthy seedlings [58].

An external indicator of an aonla fruit's maturity is a change in colour from greenish to whitish green or yellowish green, as well as a change in seed colour from creamy white to brown [59]. In addition to physiological maturity, other factors that can be used to assess maturity include specific gravity, fibre content, TSS/acid ratio, fibre appearance on the seed cover, and browning of the seed. Three years after budding, aonla trees begin to bear fruit [60]. On the other hand, the grove's commercial yield, or economic bearing, begins in its fifth year of life. After they reach maturity, Aonla fruits can be kept on the tree for up to 30 days without losing any of their quality. Plant hormone sprays, pre- and postharvest chemical treatments, grading, and packaging can all extend the shelf life of aonla fruits. Large-sized "A" grade fruits (more than 4.00 cm in length and diameter) are used to make murabba and candies; small-sized "B" grade fruits are used to make trifla and chavanprash; and blemished "C" grade fruits are used to make powder and shampoo [61].



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Multivariate Analysis of Genetic Divergence among Niger Genotypes in Relation to Quantitative Traits

Rajani Bisen¹, Pooja Patel¹, Vinod Kumar¹, Rishikesh Tiwari¹, Vikrant Khare¹ and M. Sujatha²

¹Project coordinator Unit (Sesame & Niger), ICAR, JNKVV, Jabalpur-482004 M.P.

²IIR, Hyderabad-500030, Telangana

*Corresponding Author Email : poojaarchana449@gmail.com

Abstract

Variability in 50 accessions of niger (*Guizotia abyssinica*) was assessed for yield and its attributing traits. Cluster I included thirty one accessions, cluster II included five accessions with high mean value of thousand seed weight and seed yield, cluster IV included four accessions, and the cluster III, V, VI, VII, VIII, IX, X, XI, XII and XIII were solitary since they had only one genotype. Cluster V with high mean value of number of branches per plant, cluster VII with high mean value of plant height, cluster VIII with high mean value of days to 50% flowering, cluster IX with high mean value of number of capsule per plant, cluster X with high mean value of number of seed per capsule and cluster XIII with high mean value of days to maturity. Maximum inter cluster distance was observed between cluster XII and cluster IX followed by clusters XII and V while, lowest divergence was noticed between cluster IX and V. Maximum intra cluster distance observed within cluster IV while lowest intra cluster distance was observed within cluster II. On the basis of present findings, it is evident that a lot of variability exists for the yield parameters among the niger accessions grown in different states of the country. Hybridization between accessions of different clusters will result in creation of wide spectrum of variability in subsequent segregating generations for further use in breeding programmes.

Key Words : Genetic diversity, inter-intra cluster, mean, niger, seed yield per plant.

Introduction

Niger (*Guizotia abyssinica*), is the only cultivated member of the taxon, Guizotia. Niger is diploid, with a chromosome number of $2n=30$ [1-5]. Its origin has been reported in Ethiopia and it was introduced in India before the Christian era [6] via trader route. It is completely self incompatible and highly cross-pollinated oil seed crop. It is used for human consumption as well as for industrial uses [7,8]. In Ethiopia, 50-60% of the edible oil requirement for domestic consumption is obtained from niger seed [9]. In India, it provides only about 3% of the edible oil requirement of the country and is cultivated in Andhra Pradesh, Madhya Pradesh, Orissa, Maharashtra, Bihar, Karnataka, West Bengal and union territory of Nagar Haveli. Madhya Pradesh has the largest area under the crop [10]. In addition to its use as an edible crop, its oil is used for industrial and pharmaceutical purposes also [11]. The oil content of niger is reported to be in the range of 30 to 50% of the seed weight and the oil has four major fatty acids which include two main unsaturated fatty acids viz., linoleic acid (18:2) and oleic acid (18:1); and two major saturated fatty acids viz., palmitic acid (16:0) and stearic acid (18:0) [12]. Genetic diversity has paramount importance in breeding and It is pre-requisite for any successful breeding programme. Genetic divergence among the parents play a vital role in cultivar improvement because a cross involving genetically diverse parents is

likely to generate more variability in segregating generations, and also which can be used for the desired improvement. Generally, plant breeders select the parents on the basis of phenotypic diversity. Hence the knowledge of genetic diversity among the parents with respect to characters which are to be improved is essential. Therefore it is necessary to collect, conserve and study the genetic diversity among various crops in the form of germplasm for establishing the wide genetic base for the posterity. Keeping these things in view, an effort has been made in the present study to evaluate a set of Niger genotypes with the objective to study the nature and magnitude of divergence.

Materials and Methods

Field experiment was conducted at Project Coordinating Unit (Sesame and Niger) Research Farm, JNKVV, Jabalpur (M.P) during *Kharif* 2022. Jabalpur is situated in 'Kymore plateau and Satpura hills agro-climatic region of Madhya Pradesh the total annual rainfall is mainly received between June last week to end of September last week. Fifty germplasm were used for this study. All of the germplasm shows national collection which is collected from the different growing region of the Indian country. The soil of experimental area was vertisol having clayey loam texture with uniform topography. The augmented block design was used for this experiment. Distance between the row and within the row was 40 cm and 15 cm.

Table-1 : Inter and intra cluster distances in 50 germplasm of niger.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10	Cluster 11	Cluster 12	Cluster 13
Cluster 1	229.60	455.74	404.53	1005.67	426.28	383.02	353.30	410.99	600.17	583.54	445.09	798.78	510.36
Cluster 2		217.90	646.29	1457.02	747.54	471.18	586.92	723.00	1026.99	834.71	580.70	535.52	492.12
Cluster 3			0.00	327.36	825.64	627.00	882.03	318.01	884.18	774.71	219.36	543.62	389.27
Cluster 4				271.33	1165.76	1398.53	1575.92	1039.09	1009.78	1294.05	875.57	1468.07	795.95
Cluster 5					0.00	601.17	324.33	1134.02	95.53	537.79	1211.92	1790.89	697.53
Cluster 6						0.00	219.76	757.14	825.23	129.35	753.85	850.72	396.03
Cluster 7							0.00	953.19	432.16	256.41	913.80	1266.91	465.88
Cluster 8								0.00	1413.76	1207.42	134.80	442.16	951.62
Cluster 9									0.00	599.02	1354.73	2061.80	633.77
Cluster 10										0.00	1139.74	1408.42	380.60
Cluster 11											0.00	201.60	584.14
Cluster 12												0.00	751.53
Cluster 13													0.00

Bold figures denote the intra cluster distances.

Table-2 : Cluster means of seed yield and its attributing characters of niger.

	Days to 50% flowering	Days to maturity	Plant height	Number of branches per plant	Number of capsule per plant	Number of seed per capsule	Thousand seed weight	Seed yield per plant
Cluster 1	43.13	104.13	103.44	9.56	64.67	35.71	4.40	8.48
Cluster 2	43.00	102.80	108.34	8.67	64.87	39.07	5.19	23.28
Cluster 3	44.00	102.00	90.00	10.00	56.67	41.67	4.13	11.26
Cluster 4	44.00	104.25	76.08	9.50	61.25	41.34	4.51	8.95
Cluster 5	43.00	105.00	100.00	12.00	81.67	33.33	4.73	7.17
Cluster 6	44.00	104.00	110.33	9.33	67.67	50.33	4.93	7.71
Cluster 7	42.00	113.00	111.33	10.00	73.00	40.33	4.78	5.50
Cluster 8	45.00	98.00	102.00	9.00	49.00	33.00	4.26	6.57
Cluster 9	41.00	112.00	94.00	10.33	82.67	34.33	4.51	5.87
Cluster 10	44.00	109.00	104.67	11.00	74.00	54.00	4.67	3.72
Cluster 11	43.00	106.00	99.33	9.33	47.67	36.33	5.12	13.35
Cluster 12	42.00	103.00	105.67	8.33	44.33	43.33	5.09	22.85
Cluster 13	44.00	115.00	97.00	7.67	66.00	48.33	4.88	17.08

Table-3 : Contribution of different characters towards genetic divergence (D^2) in niger germplasm.

S. No.	Source	Times ranked 1 st	Contribution %
1.	Days to 50% flowering	3	0.24 %
2.	Days to maturity	50	04.08 %
3.	Plant height	383	31.07 %
4.	Number of branches per plant	2	0.17 %
5.	Number of capsule per plant	369	30.12 %
6.	Number of seed per capsule	142	11.39 %
7.	Thousand seed weight	3	00.20 %
8.	Seed yield per plant	278	22.69 %

Genetic divergence was estimated using the Mahalanobis D^2 statistics. Character means were transformed into sets of uncorrelated variables using the pivotal condensation of common dispersion matrix according to Rao (1952). Although the D^2 statistics can handle a multidimensional

situation, higher order interactions do not contribute very much in any experiment. In all the D^2 combinations, the characters were ranked on the basis of their contribution to D^2 . Grouping of genotypes into different clusters was done according to Tocher's method (Rao, 1952).

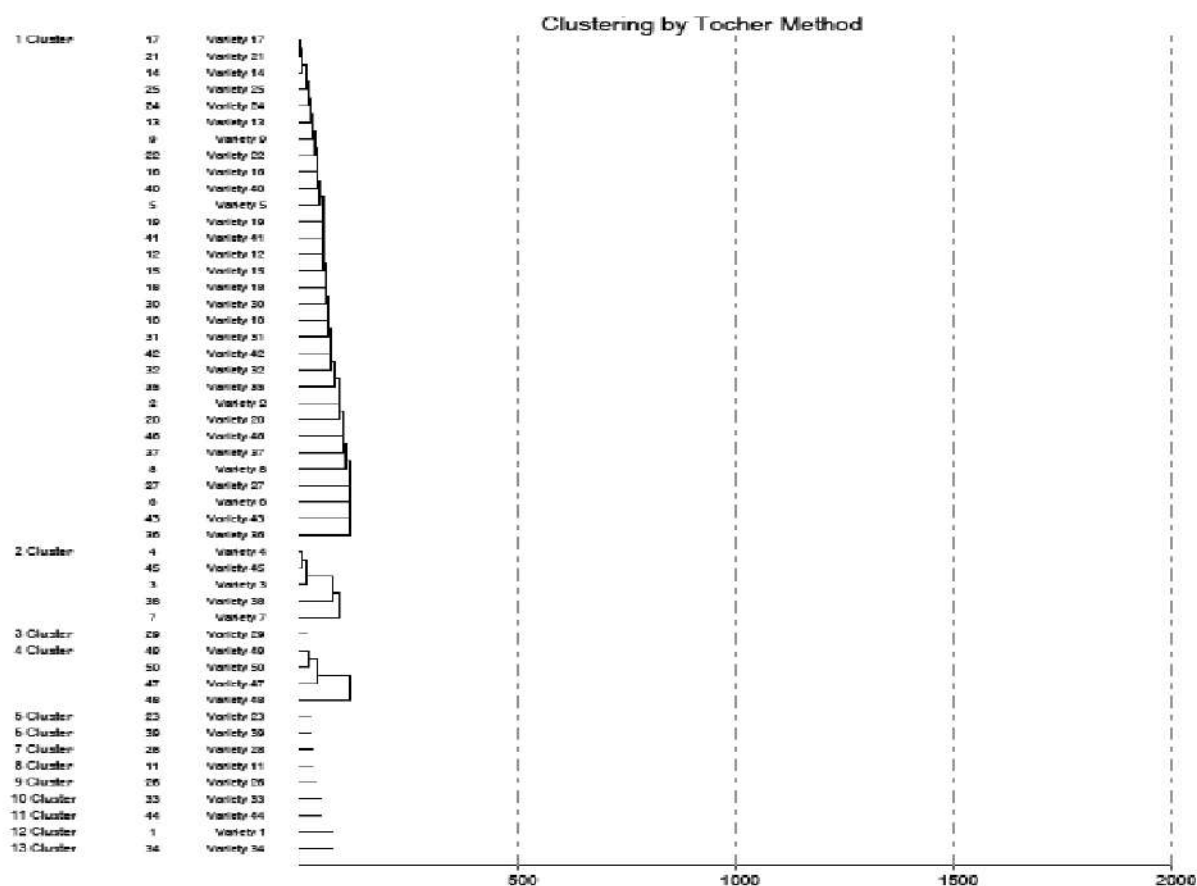


Figure-1 : Clustering by Tocher's Method.

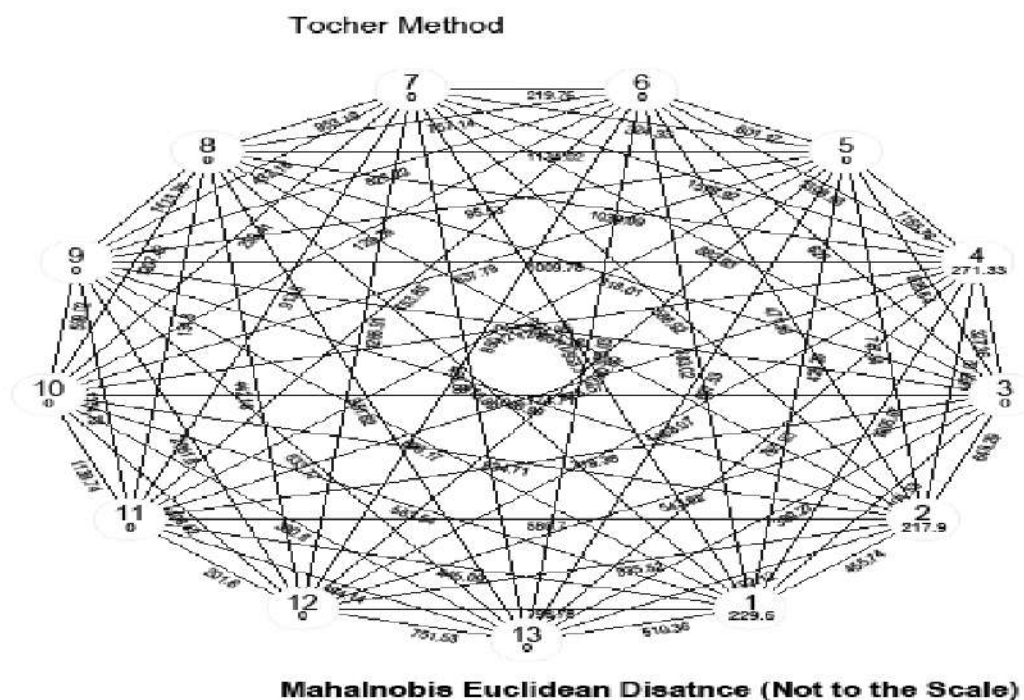


Figure-2 : Diagram showing intra and inter cluster distances among XIII clusters.

Results and Discussion

On the basis of D^2 statistics, the fifty genotypes evaluated for eight characters were grouped into thirteen clusters by using the Tocher's method as described by Rao (1952) [12]. Cluster I was largest with 31 genotypes followed by cluster II (5 genotypes), cluster IV (4 genotypes), while remaining were monogenotypic. In the present investigation grouping of genotypes into thirteen clusters (Fig.1) suggested the presence of substantial amount of genetic diversity in the material under investigation. The similar results depicted by earlier while evaluating niger genotypes Pulate *et al.*, (2013) [11], Khuntay and Kumar (2015) [4], Bisen *et al.*, (2016) [1] and Goyal and Bisen (2017) [3], Surayanarayana *et al.*, (2018) [14] and Patil *et al.*, (2019) [10].

The maximum intra cluster distance was observed for cluster IV ($D=271.33$) followed by cluster I ($D=229.6$) suggesting that genotypes present in these clusters might have different genetical architecture (Table 1). However, lowest intra cluster distance was observed in cluster II ($D=217.9$) indicating that genotypes present in these cluster might have genetical similarities with one another and appeared to have evolved from common gene pool. Cluster III, V, VI, VII, VIII, IX, X, XI, XII and XIII showed no intra cluster distance due to its monogenotypic nature.

Maximum inter cluster distance was observed between cluster XII and cluster IX ($D=2061.80$) followed by cluster XII and V ($D=1790.89$), cluster IV and VII ($D=1575.92$), cluster XII and IV ($D=1468.07$) and cluster IX and VIII ($D=1413.76$) indicating wide divergence among these clusters (Table-1 and fig.-2). These also suggest that genotype present in one cluster differ entirely from those presenting other clusters. The minimum inter cluster distance was found between cluster IX and V ($D=95.53$). The less inter cluster distance between these clusters revealed that genetic constitution of genotypes had close proximity.

Based on mean performance of clusters for 8 characters (Table-2), it was observed that cluster II exhibited the highest mean value of thousand seed weight and seed yield, Cluster V exhibited the highest mean value of number of branches per plant, cluster VII exhibited the highest mean value of plant height, cluster VIII exhibited the highest mean value of days to 50% flowering, cluster IX exhibited the highest mean value of number of capsule per plant, cluster X exhibited the highest mean value of number of seed per capsule and cluster XIII exhibited the highest mean value of days to maturity. On the basis of mean performance of different clusters, it was observed that cluster II and V, IX and X were performing well for most of the characteristics.

The variance of cluster mean provides information on relative importance of different characters towards seed yield per plant. The present study revealed that plant height was (31.07 per cent) contributed more to genetic diversity followed by number of capitula per plant (30.12 per cent), seed yield per plant (22.69 per cent) and number of seed per capitula (11.39 per cent). However, days to maturity (4.08 per cent), days to 50% flowering (0.24 per cent), thousand seed weight (0.20 per cent) and number of branches per plant (0.17 per cent) contributed least to the divergence (Table 3). Yadav *et al.* (2020) [15] also reported number of seeds per capitula was contributed highest per cent to genetic diversity. Patil *et al.*, (2007) [9] observed more divergence for number of capitulum per plant and seed yield per plant. Sreedhar *et al.* (2006) [13] were also of same opinion.

Conclusions

Cluster analysis revealed the wide range of diversity in the germplasms were grouped in thirteen clusters. On the basis of inter-cluster distance and cluster mean values, the genotypes of cluster XII, IX, V, VIII, X and VII were found superior and may be further utilized in breeding programmes. Thus, geographic origin cannot be considered as sole criteria for the selection of desirable donors for breeding programmes.

Author Contributions

Rajani Bisen and M. Sujata designed the experiments. Vinod Kumar analyzed the data and prepares the first draft. Pooja Patel, Rishikesh Tiwari and Vikrant Khare provided inputs and finalized the draft; all authors reviewed and finalized the manuscript. All authors have read and agreed to the published version of the manuscript.

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Evaluation of Wheat Yield and Economics of Wheat under Late Sown Conditions

Sintu Malik*, Pawan Kumar, Parveen Kumar and Pooja

Department of Agronomy, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana

*Email : sintumalik01@gmail.com

Abstract

Wheat is very important food grain crop in the world having high productivity and high production. Due to aberrant climatic conditions, there is urgent need to study the best possible ways to feed the increasing population. The present investigation was carried out in last week of December in which six varieties (WH 1124, WH 1105, HD-2967, HD 3059, WH 1021 and HD-3086) against six seeding treatments (T₁- Recommended seed rate (100 kg ha⁻¹), T₂- 25% higher seed rate (dry) than recommended with 18 cm row spacing, T₃- 25% higher seed rate (dry) than recommended + reduced row spacing (15cm), T₄- 25% higher seed rate (soaked) than recommended + reduced row spacing (15cm), T₅- 25% higher seed rate (soaked) than recommended + reduced row spacing (15cm) + 25% higher NPK than recommended, T₆- 25% higher seed rate (soaked) than recommended + reduced row spacing (15cm) + 25% higher NPK than recommended + 2.5% urea + 0.5% ZnSO₄ spray at anthesis) in sub plot with three replication. Maximum grain yield was recorded by HD 3086 higher than rest of varieties. The net returns, gross returns and B:C increased significantly with seeding treatments and T₆ treatment gave significantly higher returns.

Key words : Variety, seeding treatment, yield, seed rate.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important food grain crop in the world. In terms of production and consumption wheat is placed just after rice in India. It is the most important staple food of about two billion people i.e about 36% of the world population. Among various factors responsible for low yield of the wheat crop, sowing time and varietal selection are of primary importance. A proper planting date is a primary factor for crop production of wheat. The ideal temperature regime during the wheat crop season is 20-22°C at sowing, 16-22°C at tillering to grain filling and slow rise of temperature to 40°C at harvesting (Sharma, 2000). However, the seed can germinate in the temperature range of 3.5-35°C. A sudden increase in temperature for a period of 4-5 days at any stage of the wheat crop can adversely affect the crop yield (Spiertz et al., 2006) and even a one-day abnormal increase in temperature at grain formation and filling stage can result in large grain losses (Alexander et al., 2010). Ideally the best temperature regime during the wheat crop season is 20-22°C at sowing, 16-22°C at tillering to grain filling and slow rise of temperature to 40°C at harvesting (Sharma, 2000). However, the seed can germinate in the temperature range of 3.5-35°C. A sudden increase in temperature for a period of 4-5 days at any stage of the wheat crop can adversely affect the crop yield (Spiertz et al., 2006) and even a one-day abnormal increase in temperature at grain formation

and filling stage can result in large grain losses (Alexander et al., 2010).

Materials and Methods

The experiment was laid out in split plot design for two consecutive years during (Rabi season) 2018-19 and 2019-20 having six varieties (WH 1124, WH 1105, HD-2967, HD 3059, WH 1021 and HD-3086) in main plot and six seeding treatments (T₁- Recommended seed rate (100 kg ha⁻¹), T₂- 25% higher seed rate (dry) than recommended with 18 cm row spacing, T₃- 25% higher seed rate (dry) than recommended + reduced row spacing (15cm), T₄- 25% higher seed rate (soaked) than recommended + reduced row spacing (15cm), T₅- 25% higher seed rate (soaked) than recommended + reduced row spacing (15cm) + 25% higher NPK than recommended, T₆- 25% higher seed rate (soaked) than recommended + reduced row spacing (15cm) + 25% higher NPK than recommended + 2.5% urea + 0.5% ZnSO₄ spray at anthesis) in sub plot, giving rise to 36 treatment combinations which were sown at last week of December and replicated three times making 108 of total plots.

Results and Discussion

Grain yield (q/ha) : treatment T₆ have highest influence of grain yield of wheat whereas in varieties HD 3086 recorded maximum grain yield that was at par with WH 1124 (48.2 and 49.9 q ha⁻¹ and 47.6 and 49.6 q ha⁻¹) during both rabi seasons. Both treatment and varieties

Table-1 : Effect of agronomic management practices on yield of wheat.

Varieties	Grain yield (q/ha)		Straw yield (q/ha)		Biological yield (q/ha)		Harvest Index (%)	
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
WH 1105	42.9	44.4	58.9	59.0	101.9	103.4	42.2	42.9
WH 1124	47.6	49.6	69.7	67.1	117.3	116.7	40.6	42.5
HD 3059	44.9	47.2	65.1	65.4	110.0	112.6	40.9	41.9
HD 2967	42.9	43.9	59.7	59.7	102.6	103.6	41.8	42.4
WH 1021	31.7	33.2	49.5	51.0	81.2	84.1	39.1	39.4
HD 3086	48.2	49.9	67.6	68.5	115.8	118.4	41.6	42.2
SEm+	0.17	0.22	0.44	0.25	0.54	0.27	0.16	0.14
CD (p=0.05)	0.54	0.70	1.41	0.81	1.71	0.75	0.51	0.43
Seeding Treatments (T)								
T ₁	41.4	42.8	59.9	60.6	101.3	103.5	40.9	41.3
T ₂	42.3	43.8	61.8	61.5	104.1	105.4	40.6	41.5
T ₃	41.9	43.3	61.5	61.2	103.3	104.5	40.5	41.4
T ₄	42.5	44.5	61.4	61.3	103.9	105.9	40.8	42.0
T ₅	44.7	46.4	62.7	62.8	107.4	109.2	41.5	42.4
T ₆	45.5	47.3	63.2	63.3	108.6	110.5	41.8	42.7
SEm+	0.17	0.11	0.28	0.21	0.54	0.37	0.10	0.09
CD (p=0.05)	0.47	0.32	0.78	0.60	1.10	1.19	0.29	0.26

Table-2 : Effect of agronomic management practices on economic returns of wheat.

Varieties	Economic returns							
	Cost of Cultivation		Gross return		Net return		BC ratio	
	(₹ ha ⁻¹)		(₹ ha ⁻¹)		(₹ ha ⁻¹)			
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
WH 1105	58226	59775	96087	99995	37861	40220	1.65	1.67
WH 1124	58226	59775	107867	112013	49641	52238	1.85	1.87
HD 3059	58226	59775	101536	107105	43309	47330	1.74	1.79
HD 2967	58226	59775	96190	99343	37964	39568	1.65	1.66
WH 1021	58226	59775	72672	76846	14446	17071	1.25	1.28
HD 3086	58226	59775	108272	113067	50046	53293	1.86	1.89
Seeding Treatments (T)								
T ₁	57518	59068	93599	97611	36081	38543	1.63	1.65
T ₂	57818	59368	95685	99726	37867	40358	1.66	1.68
T ₃	57818	59360	94887	98608	37069	39248	1.64	1.66
T ₄	57920	59470	96052	100955	38132	41485	1.66	1.70
T ₅	58445	59995	100419	104896	41974	44901	1.72	1.75
T ₆	59838	61388	101981	106574	42143	45186	1.70	1.74

have significant effect on grain yield. In year 2018-19, T₆ obtained highest yield of 45.5 q ha⁻¹ and HD 3086 of 48.2 q ha⁻¹ (Table-1). It might be due to its genetic makeup and it can be reflected to higher dry matter accumulation in the variety. Corroboration findings were reported by Yusuf (2019).

Straw yield (q/ha) : Variety WH 1124 recorded maximum straw yield (69.7 and 67.1 q ha⁻¹) which was at par with HD 3086 (67.6 and 68.5 q ha⁻¹) whereas, WH 1021 recorded minimum (49.5 and 51.0 q ha⁻¹), respectively. Among seeding treatments, T₆ recorded

maximum straw yield (63.2 and 63.3 q ha⁻¹) for both years (Table-1). This might be due to considerable increase in number of tillers, plant height and dry matter accumulation in wheat crop which was also reported by several workers (Kumar *et al.*, 2000, Negi *et al.*, 2003 and Kamboj (2018).

Biological yield (q/ha) : In year 2018-19, WH1021 obtained lowest biological yield of 81.2 q ha⁻¹ among varieties and T₁ obtained lowest biological yield of 101.3 q ha⁻¹ among seeding treatments. In year 2019-20 T₆ have highest yield *i.e.* 103.5 q ha⁻¹ and HD 3086 of 118.4 q

ha⁻¹. This was due to higher production of dry matter, higher number of tillers and higher test weight. Amrawat *et al.* (2013), Kamboj (2018) and Yusuf (2019) reported that varieties differed from each other with respect to biological yield.

Harvest Index (%) : Seeding treatments and varieties have significant effect on harvest index. In varieties, it varied between 39 to 42% while, among treatments, it varied between 40 and 42%. WH 1105 was found to have highest harvest index of 42.2 % followed by HD 2967 (41.8%), HD 3086 (41.6%), HD 3059 (40.9%), WH 1124 (40.6%) and WH 1021 (39.1%), respectively. It might be due to its high grain yield production ability. Several workers have also noticed the variation in the varieties of wheat for harvest index (Gill *et al.*, 2016; Kumar *et al.*, 2017, Singh *et al.*, 2017 and Kamboj 2018).

Economics : A critical examination of data revealed that gross return, net return and B:C ratio decreased in variety WH 1021 during 2018-19 and 2019-20, while it was recorded maximum in HD 3086 (1,08,272 and 1,130,68 ? ha⁻¹, 50,046 and 53,293 ? ha⁻¹, 1.86 and 1.89, respectively). Among seeding treatments, highest gross return, net return and B:C was recorded in T₆ (1,01,981 and 1,06,574 ? ha⁻¹, 42,143 and 45,186 ? ha⁻¹ and 1.70 and 1.74, respectively) followed by treatment T₅ (Table 2). Higher economic returns with enhanced 25 percent NPK dose and seed rate might be reason for increase in grain and straw yields. Similar results of combined application of N and biofertilizer on net returns and B:C were reported by Verma *et al.* (2015) and Kumar *et al.* (2016).

Conclusions

It was concluded that HD 3086 and WH 1124 were best varieties for late sowing with T₆ (25% higher seed rate (soaked) than recommended + reduced row spacing (15cm) + 25% higher NPK than recommended + 2.5% urea + 0.5% ZnSO₄ spray at anthesis) seeding treatment being significantly at par with T₅ (25% higher seed rate (soaked) than recommended + reduced row spacing (15cm) + 25% higher NPK than recommended). Among the varieties, the maximum yield and yield attributes were recorded in HD 3086 variety significantly at par with WH 1124.

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Nanotechnology in Horticulture : A Blossoming Frontier for Sustainable Agriculture

**Anushi¹, Shubham Jain^{2*}, Rajat Sharma³, Vivek Thapliyal⁴, Swosti Debapriya Behera⁵,
Mohamad Tayeeb Ulla H.⁶, Songthat William Haokip⁷ and Avdhesh Kumar⁸**

¹Department of Fruit Science, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh

²Department of Fruit Science, College of Horticulture and Forestry, ANDUAT, Ayodhya, U.P.

³GBPUAT, Pantnagar, Uttarakhand, Now serving as District Horticulture Officer or Equivalent, Govt. of Haryana

⁴GBPUAT, Pantnagar, Uttarakhand, Now serving as Horticulture Development Officer or Equivalent, Govt. of Haryana

⁵School of Agriculture, GIETU, Gunupur, Odisha.

⁶Department of Postharvest Technology, University of horticultural Sciences, GKVK Bengaluru, Karnataka

⁷Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University (I), Pasighat-791102, Arunachal Pradesh

⁸Department of Fruit Science, ANDUAT, Kumarganj, Ayodhya, Uttar Pradesh

*Corresponding Author Email : shubhu15296@gmail.com

Abstract

Nanotechnology has emerged as a promising frontier in horticulture, offering innovative solutions to various challenges in plant production, crop protection, and resource management. This review explores the diverse applications of nanotechnology in horticulture, including nanomaterials, nano sensors, and nano delivery systems, with a focus on their impact on crop yield, quality, and environmental sustainability. We examine recent developments in nanotechnology and their potential to revolutionize the way we cultivate, monitor, and protect plants. The utilization of nanomaterials in fertilizer and pesticide delivery, the development of smart nano sensors for precision agriculture, and the enhancement of plant stress tolerance are discussed. The review also addresses the safety and regulatory concerns associated with nanotechnology in horticulture. As we confront the challenges of feeding a growing global population while preserving natural resources, nanotechnology holds great promise for shaping the future of sustainable horticulture.

Key words : nanotechnology, horticulture, nanomaterials, sensors, plant.

Introduction

The Greek word “nano,” which means dwarf, is where the word “nanotechnology” originated. The Nobel Prize winner Richard Phillips Feynman’s historic statement is closely linked to the development of nanotechnology. [1]. Nanotechnology is the study of science, engineering, and technology at the nanoscale (roughly 1 to 100 nanometers) [2,3,4,5,6]. In fact, because of their high surface to volume ratio, nanoparticles show off excitingly distinct features compared to bulk materials. Furthermore, any molecule, element, or material’s catalytic activity is significantly increased by quantum phenomena that take place at the nanoscale [5,6,7,8].

With a history spanning more than two millennia, nanotechnology is an emerging field of technology [12]. It has been thriving as a cutting-edge instrument in many scientific fields, such as chemistry, physics, medicine, materials science, aerospace, pharmaceutical, agriculture, food science, and even horticulture [13]. A subfield of agricultural science and art that deals with the management and cultivation of ornamental plants, fruits, vegetables, and flowers is called horticulture. Given the changing global climate, ensuring the food and nutritional

security of the world’s growing population is undoubtedly a formidable and challenging task. Thus, employing cutting-edge technological methods like biotechnology and nanotechnology to increase productivity and reduce post-harvest losses are thought to be the most effective ways to handle this difficult task.

The benefits of nanomaterials in enhancing crop plant yield, quality, and postharvest losses have been extensively documented in the literature [14]. While numerous reviews have examined the potential of nanotechnology in agriculture, no thorough analysis has yet to focus on how applying nanomaterials to horticultural crops can improve their yield, quality, and decrease postharvest losses.

Nanomaterials and their various aspects in horticulture

Nano fertilizers : Any synthetic or natural material (apart from liming materials) that is sprayed on plant tissues or mixed into the soil to supply one or more critical nutrient elements to enhance crop plant nutrition is referred to as a fertilizer. Fertilizers come from a variety of sources, both naturally occurring and artificially manufactured. In modern agriculture, fertilizer application is essential for

increasing crop productivity. A major obstacle to crop fertilization is the significant amount of fertilizer that is lost through various means, which ultimately contaminates the environment and raises production costs [15,16]. The application of nano fertilizers is a noteworthy recent development in lowering the loss of applied fertilizers to the environment.

The process of creating nano fertilizers involves combining plant nutrients with nanomaterials, coating nutrient molecules with a thin layer of nanomaterials, and creating nanosized emulsions. In comparison to traditional fertilizers, nano fertilizers and nano biofertilizers carefully increase soil fertility and bioavailability by incorporating both natural and synthetic materials [17]. Retaining its nano size and aggregates when interacting with soil particles or crop plant roots is another characteristic of a nano-fertilizer. The size and form of the nanoparticles completely determine the reactivity of the fertilizers [18].

Different ways using nano fertilizers in horticulture is macronutrient nano fertilizers, micronutrients nano fertilizers, nano plant growth stimulator, nano pesticide, nano fungicide etc.

Macronutrient nano fertilizers : Macronutrients are those necessary nutrient elements that are needed in comparatively greater amounts for healthy plant growth and productivity. One or more of these nutrient elements are typically combined with nanoparticles to increase their efficiency of use [17,19]. This allows the nutrients to be added to the target crops in the right ratio and their extent quantity to be reduced while also providing extra benefits. The term “slow” or “controlled release” refers to the N source nano fertilizers, which include hydroxyapatite, zeolites, and mesoporous silica nanomaterials. The efficiency and productivity of crop plants have increased with the use of nano fertilizers, showing encouraging results [20,21].

Micronutrients nano fertilizers : Micronutrients help plants fend off diseases and pests by regulating hormones (such as auxins) and facilitating the biosynthesis of proteins and carbohydrates. It has been reported that zinc-based nano fertilizers are beneficial for a variety of horticultural crop plants, including garden peas, cucumbers, spinach, tomatoes, eggplants, chilies, coriander, and onions [22,23,24,25]. Copper (Cu), another significant micronutrient, is necessary for the growth and development of plants. Many horticultural crop plants, including lettuce and tomatoes, have their physiological development significantly improved by

the application of Cu nanoparticles at the right concentration [26,27]. Additionally, manganese (Mn) is essential to the physiological and metabolic processes that plants go through. It also acts as a co-factor, regulating various enzyme activities to help plants tolerate a range of environmental stresses [28].

Nano pesticide : Dilution of pesticides with water that has been nano treated could significantly increase their efficacy and decrease the amount of chemicals used. When it comes to pest control, nano pesticides are more effective than traditional pesticides. In addition, using them cuts the cost in half when compared to traditional pesticides [29]. The majority of nano pesticide formulations are highly target-specific and have controlled release, making them environmentally friendly. These characteristics of nano-pesticides improve pesticide usage while significantly lowering residue levels and pollution in the environment.

Nano fungicide : Chemically diverse fungicides, including dicarboximides, cupric salt, dithiocarbonates, dinitrophenol, triazoles, thiabendazole, organotin compounds, and thiocarbamates, are used to control fungal diseases. With regard to their target specificity, the majority of these fungicides are ill-suited. The target specificity of these chemical fungicides can be readily ensured through the application of nanotechnology.

Nanoparticle uptake, translocation, and accumulation

There is currently very little knowledge regarding precise mechanisms and precise details pertaining to the uptake, translocation, and accumulation of nanoparticles. But the literature that is currently available only paints a partial picture of how nanoparticles enter, travel through, and move [30]. The primary routes by which nanoparticles enter plants are through their roots (root entry) or their leaves (foliar entry), though they can also enter through other vegetative parts. Following treatment with nanoparticles, the plant passively absorbs the particles through its stomata, bark, lenticels, damages, and wounds. Nanoparticle size has an impact on the uptake, translocation, and accumulation of NPs. Nanoparticles that are smaller than the diameter of a cell pore can enter readily [31].

Seed priming through nanotechnology

In order to start the germination's metabolic processes, seeds are hydrated under carefully regulated temperature and osmotic potential. Following this, the seeds are redried to their initial moisture content. This process is known as seed priming. germination, after which it was

dried again to its initial moisture content [32]. These seeds germinate right away because the process has already begun when they are sent to the farm to be sown. This method improves germination rate and uniformity while shortening the germination period. The most delicate time when seeds are susceptible is during the germination phase. Consequently, seed priming can shorten the germination period and speed up the process [33]. Improved yield and quality can be obtained by seed priming watermelon with Ag nano particles, onion with Au and Ag NPs, carrot, beetroot, and fenugreek with nano-iron pyrite for 12 hours, and spinach with nano-iron pyrite for 14 hours [34].

When parsley seeds were treated with nano-anatase, the amount of chlorophyll in the seedlings increased, as did their fresh weight, seed vigor index, and germination rate. The new technology known as “seed nano priming” makes use of media containing nano formulations that are held in place by the seed coat. These nanoparticles fall into two categories: sustained release nanocarrier systems and active nanoparticles [35].

Using nanotechnology for gene editing and genetic engineering

The use of nanoparticles for gene transfer has gained attention recently due to the development of nanotechnology. Because each type of nanoparticle is unique, there are differences in the delivery mechanism [36]. Therefore, the process of pollen-mediated gene transformation is used to create transgenic seeds. Consequently, nanotechnology plays a bigger part in improving crops [37]. Third-generation genome editing (GE) technology, known as the clustered regularly interspaced short palindromic repeat (CRISPR)/Cas 9 system, is a novel and effective tool for crop protection and improvement [38]. The transfer of proteins and DNA to the target site is a crucial step in CRISPR/Cas9 gene editing. Due to their effectiveness as transport agents, nanoparticles carry the material to the desired location [39].

Horticultural nanofabrication

It is the process of creating instruments to gauge the size of nanomaterials and nanoparticles. It employs a bottom-up method, in which the desired structure is created by assembling atoms or molecules at the nanoscale, or a top-down method, in which the desired structure is obtained by removing one atom at a time [40]. In contrast to traditional nanomaterials used in the creation of goods like clothing or mobile phones, clay minerals and composites are utilized in agriculture for nanofabrication. Their abundance, affordability, crystalline

nature, high adsorption capacity, and other unique qualities make them advantageous to use. They have both covalent and ionic bonds, which makes them a superior nutrient transport system that can be better utilized [41]. Microfabricated xylem vessels are an excellent example of a nanofabrication application. These nanofabricated instruments are helpful in comprehending the biological and physio-chemical interactions of bacteria that inhibit plant xylem growth [42].

Food packaging using nanotechnology

For food to travel over long distances and maintain its quality and freshness, safe packaging is essential. Nanotechnology appears to be a viable substitute for current food packaging techniques. The primary drawback of food packaging is the material utilized, which degrades the food it contains. Common polymers used in food packaging include polyethylene, polystyrene, and polyvinyl chloride. These materials are impermeable to water and atmospheric gases, preventing the growth of microorganisms. Polymer nanocomposites, which can take the shape of nanotubes, nanosheets, nanoplatelets, nanorods, and nano whiskers, are created by combining nanomaterial and polymer matrix. These materials are thought to be novel for use in food packaging. Several nanoparticles, including clay and silica NPs, CNTs, TiO₂, and ZnO, are utilized in packaging as either organic or inorganic fillers [43]. Food packaging techniques based on functional nanomaterials include bio-based packaging, active packaging, smart packaging, and enhanced food packaging. These various packaging techniques keep an eye on food conditions and enhance freshness, flavour, and shelf life. The application of calcium oxide nanoparticles was found to extend the shelf life of cucumber plants [44]. experiments were carried out on *Cucumis sativus*, a member of the Cucurbitaceae family, to investigate the effects of CaO nanoparticles added to latex coatings and poly vinyl acetate-co-vinyl alcohol during the postharvest storage period. According to their findings, applying Poly vinyl acetate-co-vinyl combined with CaO NPs had a good impact on cucumber fruit, extending its shelf life [45]. Better flavour, taste, nutritional value, and extended shelf life are all provided by these nano products. They effectively transport to the intended location, stop the breakdown of bioactive compounds in highly acidic environments, and keep food items fresh thanks to their edible coatings [46].

Nanofilms/Coatings for horticultural crops

Metal nanoparticles are transported by nanofilms, which act as barriers to prevent microbe growth. These innovative materials control the rate of respiration, regulate colour change and decomposition, balance storage conditions, and increase the shelf life of

horticultural crops. It is suggested that using edible nanofilms to balance the properties of horticultural products during storage and shelf life is a feasible solution. Recently, an edible nano-composite film containing solutions of ZnO-NPs, glycerol, and aloe vera gel was created [47].

Nanosensors for Accurate Gardening

Any device that can transmit information from the nanoscale level to the macroscopic level regarding the behaviour and properties of nanoparticles is referred to as a nano sensor. Real-time tracking of field crops, crop growth, and the incidence of pests and diseases requires the use of nano sensors. Metal nanotubes, nanowires, nanofibers, nanocomposites, nanostructured polymers, and various allotropes of carbon, such as carbon nanotubes, graphene, and fullerenes, are examples of nanosized materials that can be used to manufacture sensors [48]. In order to reduce environmental pollution and production costs, real-time monitoring can help reduce the overuse of pesticides and fertilizers during crop production. Smart agriculture, which is more environmentally friendly and energy-efficient for sustainable agricultural practices, is created through the application of nano sensors to conventional agriculture [49].

Constraints of nanotechnology in horticulture

Even though contemporary technologies have greatly improved the world in many ways, they also have negative effects [50]. Therefore, it is impossible to ignore the negative effects of nanotechnology, even though it represents a frontier of scientific advancement in the modern era. Any kind of biotic or abiotic element of the environment, including soil, water, air, animals, plants, and insects, can be negatively impacted by nano formulations released into the environment [38]. The harm that toxic concentrations of nanomaterials can do to a plant or the environment is known as nano phytotoxicity. Cucumis sativus (cucumber) grown in soil systems containing higher doses of zinc oxide NPs also showed negative effects [51].

Conclusions

In conclusion, the integration of nanotechnology into horticulture presents a promising frontier for achieving sustainable agriculture and addressing the challenges of a growing global population. The innovative applications of nanomaterials, nano sensors, and nano delivery systems have the potential to revolutionize the way we cultivate, monitor, and protect plants. Nanomaterials improve soil quality, enhance nutrient delivery, and offer effective solutions for disease and pest management, contributing to increased crop yields and better-quality produce. Nano

sensors enable precision agriculture, allowing real-time monitoring of plant health and environmental conditions, thereby optimizing resource use and decision-making. Nano delivery systems enhance the efficiency and reduced environmental impact of nutrient and agrochemical application. Furthermore, nanotechnology aids in improving plant stress tolerance, making crops more resilient to adverse conditions. However, it is crucial to address safety and regulatory concerns to ensure the responsible use of nanotechnology in horticulture. As we continue to explore this blossoming frontier, the future of sustainable horticulture looks promising, with the potential to meet the ever-growing demand for food while conserving natural resources and minimizing environmental impact. Nanotechnology stands poised to play a crucial role in shaping the future of horticulture for the better.

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Effect of Heating on Physico-Chemical, Whey Syneresis, Textural and Microbiological Properties of Ricotta Cheese Spread during Storage

Avinash Chandra Gautam¹, Nitika Goel¹, Veena N.², Pranav Kumar Singh¹ and S. Siva Kumar¹

¹Department of Dairy Technology, CoDST, GADVASU, 141004, Punjab, India

²Department of Dairy Chemistry, CoDST, GADVASU, 141004, Punjab, India

Abstract

Ricotta cheese spread is a novel product obtained by blending ricotta cheese with hydrocolloids and water for moisture adjustment. The product have low shelf-life due to its high moisture content and water activity close to unity. In this study the sample were heat treated to improve the shelf life of the ricotta cheese spread. Result showed that the pH of both the samples were increased during the storage. Moisture content of the heat treated sample was decreased during storage whereas whey syneresis was increased during storage. Textural evaluation revealed that the heat treated sample losses its structure and consistency which make it less spreadable. Microbiological evaluation revealed that the heat treated sample is safer than control sample as SPC were found to nil till 21st day and coliform were reported nil till 35th day.

Key words : Ricotta cheese spread, hydrocolloids, heating treatment.

Introduction

Whey is the major by-product obtained from cheese industry which is considered as waste for the industry. Hence, it is usually discarded but discarding whey will create lots of environmental issue as BOD of whey reported around 30,000 mg/l (Pintado *et al.*, 2001). So it is better to utilize this by-product into some value added products as it is nutritionally rich. Whey cheeses hold great potential for its utilization.

Ricotta cheese is one of the most common whey cheese consumed freshly due to its low shelf-life. It was originated in Italy and is now gaining lots of consumers' interest. It is generally yellowish-white coloured cheese with high moisture content and water activity around one. It is prepared by direct acidification of whey, milk or combination of whey and milk in a definite proportion after heating to 90°C and finally produces a compact mass with granular texture. (Martins *et al.*, 2010; Rubel *et al.*, 2019). Kisan *et al.*, 2020 reported the shelf life of ricotta cheese and probiotics ricotta cheese 12 days.

Ricotta cheese spread is the product obtained from ricotta cheese curd which is used as raw material for ricotta cheese spread. Ricotta cheese spread is obtained by blending the ricotta cheese curd with appropriate hydrocolloids and required amount of water for moisture adjustment to make the ricotta cheese curd spreadable (Gautam *et al.*, 2023). Ricotta cheese spread consumed fresh due to its low shelf-life as it contain large amount of water.

Hydrocolloids are high molecular weight molecules and are among the most commonly used ingredients in

the food industry because of their versatile role in food matrices such as fat replacers, stabilizing and thickening agents (dairy based products), emulsifiers (beverages), bulking agents (bakery), coating and texturizing agents (confectionary), etc. (Jafari *et al.*, 2012; Nishinari *et al.*, 2018). The selection of hydrocolloids is based on the reduction of whey syneresis during storage. LBG is very effective in reducing the whey syneresis but it is secondary hydrocolloids which make it costly. Hence we decided to use LBG and Guar gum in combination. Many authors uses hydrocolloids in combination to study its effect (Zhao *et al.*, 2023; Gulzar *et al.*, 2015; Ruble *et al.*, 2019; Joyner and Damiano, 2015). But there is very limited study were in combination of LBG and Guar gum.

Moreover, the application of heat is the most suitable approach for eradicating microorganisms and enhancing the longevity of a product. The lack of heating typically associated with cheese can be attributed to its dense composition and texture. Currently, there is a lack of relevant information regarding the impact of heating on the quality of cheese in terms of its physico-chemical properties, texture, color, and microbiological aspects. We have made the decision to subject one of our cheese samples to heat in order to investigate the aforementioned phenomenon. The objective of this study was to investigate the effect of heating on physico-chemical, textural and microbiological properties of RCS.

Materials and Methods

Raw materials : Fresh, clean and good quality mozzarella cheese whey (sweet whey) and mixed milk with 1.5% fat was for the preparation of LF-RCS was obtained from

Experimental Dairy Plant, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana and stored at 4°C until utilized for the product making. Good quality common salt and citric acid was obtained from the local market. Hydrocolloids like Locust bean gum (LBG) and Guar gum (GG) were procured from Hi-Media Laboratories, Mumbai. Preservatives procured from CHR-Hansen (Nisin), Pune and Hi-Media Laboratories (Potassium Sorbate), Mumbai.

Double jacketed milk boiler (DJMB) : DJMB parched from local market which is made up of stainless steel (AISI-304).

Preparation of Ricotta Cheese Spread (RCS) using sweet cheese whey and mixed milk with 1.5% fat : Ricotta cheese curd (RCC) is the intermediate product prepared for the preparation of RCS. Sweet whey obtained after the preparation of mozzarella cheese was used for the manufacturing of RCC. RCC then further converted into RCS as per the method standardized by Gautam et al., 2023. RCC was prepared using mixture of whey and milk (1.5% fat) in the ratio 80:20. The procedure for the preparation of LF-RCC is given in fig-1:

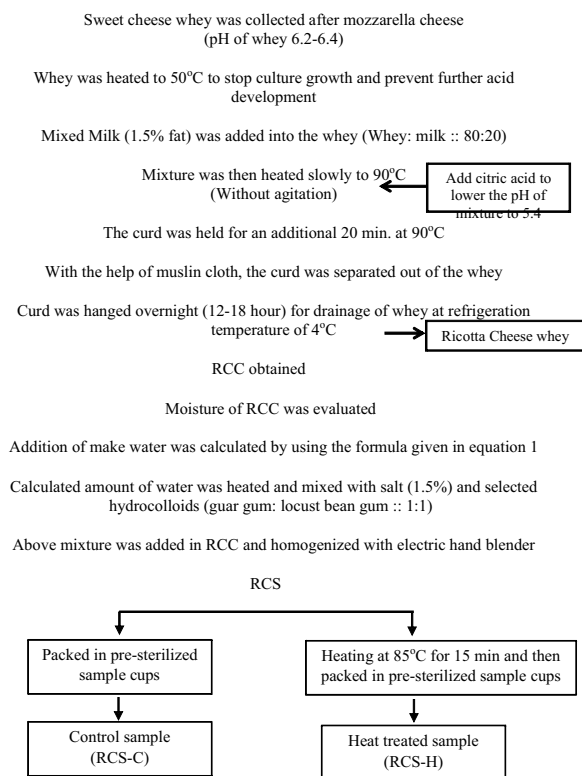


Fig.-1: Preparation of RCS using milk with 1.5% fat along with heat treatment

Calculation of required amount of water for adjustment of moisture in LF-RCS : For the preparation of RCS, RCC curd was analyzed for moisture content and then calculated amount of water was added to maintain the final moisture of RCS to 75%. Amount of water to be

added in RC curd was calculated by the formula given below:

$$M1/100 \times G + X = M2/100 (G + X)$$

$$\text{Therefore, } X = (M2 - M1/100 - M2) \times G \text{ —equation 1}$$

M1 is the % Moisture present in RCC

G is the Weight of cheese in gram

M2 is the % Moisture required in RCS (75%)

X is the Amount of water in gram to be added in RCC

Preservation techniques were studied in shelf life extension of RCS

Physico-chemical analysis of RCS : The pH of RCS was measured using a digital calibrated hand pH meter (Cole Parmer) at a temperature of 20°C. The titrable acidity of RCS was determined using the method outlined in the AOAC 2006 protocol. The moisture content of RCS was determined in accordance with the methodology outlined in IS: SP: 18 (Part XI- 1981). Every measurement was conducted three times.

Induced Whey Syneresis (IWS) : IWS of RCS were done by method described by Aichinger et al., 2003. The IWS (%) was evaluated as the ratio of weight of serum to the weight of separated gel and multiplied by 100. This analysis were carried out at every 7th day. Each measurement was done in triplicate.

$$\% \text{ serum} = \text{weight of serum} / \text{weight of gel} \times 100$$

Textural analysis : The textural properties of firmness, work of shear, stickiness, and work of adhesiveness were assessed using a Texture Analyzer TA-XT Plus, manufactured by Stable Micro Systems in Surrey, UK. The analysis was conducted with the TTC Spreadability Rig attachment and a 5 kg load cell. This rig consists of a male 90° cone probe and female Perspex cone-shaped product holders that are precisely matched. The instrument underwent calibration at a test speed of 2 mm/ second, a post-test speed of 10 mm/ second, a trigger force of 0.10 Newton's, a height of 25 mm, a penetration depth of 23 mm, and a data acquisition rate of 200 points per second. Following the calibration process, the RCS sample was inserted into the female cone and subsequently compressed using a spatula to ensure the removal of any air pockets. The surplus samples should be eliminated by means of a spatula, followed by the insertion of the male cone into the sample. The measurements were conducted by achieving thermal equilibrium of the sample at a temperature of $20 \pm 1^\circ\text{C}$. The application was utilized to record the textural data, namely the force versus time measurements. The analysis of cheese spreadability was then conducted using the instrument software TEE 32. The textural values were quantified using the utilization of

the exponent software (version 6.1.1.0). The experimental parameters established in the Texture Analyser for the assessment of textural characteristics were as follows:

Pre-Test Speed, 1 mm/s; Post-Test Speed, 10 mm/s; Test speed, 3.00 mm/s; Trigger force, 10.0 g; Time: 35.0 s.

Microbiological analysis : Samples of RCS were packed in pre-sterilized PP cups and kept at refrigerated temperature for storage. Samples were examined at the interval of 7th day for standard plate counts, coliform count and yeast and mold count. Each measurement was done in triplicate.

Sensory evaluation : Sensory evaluation was carried out by presenting approximately 20 g of RCS sample to seven semi-trained panelists each, selected from the faculty of College of Dairy Science and Technology. Nine-point hedonic scale was used to carry out the evaluation of samples for all the sensory attributes. For sensory evaluation of attributes viz. flavor, mouthfeel, colour & appearance and overall acceptability, panelist were asked to taste the samples and observe for the characteristics as per protocols of sensory evaluation. However, for spreadability, panelists were given a slice of bread, and they were asked to apply the spread on the bread slice and rate the attribute accordingly (Gautam et al., 2023).

Statistical Analysis : Mean $\pm$ standard deviation was calculated using Microsoft excel (Microsoft office 2010). The data was subjected to statistical analysis of variance (ANOVA) (i.e. one-way, two-way) using SPSS 16. Post hoc Tuckey has been used to compare means of every treatment to means of every other treatment for pairwise comparisons. Significant difference between means of treatment were taken in software at 95% confidence interval.

Results and Discussion

The prepared RCS samples with applied preservation technique, were packed in pre-sterilized PP cups and stored at 4°C and were analyzed for water activity and sensory properties at regular intervals of 7 days till spoilage. Samples of RCS with their notation are listed below as per the preservation technique used :

- (a) RCS with no any preservation treatment (control) – RCS-C
- (b) RCS which is heat treated @ 85°C for 15 minute – RCS-H

Effect on physico-chemical properties of RCS samples : Figure-2 shows the results of pH analyzed during storage. Both the samples of RCS were stored for 35 day at 4°C and were analyzed for pH and acidity on every 7th day. It was observed that the pH of the samples

decreased significantly ($P < 0.05$). The pH of RCS-C was in the range of 6.0 on 0th day and 5.82 on 35th day. Whereas pH of heat treated sample was in the range of 6.0 on 0th day and 5.87 on 35th day.

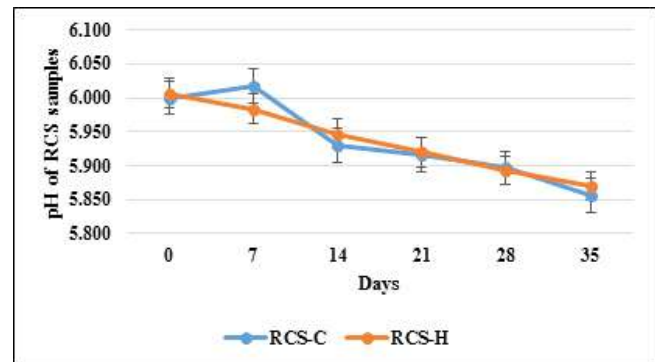


Fig.-2 : Effect on pH of both the samples during storage.

Figure-3 shows the results of acidity of sample during storage. As we know that pH and acidity are inversely related. Hence acidity of both the samples were found to be increased significantly during storage. The increase in acidity was highest in control sample which might be due to the microbial growth in the sample. The acidity of heat treated sample increased slightly due to less or no any microbial growth in the sample.

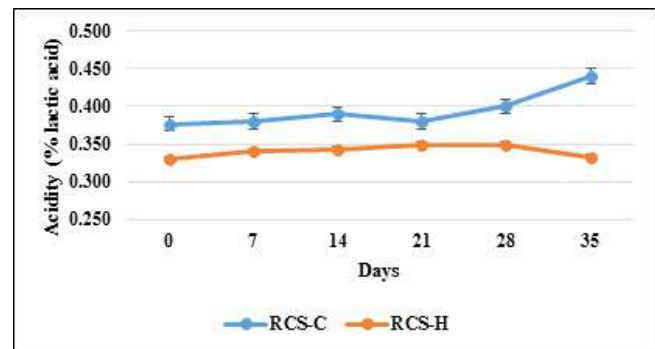


Fig.-3 : Effect on acidity of both the samples during storage.

Figure-4 shows the results of moisture content in the samples during storage. The moisture content in the control sample reported non-significant during storage which might be due to the synergistic effect of both the hydrocolloids which bind the water strong with itself. Whereas heat treated sample were found to decrease in moisture content during storage which might be due to expulsion of water during storage and also heating leads to the destruction of structure of the cheese which lower the water binding ability of hydrocolloids. The moisture content of heat treated sample decreased from 75.21 to 72.08 during the storage.

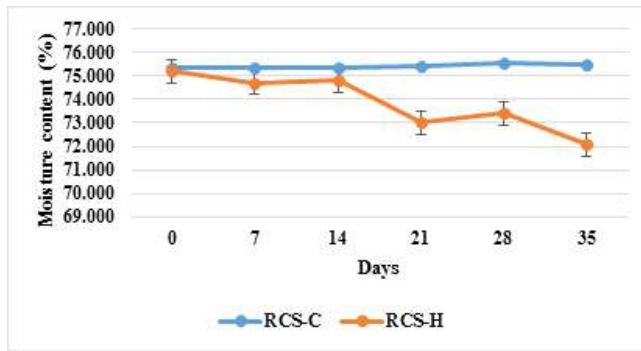


Fig-4 : Effect on moisture content of both the samples during storage.

Induced whey syneresis : Figure-5 represents the effect on induced whey syneresis in both the sample. IWS may be defined as the removal of moisture from the RCS after applying some external force i.e. centrifugal force for a certain period of time at a particular temperature. Addition of hydrocolloids leads to reduce whey expulsion due to its water binding ability (Yousefi and Jafari, 2019; Alnemr et al., 2016). Result showed that control sample reported highest whey syneresis on 0th day but further it reduced to 0% till 35th day. Whereas IWS in heat treated sample were increased after 7th day which might be due to the destruction in the structure of the sample due to heating which leads to expulsion of whey during storage.

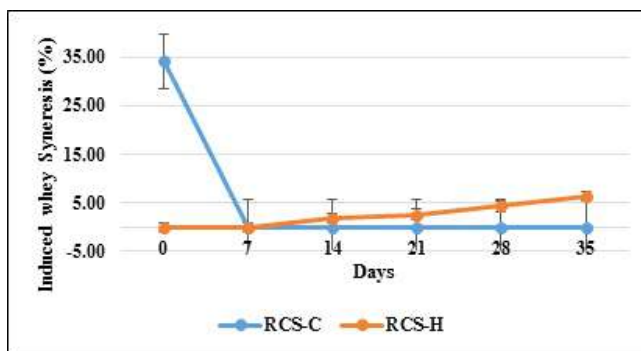


Fig-5 : Effect on moisture content of both the samples during storage.

Textural properties : Figure-6 represents the effect on firmness, work of shear, stickiness and work of adhesion in both the sample during storage. Firmness is the maximum force observed during the penetration of the probe in the sample. It is basically related to the spreadability which means more the firmness lower will be the spreadability of the spread. Firmness of the control sample were found to be increased during the storage which might be due to the presence of both the hydrocolloids which increases the binding ability within the sample during storage. Whereas for heat treated sample the firmness was found to be highest on 0th day and

remain non-significant till 35th day. It might be due the destruction of the structure of the sample. Work of shear is the resistance offered by the sample during penetration of the probe within the sample. Heat treated sample reported the highest work of shear during the storage due to the destruction of the structure of the sample which leads to reduce its smooth consistency. Whereas for control sample work of shear were found to be increased significantly during storage might be due to the synergistic effect of the hydrocolloids. Stickiness is the maximum force required during the removal of the probe from the sample. Stickiness of the heat treated sample was reported highest on 0th day and increases during the storage. From 7th day it was found that stickiness of both the sample are non-significant to each other. Work of adhesion is the work required to overcome the attraction force between the sample and the probe. It was found that both the sample reported work of adhesion non-significant to each other.

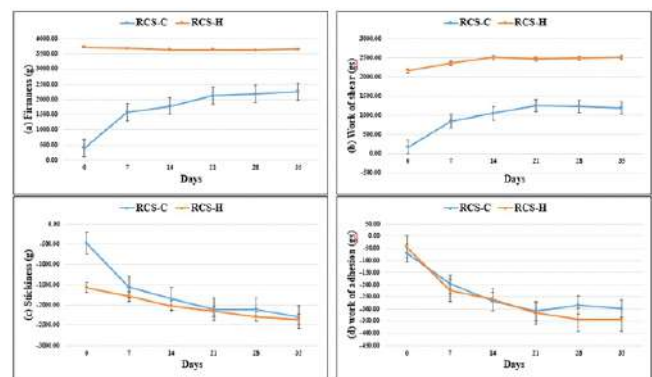


Fig-6 : Effect on (a) firmness, (b) work of shear, (c) stickiness and (d) work of adhesion of both the samples during storage.

Microbiological evaluation : Figure-7 represents the effect on SPC and coliform in both the sample during storage. SPC of both the samples were evaluated on every 7th day. SPC of control sample were found to be decreased till 21st day non-significantly which might be due to the synergist effect of both the hydrocolloids due to its water binding capacity and making it unavailable for the microbes to grow further. After 21st day the SPC in control sample were further increased. Whereas SPC in heat treated sample were found to be nil till 21st day which might be due to heating at such a high temperature which leads to destruction of all microbes. After 21st day SPC in heat treated sample were found to be increased might be due to expulsion of moisture which supported the growth of microbes.

Coliform of the control sample were found to be increased during storage. The increase was within

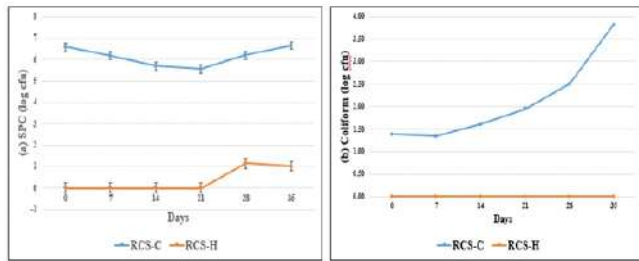


Fig-7 : Effect on (a) SPC and (b) coliform count of both the samples during storage.

permissible limit till 21st day. From 28th day it exceeds the coliform limit. This increase is might be due to the contamination during the preparation of RCS during manufacturing in experimental Dairy Plant. Whereas in heat treated sample coliform were found to be nil during the storage till 35th day which might be due to destruction of all coliform at such a high temperature i.e. 85°C for 15 minutes.

The yeast and mold counts in both the samples remained at zero during the storage period as a result of maintaining a sterile packaging environment. Additionally, it should be noted that the packing material utilized in this study was pre-sterilized, ensuring aseptic conditions. Furthermore, meticulous attention was given to maintaining a minimal head space within the package.

In general, the heat-treated samples were determined to be microbiologically safe; nonetheless, they exhibited a loss in the original texture of the product. Hence, it is not advisable to employ them in RCS.

Conclusions

The aim of this study was to study the effect of heating on physico-chemical, whey syneresis, textural and microbiological properties of ricotta cheese spread. Study revealed that both the sample showed decrease in pH and increase in acidity during storage. The reduction in whey syneresis was observed in control sample whereas the heat treated sample showed increase in syneresis during storage. Study also revealed that heating leads to make the ricotta cheese spread microbial safe but heating affect the textural attributes of the spread and make unacceptable as consumers prospective. The consistency of the heated sample is completely lost and further we can't consider it as a spread as it losses its spreadable consistency and reported the highest firmness during the storage.

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Screening of Genotypes and Role of Pycnidial Stages of *Rhizoctonia bataticola* in Development of Dry Root Rot Disease of Cluster bean

Aman Dhawan*, Satish Kumar and Pankaj Kumar Sharma

Department of Plant Pathology, College of Agriculture, CCS Haryana Agricultural University, Hisar, Haryana, India 125004

*Corresponding Author Email : dhawan.29@gmail.com

Abstract

Cluster bean (*Cyamopsis tetragonoloba*, $2n = 14$), a member of family Leguminaceae, is an important crop of arid and semi-arid regions. It is believed that geographic centre of origin of cluster bean is India although no wild species has been reported in country. The maximum pycnidia ($29.7/\text{cm}^2$ surface area) were seen in cowpea stem after 30 days of inoculation followed by clusterbean stem ($27.7/\text{cm}^2$ surface area), and the minimum pycnidia ($8.2/\text{cm}^2$ surface area) were seen in clusterbean leaves after 7 days of inoculation. Two genotypes viz. HG-100 and HG-75 were categorized as moderately resistant with a total plant mortality of 16.7 per cent and 20.0 per cent, respectively. Five genotypes viz. HFG-119, RGC-0033, RGC-1003, RGC-1019, and RGC-1038 were categorized as moderately susceptible. Seven genotypes of the clusterbean viz., HG 2-20, HG-365, HG-563, HG-876, HG-884, GAUG-0013, and RVG-2-30 were susceptible with a plant mortality of 50.1-75.0 per cent. Two genotypes viz. FS-277 and HG-182 were highly susceptible with a total plant mortality of 89.9 per cent and 79.9 per cent, respectively.

Key words : Cluster bean, pycnidia, genotypes, resistant, moderately resistant, susceptible.

Introduction

Cluster bean (*Cyamopsis tetragonoloba*, $2n = 14$), a member of family Leguminaceae, is an important crop of arid and semi-arid regions. It is believed that geographic centre of origin of cluster bean is India although no wild species has been reported in country. Tropical Africa is its probable centre of origin as wild species were found to occur in that region. Due to deep rooted system, this short duration, hardy and drought resilient legume is extremely adapted to the inhospitable environment of rainfed regions. This ancient legume is mainly cultivated for feed and food (Singh and Dahiya, 2004) therefore providing nutrition to both mankind and animals. It is used for human consumption and cattle feed (30–40%), industrial purpose (50–55%), medicinal (5%) as well as for soil improvement and other miscellaneous purposes. Due to multiple usages and presence of gum in its seeds, cluster bean has been emerged as a unique high-valued commercial crop. The availability of genetic diversity and its successful collection, maintenance, utilization and conservation is pre-requisite for crop improvement program.

Dry root rot caused by *Rhizoctonia bataticola* is the major disease responsible for its low productivity in Haryana and Rajasthan. the role of mycelium and pycnidiospores in disease development is generally overlooked. However, some of the workers have reported pycnidia of *R. bataticola* which served as secondary inoculum for aerial infection.

Materials and Methods

The present study entitled “Studies on the dry root rot of clusterbean caused by *Rhizoctonia bataticola* (Taub.) Butler” was carried out in the Department of Plant Pathology, CCS Haryana

Role of pycnidial stages in disease development of cluster bean

Induction of pycnidia on their respective hosts : Healthy fresh leaves, stems and roots pieces of different hosts (clusterbean cv. HG-365, cowpea cv. CS-88, cotton cv. HD-432, mungbean cv. MH-421, urdbean cv. UH-1 and okra cv. Varsha Uphar) were steam sterilized separately in 100 ml Erlenmeyer flasks each containing five ml of distilled water. After steam sterilization, the plant parts were spread out with the help of a sterilized forcep on the sterile Petriplates containing water agar medium. A 5 mm mycelial disc of *R. bataticola* was placed at the center of a Petriplate having their respective host plant part, and kept at room temperature ($30 \pm 7^\circ\text{C}$). Numbers of pycnidia produced/ cm^2 surface area of plant parts were counted after 7, 15 and 30 days of incubation under a stereozoom binocular microscope.

Role of pycnidiospores in the induction of disease :

Seeds of clusterbean, cowpea, cotton, mungbean, urdbean and okra were surface sterilized with 0.1 per cent mercuric chloride and 0.1 per cent streptomycin sulfate for 2 minutes each and five surface sterilized seeds of a particular crop were kept in each Petriplate (90 mm) containing water agar medium, and allowed to germinate

in a B.O.D. incubator at $25\pm 2^{\circ}\text{C}$ for 3 days. After germination, 0.1 ml pycnidiospore suspension containing 100 pycnidiospore was put on each of the germinated seedling of each host and kept at room temperature ($30\pm 7^{\circ}\text{C}$) under natural light and darkness conditions. The development of symptoms as observed.

Screening of clusterbean germplasm against *R. bataticola* under under greenhouse in artificial disease stress conditions : Sixteen clusterbean genotypes viz. FS-277, GAUG-0013, HFG-119, HG 2-20, HG-75, HG-100, HG-182, HG-365, HG-563, HG-876, HG-884, RGC-0033, RGC-1003, RGC-1038, RGC-1060, RVG2-30 were collected from Forage Section, CCS HAU, Hisar and used for screening against *R. bataticola* under greenhouse conditions in artificial disease stress condition. Ten seeds of each clusterbean genotype were sown in 15 cm earthen pots containing pathogen at the rate of 1000 mg/kg soil. The control set without inoculation was also kept. Three replications of each treatment were maintained. Observations on pre-emergence (PEM) mortality and post-emergence (POEM) plant mortality were taken up to 30 days after sowing.

Results and Discussion

Role of pycnidial stages in disease development of clusterbean

Production of pycnidia : To determine the role of different hosts on induction of pycnidia, six different crop plants viz., Clusterbean cv. HG-365, Cowpea cv. CS-88, Mung bean cv. MH-421, Urd bean cv. UH-1, Cotton cv. HD-432, Okra cv. Varsha Uphar were tested against *R. bataticola* for the production of pycnidia at room temperature ($30\pm 7^{\circ}\text{C}$) under natural light and darkness conditions. It revealed that *R. bataticola* was able to produce pycnidia and pycnidiospores in clusterbean and cowpea plants while cotton, mung bean, urd bean and okra did not support the production of pycnidium (Table 3). Leaves and stem pieces were found to produce pycnidia and pycnidiospores while no pycnidium was noticed on root pieces on any host up to 30th day after inoculation.

Cowpea was recorded as the most favoured host for maximum pycnidia production as compared to clusterbean. Pycnidia appeared in seven days after inoculation and number of pycnidia produced/cm² host surface area increased with an increase in period after inoculation. The maximum pycnidia (29.7/cm² surface area) were seen in cowpea stem after 30 days of inoculation followed by clusterbean stem (27.7/cm² surface area), and the minimum pycnidia (8.2/cm² surface area) were seen in clusterbean leaves after 7 days of inoculation.

Table-1 : Production of pycnidia by *Rhizoctonia bataticola* on different host plants at room temperature under *in vitro* conditions.

	Pycnidia Production
Clusterbean (cv. HG-365)	
Leaves	+
Root	-
Stem	+
Mung bean (cv. MH-421)	
Leaves	-
Root	-
Stem	-
Urd bean (cv. UH-1)	
Leaves	-
Root	-
Stem	-
Cowpea (cv. CS-88)	
Leaves	+
Root	-
Stem	+
Okra (Varsha Uphar)	
Leaves	-
Root	-
Stem	-
Cotton (cv. HD-342)	
Leaves	-
Root	-
Stem	-

(-) = indicates no pycnidia production upto 30 days

(+) = indicates pycnidial production after 7 days

Role of pycnidiospores in disease development :

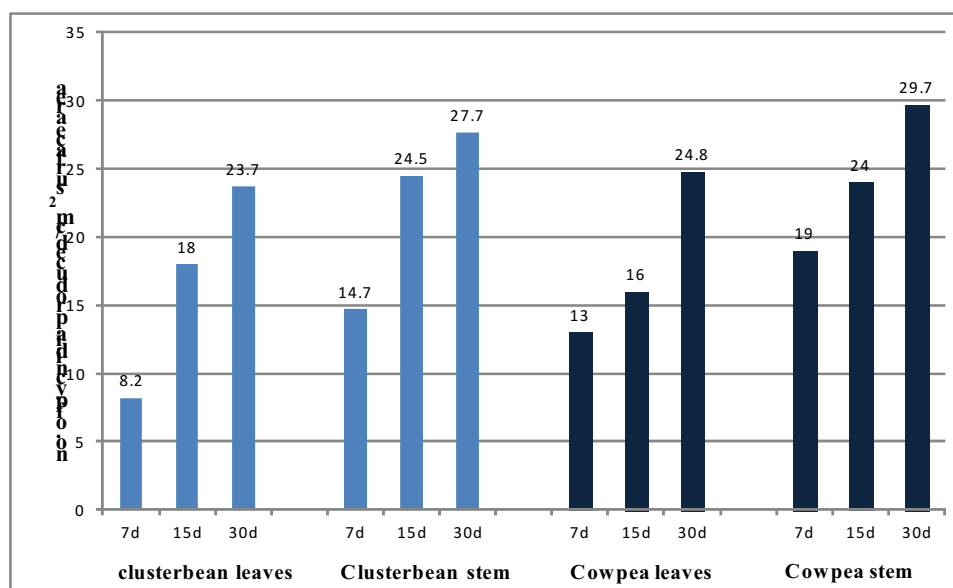
Pycnidiospores suspension of *R. bataticola* was tested for virulence on different germinated seedlings of clusterbean cv. HG-365, cotton cv. HD-432, cowpea cv. CS-88, okra cv. Varsha Uphar, urd bean cv. UH-1 and mung bean cv. MH-421 under *in vitro* conditions.

Suspension having 100 pycnidiospores per 0.1 ml sterilized water was put on each of the germinated seedlings in sterilized Petri plates containing water agar and kept at room temperature ($30\pm 7^{\circ}\text{C}$) under natural light and darkness.

Screening of clusterbean genotypes against *R. bataticola* under screen house conditions in artificial disease stress conditions : Sixteen clusterbean genotypes were screened under screen house conditions in artificial inoculated disease stress conditions and the results are presented in Table 4. Based on the reaction of clusterbean genotypes to *R. bataticola*, the genotypes were categorized as resistant (1-10% plant mortality), moderately resistant (10.1-25.0% plant mortality), moderately susceptible (25.1-50.0% plant mortality), susceptible (50.1-75.0% plant mortality) and highly susceptible (75.1-100% plant mortality). Out of 16 genotypes screened, none of the genotype was found resistant to *R. bataticola*. Pre-emergence and post-emergence plant mortality was observed in all the genotypes. Two genotypes viz. HG-100 and HG-75 were

Table-2 : Screening of clusterbean genotypes against *Rhizoctonia bataticola* under screen house in artificial disease stress conditions.

Sr. No.	Germplasm	PEM1 (%)	POEM2 (%)	Total mortality (%)
1.	HG-100	06.7 (14.7)	10.0 (18.4)	16.7
2.	HG-182	36.6 (37.2)	43.3 (41.3)	79.9
3.	HG 2-20	20.0 (26.6)	33.3 (35.2)	53.3
4.	HG-884	16.7 (24.0)	36.6 (37.2)	53.3
5.	HG-365	23.3 (28.8)	43.3 (41.1)	66.6
6.	HG-563	23.3 (28.8)	36.6 (37.2)	59.9
7.	HG-876	20.0 (26.5)	43.3 (41.1)	63.3
8.	HG-75	03.3 (9.9)	16.7 (24.0)	20.0
9.	HFG-119	06.8 (14.8)	26.6 (31.1)	33.4
10.	RGC-0033	16.7 (24.0)	33.3 (35.2)	50.0
11.	RGC-1038	16.7 (24.0)	26.6 (31.1)	43.3
12.	RGC-1019	10.0 (18.4)	16.7 (24.0)	26.7
13.	RGC-1003	13.3 (21.3)	36.6 (37.2)	49.9
14.	GAUG-0013	26.6 (31.1)	43.3 (41.1)	69.9
15.	RVG 2-30	20.0 (26.6)	36.6 (37.2)	56.6
16.	FS-277	36.6 (37.2)	53.3 (46.9)	89.9
	CD at 5%	(4.22)	(4.5)	

**Fig-1 : Number of pycnidia produced by *Rhizoctonia bataticola* on different host plants at room temperature under *in vitro* conditions.**

categorized as moderately resistant with a total plant mortality of 16.7 per cent and 20.0 per cent, respectively. Five genotypes viz. HFG-119, RGC-0033, RGC-1003, RGC-1019, and RGC-1038 were categorized as moderately susceptible. Seven genotypes of the clusterbean viz., HG 2-20, HG-365, HG-563, HG-876, HG-884, GAUG-0013, and RVG-2-30 were susceptible with a plant mortality of 50.1-75.0 per cent. Two genotypes viz. FS-277 and HG-182 were highly susceptible with a total plant mortality of 89.9 per cent and 79.9 per cent, respectively.

The pycnidiospores of *R. bataticola* were able to produce disease symptoms separately in germinated seedlings on cotton, cowpea, okra, mungbean, urdbean and clusterbean under laboratory conditions. The above

study revealed that sporulation of *R. bataticola* depends upon the host. Since the small sized, hyaline and elliptical shaped pycnidiospores were profusely filled with pycnidiospores in pycnidium and a number of pycnidia are produced on the plant surface within 7 days. These pycnidiospores may cause the aerial infection to the same host or other hosts also under favourable environmental conditions. Mahrshi and Gupta (1984) and Mehta *et al.* (2006) have already reported a leaf blight disease of okra in severe form in Rajasthan. They observed infected leaves of okra with numerous pin head like brown to black pycnidia containing pycnidiospores, which were found to be causing secondary infection. In the present study, pycnidiospores were able to cause diseases even in the hosts like okra, mungbean, urdbean and cotton which did not support pycnidia production. Hence it can be inferred

from the above studies that a sporulating strain of *R. bataticola* may cause more damage to many crops than non-sporulating strain of *R. bataticola*. Therefore, this information revealed that a detailed study on sporulation (like number of sporulating and non-sporulating strains in a region, host range, influence of different weather conditions on sporulation etc.) under field conditions is required.

Among the 16 clusterbean genotypes screened under screenhouse conditions in artificial inoculated disease stress conditions and based on the reaction of clusterbean genotypes to *R. bataticola*, the genotypes were categorized as resistant (1-10% plant mortality), moderately resistant (10.1-25.0% plant mortality), moderately susceptible (25.1-50.0% plant mortality), susceptible (50.1-75.0% plant mortality) and highly susceptible (75.1-100% plant mortality). Out of 16 genotypes screened, none of the genotype was found resistant to *R. bataticola*. Pre-emergence and post-emergence mortality was observed in all the genotypes. Two genotypes viz. HG-100 and HG-75 were categorized as moderately resistant with a total plant mortality of 16.7-20.0 per cent. Five genotypes viz. HFG-119, RGC-0033, RGC-1038, RGC-1019 and RGC-1003 were categorized as moderately susceptible. Seven genotypes of the clusterbean genotypes were susceptible with a plant mortality of 50.1-75.0 per cent. Two genotypes viz. FS-277 and HG-182 were highly susceptible with a total plant mortality of 89.9 per cent and 79.9 per cent, respectively. Pre and post-emergence plant mortality was observed in all the genotypes, however, post-emergence mortality was more in all the genotypes as compared to pre-emergence mortality. However, Gupta *et al.* (2003) investigated that out of 220 genotypes of clusterbean, 67 genotypes were resistant, 69 genotypes

were susceptible and 10 genotypes were highly susceptible to root rot caused by *R. Bataticola*. Similarly Loksha and Benagi (2006), Vijay Mohan *et al.* (2006), Kumar (2002) screened pigeonpea genotypes against *M. phaseolina*.

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A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Plant Pathology, faculty members and non-teaching staff of Department of Plant Pathology for providing me the necessary help and suggestions during the course of the study.

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Role of Mycelial and Sclerotial Stages of *Rhizoctonia bataticola* (Taub.) Butler in Development of Dry Root Rot Disease of Cluster bean

Aman Dhawan*, Satish Kumar and Pankaj Kumar Sharma

Department of Plant Pathology, College of Agriculture, CCS Haryana Agricultural University, Hisar, Haryana, India 125004.

*Corresponding Author Email : dhawan.29@gmail.com

Abstract

Cluster bean is a drought –tolerant crop, widely grown in arid and semi-arid regions receiving an annual rainfall 200-600 mm. It is now one of the most important crops for industries due to its gum content (35-40 %). This study was aimed to find out the Role of mycelial and sclerotial stages of *Rhizoctonia bataticola* (Taub.) Butler in development of dry root rot disease of clusterbean. Results showed that the maximum pre-emergence plant mortality was 23.3 per cent and post-emergence plant mortality was 43.3 per cent when mycelial suspension was used at the rate of 2000 mg/kg soil. The disease incidence was directly proportional to the inoculum level. Pre-emergence mortality was seen at 200 mg or more of inoculum level of the pathogen, whereas, post-emergence mortality of 16.7 per cent was observed even at 100 mg/kg soil inoculum (Table 2). The maximum plant mortality of 60.0 per cent was observed at inoculum levels of 2000 mg/kg soil followed by total plant mortality of 49.9 per cent at an inoculum level of 1000 mg/kg soil.

Key words : Cluster bean, mycelial stages, sclerotial stages, mortality, inoculum.

Introduction

Cluster bean is a drought –tolerant crop, widely grown in arid and semi-arid regions receiving an annual rainfall 200-600 mm. It is now one of the most important crops for industries due to its gum content (35-40 %). Gum is extensively used as sizing agent in paper and textile industries, as an effective flocculent and filterant in mining and metallurgical processes, as water blocking agents in explosives and as a thickener etc., Protein rich guar meal (42 % protein), is a by-product used as an animal feed concentrate. Guar, being a leguminous crop, also adds fertility to the soil by fixing atmospheric nitrogen (Kalyani, 2011).

It suffers severely from the vagary of diseases caused by fungi and bacteria. Dry root rot caused by *Rhizoctonia bataticola* is the major disease responsible for its low productivity in Haryana and Rajasthan. *R. bataticola* survives predominantly as black sclerotia in diseased plant parts or in soil and is responsible for plant infection under favourable conditions. The pathogenesis of the disease is still not fully worked out. Most of the workers have concentrated mainly on sclerotial stages as inocula of *R. bataticola* but the role of mycelium in disease development is generally over looked.

Materials and Methods

Role of mycelial and sclerotial stages in disease development of cluster bean

Role of different mycelial inoculum concentrations (mg/kg soil) in disease development : The mycelial mat of

R. bataticola prepared on PDB after three days of growth was harvested, washed, air dried, homogenized, diluted with the help of sterilized distilled water and mixed thoroughly with loamy sand soil separately at the rate of 100, 200, 500, 1000 and 2000 mg/kg soil in 15 cm earthen pots, and allowed to establish for two days. Ten seeds of clusterbean cv. HG-365 were sown in each pot. The control set without inoculum was also maintained, and each treatment was replicated thrice. The data on pre-emergence and post-emergence plant mortality were recorded. Post-emergence mortality data were recorded up to 30 days of sowing.

Per Cent Plant Mortality = 100

$$\frac{\text{Plants stand in inoculated control}}{\text{Plants stand in uninoculated control}} \times 100$$

Role of different sclerotial inoculum concentrations

(mg/kg soil) in disease development : The mycelial mat embedded with sclerotia of *R. bataticola* prepared on PDB after seven days of growth was harvested, washed, air dried, homogenized, diluted with the help of sterilized distilled water and mixed thoroughly with loamy sand soil separately at the rate of 100, 200, 500, 1000 and 2000 mg/kg soil in 15 cm earthen pots, and allowed to establish for two days. Ten seeds of clusterbean cv. HG-365 were sown in each pot. The control set without inoculum was also maintained, and each treatment was replicated thrice. The data on pre-emergence and post-emergence plant mortality were recorded. Post-emergence mortality data were recorded up to 30 days of sowing.

Table-1 : Effect of mycelial inoculum concentrations of *Rhizoctonia bataticola* on dry root rot disease incidence of clusterbean cv. HG-365.

Inoculum level (mg/kg soil)	* Per cent Disease Incidence		Total mortality (%)
	¹ PEM (%)	² POEM (%)	
100	3.5 (9.9)	16.7 (24.0)	20.2
200	6.7 (14.7)	16.7 (24.0)	23.4
500	13.3 (21.3)	36.7 (37.2)	50.0
1000	16.7 (24.0)	40.0 (39.2)	56.7
2000	23.3 (31.0)	43.3 (41.1)	66.6
Check (No inoculum)	0.0 (4.05)	0.0 (4.05)	-
CD at 5%	5.2	2.86	-

*(Mean of 3 replications), Figures in parenthesis are angular transformed values

¹PEM = Pre-emergence mortality, ²POEM = Post-emergence mortality

Table-2 : Effect of mycelium embedded sclerotial inoculum concentrations of *Rhizoctonia bataticola* on clusterbean dry root rot disease incidence under screen house conditions.

Inoculum level (mg/kg soil)	* Per cent Disease Incidence		Total mortality (%)
	¹ PEM(%)	² POEM(%)	
100	0.0 (4.0)	16.7 (24.0)	16.7
200	3.5 (9.9)	16.7 (24.0)	20.2
500	6.6 (14.7)	26.6 (31.0)	33.2
1000	13.3 (21.1)	36.6 (37.2)	49.9
2000	20.0 (26.5)	40.0 (39.2)	60.0
Check (No inoculum)	0.0 (4.05)	0.5 (4.05)	-
CD at 5%	5.60	5.66	-

*(Mean of 3 replications), Figures in parenthesis are angular transformed values

¹PEM = Pre-emergence mortality, ²POEM = Post-emergence mortality

Results and Discussion

Role of different mycelial inoculum concentrations (mg/kg soil) of *R. bataticola* in disease development :

Results showed that a minimum of total plant mortality was 20.2 per cent at 100 mg/kg soil pathogen inoculum level and increased gradually with the increase in the inoculum levels of the pathogen. Among the various inoculum levels of *R. bataticola*, the maximum pre-emergence plant mortality was 23.3 per cent and post-emergence plant mortality was 43.3 per cent when mycelial suspension was used at the rate of 2000 mg/kg soil. The disease incidence was directly proportional to the inoculum level.

Role of different mycelium embedded sclerotial inoculum concentrations (mg/kg soil) of *R. bataticola* in disease development :

Mycelium embedded sclerotial culture of *R. bataticola* was comparatively less virulent at all the inoculum levels as compared to their same level of mycelial culture. Pre-emergence mortality was seen at 200 mg or more of inoculum level of the pathogen, whereas, post-emergence mortality of 16.7 per cent was observed even at 100 mg/kg soil inoculum (Table 2). The maximum plant mortality of 60.0 per cent was observed at inoculum levels of 2000 mg/kg soil followed by total plant mortality of 49.9 per cent at an inoculum level of 1000 mg/kg soil.

A minimum of total plant mortality was 20.2 per cent at 100 mg/kg soil inoculum level and increased gradually with the increase in their inoculum levels. Among the various inoculum levels of *R. bataticola*, the maximum pre-emergence plant mortality was 23.3 per cent and post-emergence plant mortality was 43.3 per cent when mycelial suspension was used at the rate of 2000 mg/kg soil. The disease incidence was directly proportional to the inoculum level, whereas in case of mycelial embedded sclerotial culture of *R. bataticola*, pre-emergence mortality was seen at 200 mg or more of inoculum level, whereas, post-emergence mortality of 16.7 per cent was observed even at 100 mg/kg soil inoculum. The maximum plant mortality of 60.0 per cent was observed at an inoculum level of 2000 mg/kg soil and 49.9 per cent at an inoculum level of 1000 mg/kg soil. No significant difference was observed in post-emergence plant mortality between 1000 mg and 2000 mg/kg soil inoculum level. It was noted that mycelial culture was more virulent as compared to mycelium embedded sclerotial culture at all inoculum levels. Pre-emergence plant mortality as well as post-emergence plant mortality was higher in the experiment involving mycelium as the inoculum as compared to the respective mycelium embedded sclerotial inoculum in clusterbean cv. HG-365 under screenhouse conditions. A similar observation has been recorded by Hooda and Grover (1982), Lodha (1998),

Sandhu and Singh (1999) and Kumar (2002) while working on root rot caused by *R. bataticola* on mungbean and okra, respectively. It can be inferred that the *R. bataticola* inoculum level and its mycelial or sclerotial growth stage may play an important role in the pre-emergence and post-emergence plant mortality in clusterbean under field conditions also.

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A feeling of sincere and heartfelt gratitude envelops me as I draft this acknowledgement. I acknowledge my esteemed Major Advisor, advisory committee, Head, Department of Plant Pathology, faculty members and non-teaching staff of Department of Plant Pathology for providing me the necessary help and suggestions during the course of the study.

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Effectiveness of Various Fungitoxicants and Bio-Agents in the Laboratory and Field Against Leaf Spot and Fruit Rot of Chilli

Manjul Pandey^{1*}, P.K. Dwivedi², R.P. Mishra³, Anjali Dwivedi⁴ and Surjeet Pandey⁵

¹KVK, Banda, Banda University of Agriculture and Technology, Banda (UP)-210001

²KVK, Raisen, M.P.

³Department of Agriculture, CGC Tech. Campus, Jhanjeri (Mohali), Punjab-140307

⁴CBSMSS Jhinhak, CSJM, Kanpur, U.P.

⁵BUAT-Krishi Vigyan Kendra, Jalaun, U.P.

*Corresponding Author Email : manjul_csa@rediffmail.com

Abstract

Twelve fungicides and three bio-agents screened in the laboratory, Bavistin, Indofil M-45, Chlorothalonil, Vitavax and Thiram proved most effective as they caused total inhibition of the pathogen. Indofil Z-78, Captafol, Ziram, Captan and Blitox-50 were also found to be significantly superior compared to other fungicides. Out of five seed dressing fungicides and three bio-agents, *Trichoderma viride* proved to be the most effective followed by *Trichoderma harzianum*, Bavistin and Thiram in controlling the seed-borne infection of *Alternaria alternata*. However, none of the seed dressing fungicides was found effective in checking the secondary spread of the disease under field conditions. Out of eight spray fungicides, Indofil M-45 proved to be most effective in controlling the disease in pot culture experiment as well as in field trials, followed by Indofil Z-78 and Chlorothalonil. Application of Indofil M-45 @ 0.2% can be recommended for the successful management of *Alternaria* leaf spot and fruit rot due to *Alternaria alternata* under field conditions.

Key words : chilli(*Capsicum annum*), fungitoxicant, bio-agent, management, *Alternaria alternata*, leaf spot, fruit rot. **Introduction**

Chilli is a unique crop among all the spices being the only source of capsaicin (Tiwari, 1990). Chillies are the best and the cheapest source of vitamin C and A. The green chillies also contain rutin (C₂₇H₃₀O₁₆), which has specific medicinal value (Purseglowe, 1977). The pungency of chilli is due to an alkaloid, "Capsaicin (C₁₈H₂₇NO₃). The red colour in fruit at the ripening stage is due to the pigment Capsanthin (Nath, 1969). Chilli is valued throughout the world for pungency. The pungent principle of red pepper consists of a mixture of seven closely related allyl vanillylamides named Capsaicinoides, which are separated by solvent extraction of the dried fruits and the subsequent removal of the solvent (Tiwari, 1990; Govindrajana, 1985; Maya, 1975).

The chilli crop suffers due to a number of fungal, bacterial and viral diseases, which render its production into stake (Mukherji and Bhasin, 1986; Singh, 2003; Agrios, 2004). Among the various fungal diseases leaf spot, fruit rot incited by *Alternaria alternata* (Fr.) Keissler is becoming a limiting factor and posing a major problem in Kanpur and adjoining areas (Narain *et al.*, 2000). The pathogen has been reported to cause seed, seedling, leaf and fruit diseases (Sreekantiah *et al.*, 1973; Mehrotra, 1980; Alam *et al.*, 1981; Singh, 2003). Post harvest decay of fruits and seeds has also been recorded due to this

pathogen (Leyendecker, 1954 a; Mathur and Agnihotri, 1961; Spalding and King, 1981).

Materials and Methods

For the control of disease, the effect of different fungitoxicants bio-agents and foliar application of fungitoxicants were adopted in the present investigation. However, the efficacy of various fungitoxicants belonging to different groups were first ascertained in bio-assay test against the pathogen in the laboratory and those found effective were used further for experiments in pots/field for control of the disease. The procedures adopted in these studies were as follows :

1. (a) Laboratory bio-assay of different fungitoxicants

: The relative efficacy of twelve fungicides was tested against pathogen under laboratory conditions. For this purpose, poison-food technique devised by Schmitz, (1930) was followed for bioassay test of fungitoxicants. The requisite quantities of fungitoxicants were incorporated into 2 per cent sterilized unsolidified Potato dextrose agar and shaken well to make it homogenous. Medium was then poured in 90 mm. sterilized Petridishes with three replications of each treatment and allowed to solidify. These dishes were then inoculated with 5mm circular discs of inoculum from 10 days old culture and this disc was placed in the centre of each Petridish in such a

way so that fungus may come in direct contact with the medium. The medium, without any fungitoxicants poured and inoculated similarly served as control. The Petridishes were incubated at $28 \pm 1^\circ\text{C}$ for 10 days. The efficacy of various fungitoxicants was assessed by measuring the radial growth of the fungal colony in mm.

The fungitoxicants, which were found effective in laboratory evaluations, were employed further tried in two way namely, as seed dressers as well as spray fungitoxicants.

Growth inhibition percentage of colony was calculated by formula given below (Bliss, 1934) :

Where,

$$I = C - T \quad 100$$

I = Inhibition percentage of colony

C= Average diameter of colony in control

T = Average diameter of colony in treatment

1 (b) Bio-assay of bio-agents : Soil samples from the Rhizosphere were taken from 3 places of the field and mixed well to make fine particles. Collection of soil samples were made for the root zone at 5-15 cm depth.

Ten gram of mixed soil samples was taken in a measuring cylinder and added 100 ml of sterile distilled water, shaken it well to make homogenous mixture (1:10). Now took one ml from the mixture and 9 ml of sterile water in tube to make solution of (1:100). Like wise, its serial dilutions were added to get 1:10,000 strength in such a way so as to transfer one ml. of this suspension to sterile Petriplates and poured Potato dextrose agar medium in the Petriplates. Shaked well the plate gently an allowed it to solidify. Now these Petriplates were incubated at room temperature. Observations were recorded after 4-5 days after development of colonies.

The antagonistic properties of bio-agents namely *Trichoderma viride*, *Trichoderma harzianum* and *Pseudomonas fluorescens* were tested by dual culture plate technique. Inoculation of bio-agents against test fungus was made from 10 day old culture of bio-agent and test fungus. The 5 mm disc of bio-agents and test organism were cut by a cork borer and bio-agents bits at one edge of the Petriplates and test organism at another edge of the same Petriplates were placed. The inoculated Petridishes were kept incubator at $28 \pm 1^\circ\text{C}$ for 10 days and observations were taken accordingly (Vincent, 1927).

2. Elimination of seed borne infection : Repeated isolations from chillie seeds have yielded the fungus *A. alternata*. It was therefore, considered useful to test some fungicides against this pathogen associated with the seed.

To test the efficacy of different fungicides in

controlling the seed-borne infection, naturally infected seeds of the variety 'Chaman' were tested with different fungicides. The fungicides used for seed treatment were Bavistin (0.1%), Thiram (0.2%), Captan (0.2%), Captafol (0.2%) Ziram (0.2%) and Vitavax (0.1%). Thorough seed dressing was done by shaking the seed in plugged conical flasks with requisite quantity of fungicide for 20 minutes. One hundred seeds from each treated lot were transferred to sterilized moist blotters and the experiment was repeated three times. Thus, four hundred seeds in all were taken for each treatments, keeping separate set of untreated seeds as 'Control'. Observations on the appearance of fungal growth on seeds and seedlings were recorded after 10 days of incubation at $28 \pm 1^\circ\text{C}$. Percentage infection in each treatment was noted.

To determine the efficacy of various seed dressing fungicides under field conditions, for controlling the disease, ten treated seeds from each lot were sown in 30 cm diameter earthen pots in three replications. Pots sown with untreated seeds served as control. Five plants were maintained in each pot. Pots were kept in glass house chamber for protection against aerial infection. Observations on disease intensity were recorded after the plants had attained the age of two months.

3. Fungitoxicants spray : The spray fungicides found effective *in vitro* were further employed in fungicidal control trials conducted during 2001-02 in pot culture and during 2002-03 and 2003-04 in field experiments for the control of *Alternaria* leaf spots and fruit rot of chilli.

(a) Evaluation of fungicides in pot culture experiments : The seeds of a highly susceptible chillie variety Chaman were sown in 30cm pots and after attaining the age of 30 days, these seedlings were transplanted in other pots in three replications. In each pot, five plants were maintained. After attaining the age of two months from the date of sowing, the plants were inoculated with mycelial-cum-spore suspension of the pathogen. Spraying of the fungicides was started just after 48 hours of inoculation and repeated at an interval of 15 days with four subsequent sprays. A set of unsprayed pots served as control. Observations on disease intensity were recorded on the basis of percentage leaf area infected after 15 days of last spraying, by randomly selecting 25 leaves from each replication. The percentage disease intensity was transformed into $\text{angle} = \sin^{-1}$ per cent disease intensity and then analyzed statistically. The percentage of disease control over check was calculated as below :

Per cent disease control =

$$\frac{\text{Disease intensity in control} - \text{Disease intensity in treatment}}{\text{Disease intensity in control}} \quad 100$$

Table-1 : Inhibitory effect of various fungitoxicants and bio-agents on growth of *Alternaria alternata* in bio-assay test.

S. No.	Fungicides/bio-agents	Dose (%)	Av. diameter of fungal colony (mm)	Inhibition over control (%)
(A) Fungicides				
1.	Bavistin	0.1	0.0	100.0 (90.0)
2.	Indofil M-45	0.2	0.0	100.0 (90.0)
3.	Chlorothalonil	0.2	0.0	100.0 (90.0)
4.	Vitavax	0.1	0.0	100.0 (90.0)
5.	Thiram	0.2	0.0	100.0 (90.0)
6.	Indofil Z-78	0.2	2.7	97.0 (88.9)
7.	Captafol	0.2	5.3	94.1 (84.3)
8.	Ziram	0.2	8.7	90.3 (79.8)
9.	Captan	0.2	12.0	86.6 (75.5)
10.	Blitox – 50	0.2	16.7	81.4 (71.6)
11.	Kitazin	0.2	19.2	78.6 (69.4)
12.	Topsin – M	0.2	24.6	72.6 (64.9)
(B) Bio-agents				
13.	<i>Trichoderma viride</i>	Cfu106/g	25.3	71.8 (64.4)
14.	<i>Trichoderma harzianum</i>	Cfu106/g	28.1	68.7 (62.2)
15.	<i>Pseudomonas fluorescens</i>	Cfu1022/g	32.4	64.0 (59.0)
16.	Control		90.0	

Table-2 : Efficacy of different fungicides/bio-agents against seed borne infection of *Alternaria alternata*.

S. No.	Fungicides/bio-agents	Dose (%)	Per cent disease infection	Per cent infection over control
1.	Bavistin	0.1	10.8 (21.3)	84.4 (70.8)
2.	Thiram	0.2	12.3 (22.8)	77.7 (68.7)
3.	Captan	0.2	16.9 (26.9)	69.3(62.6)
4.	Captafol	0.2	20.1 (29.5)	63.5 (58.7)
5.	Ziram	0.2	26.5 (34.4)	62.8 (58.2)
6.	<i>Trichoderma viride</i>	Cfu 10 ⁶ /gm	9.7 (20.1)	82.4 (72.4)
7.	<i>Trichoderma harzianum</i>	Cfu 10 ⁶ /gm	10.3 (20.7)	81.3 (71.5)
8.	<i>Pseudomonas fluorescens</i>	Cfu 10 ²² /gm	12.6 (23.1)	77.1 (68.2)
9.	Control	-	55.2 (53.3)	-

(b) Evaluation of fungicides in field trial : Field trials were conducted with same set of spray fungicides by sowing chilli Chaman variety. The experiment was laid out in randomized block design with three replications. The transplanting of one month old seedlings in the plots was done in the last week of July in both the years. The size of the plots was 4.5m x 3.0m and the spacing between the rows and the plants were 75cm and 60cm, respectively. Sixty days old plants were artificial inoculated by spraying mycelial-cum-spore suspension of the pathogen and the plots were irrigated from time to time, to maintain proper moisture. The first fungicidal spraying was started just after 48 hours of inoculation and repeated at an interval of 15 days with four subsequent sprays. The control plots were sprayed with water only. For recording the disease intensity, one hundred randomly selected leaves per replication were examined after 15 days of the last spray and the disease intensity was calculated according to the formula given under pot culture experiment. Fruits were also picked periodically.

Results and Discussion

(1) Laboratory screening of fungicides/bio-agents against the pathogen : In order to select suitable fungicides/bio-agents against the pathogen, 12 fungicides and 3 bio-agents were tested on two per cent Potato dextrose agar medium under laboratory conditions using the techniques described by Schmitz (1930) for chemical and Vincent (1927) for bio-agents. Each treatment was replicated three times in 98mm Petridishes. Culture medium without any fungicides served as control. The inoculated Petridishes were incubated at 28±1°C for 10 days and the data on radial growth were recorded for each treatment separately. Per cent inhibition over control was calculated and data were analysed statistically and presented in Table-1.

The results presented in Table-1, indicated that all the fungicides and bio-agents tested were significantly superior to the control (check) in inhibiting the growth of *Alternaria alternata*. Out of 12 fungitoxicants and 3

Table-3 : Efficacy of fungicides on the severity of the disease caused by *Alternaria alternata* in pot culture experiment during 2001-02.

S. No.	Fungicides	Dose (%)	Per cent disease intensity	Per cent infection over control
1.	Indofil M-45	0.2	28.6 (35.9)	62.7 (58.2)
2.	Indofil Z-78	0.2	31.2 (37.7)	59.3 (56.0)
3.	Chlorothalonil	0.2	33.5 (39.2)	56.3 (54.0)
4.	Bavistin	0.1	38.1 (42.3)	50.3 (50.2)
5.	Blitox – 50	0.2	39.4 (43.2)	48.6 (49.1)
6.	Captafol	0.2	40.2 (43.7)	47.6 (48.5)
7.	Kitazin	0.2	42.5 (45.2)	44.6 (46.5)
8.	Topsin – M	0.2	44.3 (4.3)	42.3 (45.0)
9.	Control		76.8 (68.0)	

Table-4 : Effect of fungicides spraying on the disease intensity of *Alternaria* leaf spot and fruit rot disease of chilli.

S. No.	Name of fungicides	Dose (%)	Disease intensity (%)		Percentage disease control	
			2002-03	2003-04	2002-03	2003-04
1.	Indofil M-45	0.2	17.3 (24.5)	16.5 (23.9)	65.1 (59.7)	65.5 (60.0)
2.	Indofil Z-78	0.2	18.3 (25.3)	19.6 (26.2)	63.1 (58.4)	58.5 (55.6)
3.	Chlorothalonil	0.2	19.5 (26.2)	20.3 (26.7)	60.6 (56.7)	57.0 (54.5)
4.	Bavistin	0.1	20.7 (27.0)	19.3 (26.0)	58.2 (55.2)	59.1 (56.2)
5.	Blitox – 50	0.2	25.6 (30.3)	27.8 (31.8)	48.3 (48.9)	41.2 (44.3)
6.	Captafol	0.2	35.3 (36.4)	34.2 (35.7)	28.8 (36.9)	27.3 (35.2)
7.	Kitazin	0.2	37.4 (37.7)	38.7 (38.4)	24.3 (32.0)	19.0 (28.7)
8.	Topsin – M	0.2	38.5 (38.3)	40.3 (39.4)	22.3 (32.0)	14.7 (25.0)
9.	Control	Water spray	49.6 (44.7)	47.3 (43.4)	-	-

bio-agents tested, only five fungicides viz., Bavistin, Indofil M-45, Chlorothalonil, Vitavax and Thiram proved to be effective fungicides as they inhibited the growth of the pathogen completely. The remaining fungicides/ bio-agents in order to their decreasing inhibitory effect against the pathogen were Indofil Z-78, Captafol, Ziram, Captan, Blitox-50, Kitazin, Topsin M, *Trichoderma viride*, *Trichoderma harzianum* and *Pseudomonas fluorescens* and they differed significantly from one another in checking the growth of the pathogen.

The chilli plant harbours the infection of *Alternaria alternata* through diseased seeds or from the diseased debris of the previous crop left over in the soil or from the conidia borne on the affected aerial parts of the standing crop. In each case, it is necessary to protect the plants by timely application of fungicides and bio-agents for spread of the disease. As such, the efficacy of various fungicides/bio-agents, adjudged to be the best in the laboratory tests was further ascertained both by applying them as seed dressers before sowing and using them as spray fungicides.

(2) Seed treatment : Five seed dressing fungicides and three bio-agents which proved most effective in the laboratory screening were tried to assess their efficacy in eliminating the seed borne infection of *Alternaria alternata* (Table-2).

The results of the Table-2 reveal that *Trichoderma viride* proved to be the most effective bio-agent followed by *Trichoderma harzianum*, Bavistin and Thiram for eliminating infection and significantly similar to each other. Other fungicides and bio-agents in descending order of superiority were *Pseudomonas fluorescens*, Captan, Captafol and Ziram were found moderately effective in controlling infection, but were significantly superior to control.

As already observed, most of the fungicides were found to be quite effective in mitigating the load of primary inoculums present on seed but failed to check the secondary spread of the disease, which is the most destructive phase. As such, seed treatment could hardly be recommended for the control of *Alternaria* leaf spot and fruit rot of chilli.

(3) Foliar application :

(3a) Evaluation of fungicides in pot culture experiment : On the results obtained in the laboratory screening, efficacy of eight spray fungicides was further investigated by foliar application on the highly susceptible chilli variety Chaman under pot culture experiment (Table -3).

The result of Table-3 indicate that Indofil M-45 was the most effective fungicides for controlling the disease

followed by Indofil Z-78 and Chlorothalonil were statistically similarly to each other. The next in order to superiority was Bavistin followed by Blitox-50, Captafol, Kitazin, Topsin-M which were at par to each other in controlling the diseases. Topsin M which remained in the last on account of its poor performance was significantly superior to control (check) to reducing the intensity of the disease.

(3b) Evaluation of fungicides in the field : All the fungicides employed in pot culture experiments were further evaluated in field culture experiments were further evaluated in field experiments during the two consecutive years (2002-03 and 2003-04), in order to assess their efficacy in controlling the disease. The experiments were conducted in randomized block design with three replication.

The method of inoculation and spraying schedule followed were the same as described under 'Material and Methods'. The data on disease intensity were recorded fifteen days after the last spraying and yield data were recorded during the crop season (Table-4).

It is evident from Table 4 that in the year 2002-03, all the fungicides gave significantly better control of the disease as compared in check. In this season Indofil M-45 proved to be most effective in checking the disease, followed by Indofil Z-78 and Chlorothalonil. All these fungicides differed significantly but statistically at par to each other. The next in order to superiority was Bavistin, which was at par to Chlorothalonil, Blitox-50, Captafol, Kitazin and Topsin M in order of superiority were statistically superior to each other in controlling the disease but Captafol, Kitazin and Topsin M were at par to each other.

In the year 2003-04, also all the fungicides gave significantly better control of the disease as compared to check. Indofil M-45 proved to be the most effective in checking the disease followed by Bavistin, Indofil Z-78 and Chlorothalonil, which were at par to each other.

The remaining fungicides viz., Blitox-50 Captafol, Kitazin, Topsin M were found less effecting to controlling the disease. Among them Kitazin and Topsin M were found statistically at par to each.

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Response of Environmental Factors on Disease Development of *Alternaria alternata* Causing Alternaria Leaf Spot and Fruit Rot of Chilli under Natural Conditions

Manjul Pandey^{1*}, P.K. Dwivedi², R.P. Mishra³, Anjali Dwivedi⁴ and Surjeet Pandey⁵

¹KVK, Banda, Banda University of Agriculture and Technology, Banda (UP)-210001

²KVK, Raisen, M.P.

³Department of Agriculture, CGC Tech. Campus, Jhanjeri (Mohali), Punjab-140307

⁴CBSMSS Jhinhak, CSJM, Kanpur, U.P.

⁵BUAT-Krishi Vigyan Kendra, Jalaun, U.P.

*Corresponding Author Email : manjul_csa@rediffmail.com

Abstract

The data correlated regarding the effect of atmospheric temperature, relative humidity and rainfall on disease development during 2002-03 and 2003-04 revealed that, moderate relative humidity accompanied by nearly moderate temperature favoured disease development in both the years. The maximum disease development was recorded in the second fortnight of November during both the years. The average maximum and minimum temperatures and relative humidities were 29.7°C, 13.6°C and 87.5, 39.2 per cent, respectively during 2002- 03, whereas during 2003-04 average maximum and minimum temperature were 34.0°C and 15.4 °C, respectively with average maximum and minimum relative humidities of 73.3 and 45.2 per cent, which led to maximum disease development. The rainfall in January led to rise in relative humidity and fall in atmospheric temperature hampered the disease development.

Key words : chilli (*Capsicum annuum*), epidemiology, *Alternaria alternata*, leaf spot, fruit rot

Introduction

Chilli (*Capsicum annuum* L.) is used as condiment as well as vegetable in every household of India. It has an important role in our daily diet. The fruits of chillies are used to increase the palatability and taste of cooked food and vegetable chilli is used to flavour soups, stews and sauces. The pickle of chillies is preferred by the masses. It is used in every vegetarian as well as non-vegetarian diet of the world. India is the major producer and exporter of chillies and their products to various countries including Abudhabi, Australia, Canada, Japan, U.S.A. and U.K. (Anonymous, 1992). According to Peter *et. al.* (2004), in India, chillies are grown or cultivated in an area of 9.65 lakh ha. with the production of 10.75 lakh tonnes. This contributes 35.5 per cent and 31.6 per cent, respectively, to the total area and production from all spices. In India, almost all the states cultivate chillies. However, Uttar Pradesh, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, Karnataka, Punjab, Bihar, Maharashtra, Gujarat are the major chilli producers. In Uttar Pradesh, chillies are grown in 20,900 hectares with a total annual production of 16,400 tonnes. Chillies are the best and the cheapest source of vitamin C and A. The green chillies also contain rutin (C₂₇H₃₀O₁₆), which has specific medicinal value (Purseglove, 1977). The pungency of chilli is due to an alkaloid, "Capsaicin (C₁₈H₂₇NO₃). The red colour in fruit at the ripening stage is due to the pigment Capsanthin (Nath, 1969). Chilli is valued throughout the world for pungency.

The pungent principle of red pepper consists of a mixture of seven closely related allyl vanillylamides named Capsaicinoids, which are separated by solvent extraction of the dried fruits and the subsequent removal of the solvent (Tiwari, 1990; Govindarajan, 1985; Maya, 1975).

Materials and Methods

To find out the effects of atmospheric temperature, relative humidity and rainfall on disease development, a highly susceptible chilli variety 'Chaman' was sown in the field. Recommended doses of fertilizers and cultural practices were used and irrigation were applied whenever necessary. The data on disease development were recorded every 15 days of interval during 2002-2003 and 2003-2004. The weather data also recorded during the crop period and correlated with the disease development.

Results and Discussion

Atmospheric temperature, relative humidity and rainfall play a very important role in disease development. Therefore, it was felt desirable to study the role of these factors in the epidemiology of *Alternaria* leaf spot and fruit rot of chilli by the technique described in "Material and Methods". The disease intensity under natural conditions was recorded at fortnightly intervals on the crop grown at vegetable Research Farm, Kalyanpur Kanpur. The prevailing atmospheric temperature, relative humidity and rainfall were noted from the observatory installed in the vicinity and correlated with disease development and

Table-1 : Effect of atmospheric temperature, relative humidity and rainfall on disease development under natural conditions.

Period	Average temperature (°C)				Average relative humidity (%)				Average rainfall (mm)		Disease intensity (%)	
	2002-03		2003-04		2002-03		2003-04		2002-03	2003-04	2002-03	2003-04
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.				
First fortnight of July	39.6	30.8	31.4	21.6	60.6	39.5	83.3	57.3	0.0	15.6	10.3	10.9
Second fortnight of July	40.4	30.4	31.8	20.8	70.8	55.1	91.2	64.8	1.7	8.5	11.8	12.4
First fortnight of August	33.1	26.9	31.2	19.9	87.4	71.8	91.7	65.0	13.3	5.2	15.1	15.0
Second fortnight of August	34.4	27.5	34.0	24.1	99.2	78.8	92.1	73.8	4.6	2.4	19.2	18.9
First fortnight of September	30.3	24.4	32.0	21.5	90.3	79.6	93.3	88.1	26.0	30.3	21.9	24.7
Second fortnight of September	32.3	23.1	31.7	24.3	86.1	62.6	91.0	83.4	0.0	5.6	25.3	26.6
First fortnight of October	33.3	21.8	33.5	20.8	78.9	48.4	82.8	60.7	0.1	0.0	28.7	30.3
Second fortnight of October	33.9	20.1	34.5	20.3	88.6	44.2	89.6	55.3	0.1	0.0	31.2	34.0
First fortnight of November	29.7	13.6	34.0	15.4	87.5	39.2	73.3	45.2	0.0	0.0	36.9	36.5
Second fortnight of November	27.9	15.1	27.1	18.0	84.5	36.0	79.1	47.6	0.0	0.0	35.1	36.0
First fortnight of December	23.3	16.2	26.7	11.1	85.0	32.6	83.8	57.4	0.0	0.0	33.5	32.8
Second fortnight of December	25.1	7.9	20.4	9.0	95.3	50.3	86.6	50.6	0.0	1.8	30.2	28.5
First fortnight of January	13.4	3.0	16.6	6.2	95.6	77.9	85.0	79.2	0.8	0.0	29.3	28.1

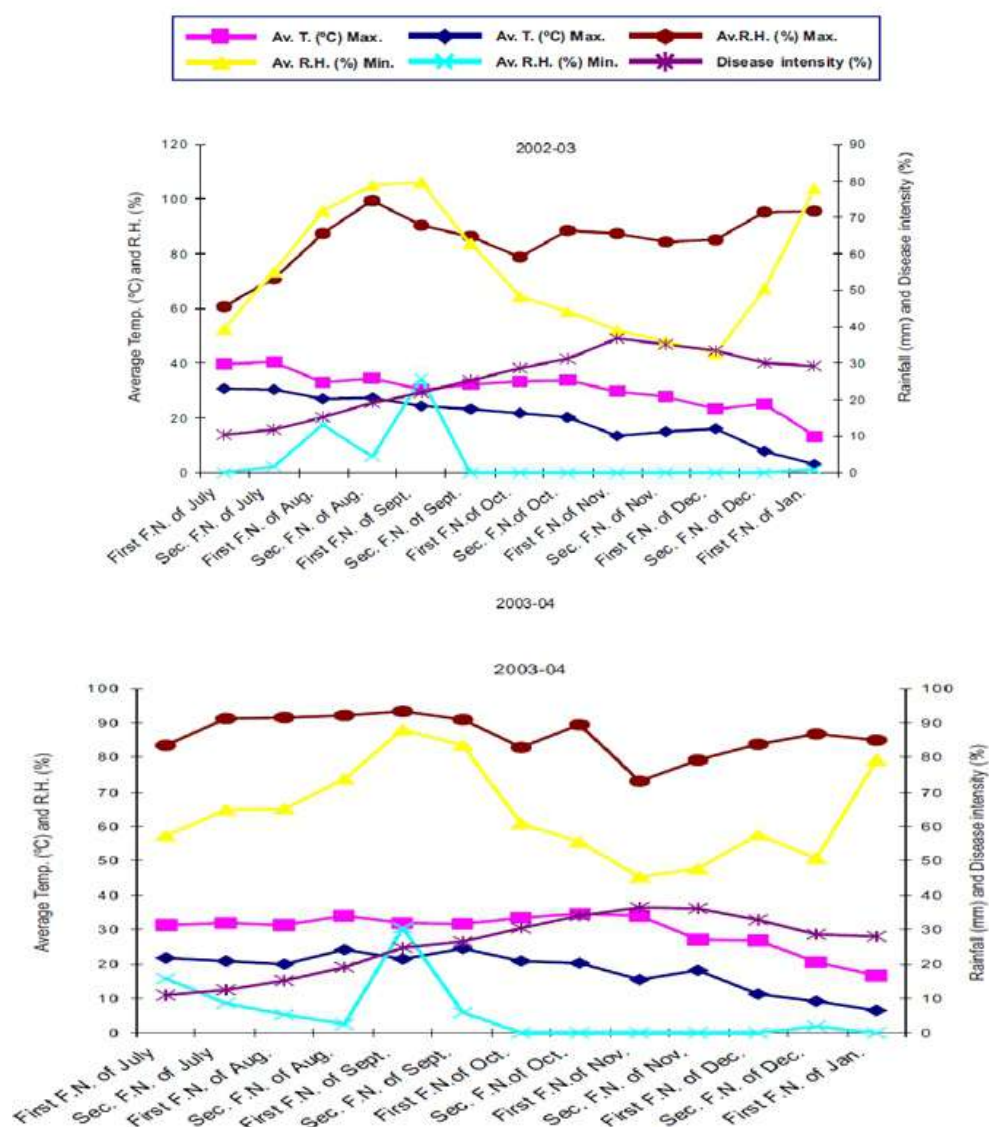


Fig-1: Effect of environmental factors on disease development.

necessary observations were taken (Table-1, Fig.-1). The results summarized in Table 1 reveal that environmental factors, viz., atmospheric temperature, relative humidity and rainfall play significant role in disease intensity. There is fairly good correlation between atmospheric temperature, relative humidity and rainfall and disease intensity. The disease appeared in the first fortnight of July which gradually increased upto first fortnight November and thereafter, there was a decline in disease intensity with lowering down of temperature and relative humidity upto the month of January. Maximum disease intensity (36.9%) during year 2002-03 and (36.5%) during 2003-04, in first fortnight of November, when the maximum and minimum atmospheric temperature varied between 29.7-13.6°C in the year 2002-03 and 24.0-15.4°C during year 2003-04, respectively and relative humidity varied upto 87.5–39.2 per cent (2002-03) and 73.3- 45.2 per cent (2003-04). However, there was no effect of rainfall on the disease development, as there was no rains during the said period. The minimum intensity (10.3 and 10.9 per cent) was observed in August when both the atmospheric temperature and the relative humidity were high, while in the month of January the disease intensity was observed low (29.3 and 28.1 per cent). The reason being instead of increase in relative humidity, the lowering down of atmospheric temperature continues to lower down disease intensity and the rainfall does not show significant any effect on it. Thus, it may be concluded that in general the maximum and minimum temperature and relative humidity have an impact on disease development, where the high temperature together with high humidity keeps the disease intensity low, whereas low temperature together with comparatively low humidity favour high disease development.

The maximum disease development was recorded in the first fortnight of November during 2002-03 and 2003-04. The average maximum and minimum temperatures and average maximum and minimum relative humidities were 29.7°C and 13.6°C and 87.5 per cent and 39.2 per cent, respectively during 2002-03, whereas during 2003-04 average maximum and minimum temperatures were 34.0°C and 15.4°C, respectively with average maximum and minimum relative humidities of 73.3 and 45.2 per cent led to maximum disease

development. The rainfall in January led to rise in relative humidity and fall in atmospheric temperature hampered disease development. No work on the epidemiology of this disease has been done before. However, Ghewande (1986) found that temperature between 25°C to 29°C and relative humidity of 87 per cent were more favourable for the development of *Alternaria* leaf spot of ground nut incited by *Alternaria alternata*. Patel and Patel (1991) reported that temperature range of 25-40°C and high relative humidity favoured the development of tomato rots in open market caused by *Alternaria alternata*. Singh and Majumdar (2000) observed that *Alternaria alternata* caused major rot disease in pomegranate. The rotting was maximum at 25°C temperature and 90 per cent relative humidity.

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In Vitro Evaluation of Efficacy of Different Plant Extracts and Chemicals Against *Bipolaris sorokiniana* (Sacc.) Shoemaker Causing Spot Blotch of Barley

Aradhna Sagwal*, Rajender Beniwal and Pooja

Department of Plant Pathology, CCSHAU, Hisar, Haryana

*Corresponding Author Email : aradhnasagwal31@gmail.com

Abstract

Spot Blotch is one of the major damaging foliar disease in barley caused by hemi-biotrophic pathogen *Bipolaris sorokiniana* (Sacc.) Shoemaker. The study was conducted at Department of Crop Protection, Indian Institute of Wheat and Barley Research, Karnal. The bioefficacy of different plant extracts viz. garlic clove, onion bulbs, eucalyptus leaves, neem leaves, neem seed kernel, turmeric powder, chrysanthemum leaves, mustard leaves was evaluated at 5% and 10% concentration against Spot Blotch of barley. Amongst the eight test botanicals, garlic clove extract @ 5% concentration showed 98% and 99% inhibition of conidial germination observed after 12 and 24 hrs respectively and 100% inhibition at 10 % concentration followed by onion bulbs extract (67%, 75%), neem seed kernel extract (65%, 73%) at 5% and 10% concentrations respectively observed after 24 hrs. Chrysanthemum leaves extract was found to be least effective in conidial germination inhibition.

Key words : *Bipolaris sorokiniana*, barley, botanicals, efficacy, garlic cloves.

Introduction

Barley (*Hordeum vulgare* L.) is an ancient cereal grain, which upon domestication has evolved from largely a food grain to a feed and malting grain (Baik and Ullrich, 2008). It is self pollinated, annual monocotyledonous grass species belong to the family Poaceae and one of the important cereal crop in the world. Barley is unique among the triticeae as it contains both annual species such as *H. vulgare*, *H. marinum* and *H. bulbosum* (Von Bothmer, 1992). The genus *Hordeum* consists of 32 species having basic chromosome number $X=7$. *H. vulgare* L. spp. *vulgare* is cultivated barley whose wild progenitor is *H. vulgare* L spp. *Spontaneum* (Wang *et al.*, 2014). Three species viz., *H. vulgare*, *H. marianum* and *H. bulbosum* have diploid chromosome number ($2n=2x=14$) while other species under genus *Hordeum* contains tetraploid ($2n=2x=28$) or hexaploid ($2n=2x=42$) chromosome number (Komatsuda *et al.*, 1999). It is further classified under the genus *Hordeum*. Three species of *Hordeum* are commonly recognized. However, only *H. vulgare* six row barley and *H. distichon* two barley are principle commercial types, out of which maximum area of cultivation is under bread barley (*H. vulgare*). The barley is highly drought tolerant and can be grown with less soil moisture (Singh, 1983). However, the barley cultivation was affected by many diseases. Amongst these diseases, spot blotch, caused by the fungus *Bipolaris sorokiniana*, is a major foliar disease affecting barley crops globally. Spot blotch caused by *B. sorokiniana*, poses a substantial threat to barley production, leading to significant economic losses. The spot blotch of barley was first reported in India from Pusa, Bihar (Butler, 1918). Later, it was reported

from different part of the country, North Bihar and India (Butler). It has been observed in several other countries (Dickson, 1956; Mathre, 1982).

Materials and Methods

The efficacy of different botanicals was tested against conidial germination inhibition of *Bipolaris sorokiniana* causing Spot blotch of barley. The botanicals used in the research work was garlic cloves (*Allium sativum*), turmeric powder (*Curcuma longa*), chrysanthemum leaves (*Chrysanthemum indicum*), eucalyptus leaves (*Eucalyptus globulus*), neem leaves (*Azadiracta indica*), neem seed kernel (*Azadiracta indica*), onion bulbs (*Allium cepa*), mustard leaves (*Brassica campestris*) at the concentration of 5 and 10% (w/v).

The surface washed plant parts macerated by grinding in mortar and pestle after mixing with equal amount of distilled water (1:1 w/v) to make the crude extract of botanicals. The extract formed was then filtered through muslin cloth to obtain stock solution of 100% concentration which then autoclaved at temperature 110°C and pressure 15 psi for about 10 minutes.

The conidia of pathogen was collected and harvested from 12 days old culture of *Bipolaris sorokiniana* and conidial suspension was maintained approximately 10^4 conidia/ml for conducting spore germination test in three block cavity slides, then the slides transferred into a moist chamber and incubated at $25 \pm 1^{\circ}\text{C}$. The observations were observed after 12 and 24 hours. The spore germination percent inhibition was calculated using formula.

Table-1 : Effect of botanicals on spore germination of *Bipolaris sorokiniana*.

Botanicals	Conidia germination inhibition (%)			
	Concentration (%) / Time (hrs)			
	5%	10%	5%	10%
	12 hrs	24 hrs	12 hrs	24 hrs
Garlic cloves	98 ^a (2)	99 ^a (1)	100 ^a (0)	100 ^a (0)
Onion bulbs	65 ^b (35)	67 ^b (33)	72 ^b (28)	75 ^b (25)
Eucalyptus leaves	20 ^g (80)	22 ^g (78)	23 ^g (77)	24 ^g (76)
Neem leaves	52 ^d (48)	55 ^d (45)	60 ^d (40)	62 ^d (48)
Neem seed kernel	58 ^c (42)	65 ^c (35)	70 ^c (30)	73 ^c (27)
Turmeric powder	25 ^f (75)	28 ^f (72)	30 ^f (70)	34 ^f (96)
Chrysanthemum leaves	15 ^h (85)	17 ^h (83)	15 ^h (85)	19 ^h (81)
Mustard leaves	38 ^e (62)	42 ^e (58)	45 ^e (55)	47 ^e (53)
Check	0 ⁱ (100)	0 ⁱ (100)	0 ⁱ (100)	0 ⁱ (100)

The Tukey test at a level of 5% of probability was applied. The averages followed by the same letter do not differ statistically between themselves. Figures in parentheses showing percent spore germination.

Inhibition (%) conidial germination = $C - T / C \times 100$

Where,

C = Number of conidia germinated in control;

T = Number of conidia germinated in treated.

The three replications were maintained, completely randomized design (C.R.D) was used for the experiment and Tukey's test was used for the comparison.

Results and Discussion

The data on the efficacy of the various botanicals viz., garlic cloves (*Allium sativum*), onion bulbs (*Allium cepa*), eucalyptus leaves (*Eucalyptus globulus*), neem leaves (*Azadiracta indica*), neem seed kernel (*Azadiracta indica*), turmeric powder (*Cucuma longa*), chrysanthemum leaves (*Chrysanthemum indicum*), mustard leaves (*Brassica campestris*) at the concentration of 5 and 10 per cent (w/v) showed varying effect on spore germination of *Bipolaris sorokiniana* (Table 1). The spore germination was reduced with increase in the concentrations of different botanicals used in the research work over control. Among the eight test botanicals, garlic clove extract showed complete inhibition of spore germination (100%) followed by onion bulbs extract (74.67%) and neem seed kernel extract (73%) at the 10.0 percent concentration observed after 24 hours of incubation. Among extracts of turmeric, chrysanthemum and eucalyptus, turmeric extract was found superior to chrysanthemum and eucalyptus extract in its effect on spore germination of *B. sorokiniana*. Chrysanthemum leaves extract showed minimum spore germination inhibition (16.67% and 19 %) at 5 and 10 per cent respectively observed at 24 hours of incubation.

The present study on the effect of the different botanicals viz., garlic cloves (*Allium sativum*), onion bulbs

(*Allium cepa*), eucalyptus leaves (*Eucalyptus globulus*), neem leaves (*Azadiracta indica*), neem seed kernel (*Azadiracta indica*), turmeric powder (*Cucuma longa*), chrysanthemum leaves (*Chrysanthemum indicum*) and mustard leaves (*Brassica campestris*) against *Bipolaris sorokiniana* causing spot blotch of barley showed their inhibitory effect on spore germination of *Bipolaris sorokiniana*. Among the tested botanical extracts, garlic clove extract was found to be the most effective in inhibiting the spore germination of *Bipolaris sorokiniana*. Yasmin (2016) observed *in vitro* efficacy of different botanicals extract i.e garlic, ginger and neem at different concentrations of 5, 10 and 15% on the mycelial growth of *Bipolaris sorokiniana*, *Fusarium oxysporum*, and *Sclerotium rolfsii* and found that different botanical extracts inhibited the mycelial growth of fungi significantly. They also found the highest % inhibition of mycelial growth of *Bipolaris sorokiniana* of 40.62% and 38.35% by the application of garlic and neem, respectively at 15% concentration and concluded that plant extracts might be a good alternative of chemical pesticide. Our results were in agreement with Prashanth *et al.* (2017) who found the direct effect of garlic cloves and different botanicals extracts against *B. sorokiniana* (Sacc.) shoemaker causing foliar blight of wheat and also reported that out of six test botanicals, garlic clove extract showed complete inhibition of spore germination (100%) followed by ginger rhizome extract (50%) and neem leaves extract (45%) at the 5.0 percent concentration (P=0.05). Magar *et al.* (2020) also found *in vitro* effect of botanicals against *Bipolaris sorokiniana*, causing spot blotch of wheat and observed that garlic clove extract at 15% concentration showed highest per cent mycelial growth inhibition (52.85%). Garlic showed antifungal effect against the fungus that might be due to the presence of various

sulphur compounds like allicin, ajoene, vinylthiines, alien, allylpropl-diallyl-trisulphides and others (Prashanth *et al.*, 2017). Awadh *et al.* (2022) also reported that terpenoids in neem (*Azadiracta indica*) extracts might have antifungal effect against *Bipolaris sorokiniana*.

Conclusions

Therefore, in the present findings, Garlic clove extract was found to be most effective *in vitro* studies and showed complete inhibition of spore germination (100%) as compared to control among the eight tested botanicals, and thus can be used in integrated disease management. Also, further investigation needs to be done along with other treatments combination in order to confirm the results and generate more information on managing the pathogen.

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Correlation Analysis of Parameters in *Apis mellifera* L. Queen Rearing Methods and Colony Performance

Rajan Kamboj¹ and Surender K. Sharma^{2*}

¹Department of Entomology, CCS Haryana Agricultural University, Hisar, Haryana, India

²Bee Research Station, Nagrota Bagwan, CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, Himachal Pradesh, India

*Corresponding Author Email : surender.brs@gmail.com

Abstract

Focused on the rearing methods of Miller, Smith, Doolittle, and Swarming, this research paper undertakes a comprehensive correlation analysis of various parameters associated with honey bee queen rearing. The correlation analysis revealed a strong positive correlation ($r = 0.997$, $p < 0.05$) between the percentage of accepted cells and the number of finished queen cells per colony. Similarly, a significant positive correlation ($r = 0.995$, $p < 0.05$) was observed between the strength of the colony and the emergence of neonate queens. The mean body weight of day-old queens showed a correlation with the queen rearing methods, with Doolittle-raised queens exhibiting the highest weight ($r =$ correlation coefficient). The time taken for queens to initiate egg laying displayed a negative correlation with certain queen rearing methods, indicating variability in the duration across techniques. Furthermore, the size of finished queen cells, both at the top and overall (depth $\times$ diameter at mid), exhibited correlations with the rearing methods, highlighting method-specific variations in cell dimensions. The brood area in colonies headed by queens reared through different methods correlated with the aggressive egg-laying behavior of queens, with Doolittle-raised queens showing the highest brood area. Notably, colony hoarding capabilities, including pollen collection, nectar collection, strength gain, and honey yield, displayed significant positive correlations with the Doolittle queen rearing method, emphasizing its impact on overall colony productivity.

Introduction

Honey bees are the important social insects which play a major role in the field of agriculture by pollination and production of important substances like honey, royal jelly, bees wax, propolis, pollen and bee venom (Alburaki and Alburaki 2008). Honey bees, along with other pollinators, are responsible for pollinating approximately 35% of the world food crops (Klein *et al.* 2007). Honey bees and other pollinators play a crucial role in shaping both economic and ecological landscapes (Neov *et al.*, 2019). The global economic significance of insect pollination is substantial, estimated at 9.5%, equivalent to USD 169.6 billion or ₹ 13,93,785.5 crores (Gallai *et al.*, 2009). In the context of Indian agriculture, insect pollination directly contributes an astounding ₹ 1,12,615.7 crores (USD 22.52 billion) annually, constituting 8.7% of the total, and brings about improvements in quality traits, seed production, and breeding efficiency (Chaudhary and Chand, 2017). The honey bee's annual economic value for pollination in India is estimated at ₹ 385.7 crores (USD 0.047 billion) based on the 2014 valuation (Chaudhary, 2014). Honey bees are recognized as keystone species among animal pollinators due to their involvement in pollinating 75% of the world's cultivated crops. Their crucial role extends to supporting humanity by enhancing production, ensuring food security, and preserving diversity in global ecosystems. Notably, out of the 20,000 to 30,000 bee species globally, farmers worldwide manage only 11 species. The Italian

honey bee, *Apis mellifera* L. (Apidae: Hymenoptera), stands out as the most recognizable and economically significant commercial species, boasting a global management of 91 million colonies (Phiri *et al.*, 2022). In India, the successful introduction of *A. mellifera* was achieved through interspecific queen introduction techniques, with initiatives starting in 1962 at the Bee Research Station, Nagrota Bagwan, Himachal Pradesh (Atwal and Sharma, 1968), followed by Punjab in 1965 (Atwal and Goyal, 1973), and Haryana in 1982 (Chaudhary, 2014). To promote optimal growth of bee colonies year-round and maximize financial yields, beekeepers must raise and supply high-quality queens before the onset of the honey flow season—specifically during winter and spring in Haryana and Himachal Pradesh. Mass rearing of top-notch *A. mellifera* queens is a crucial aspect of beekeeping, providing a practical means to supply new queens to queenless colonies and replace aging, unproductive queens (Laidlaw and Page, 1997). Since the colony's performance is directly tied to the queen's status (Tarpy *et al.*, 2000), the importance of queen bees cannot be overstated. Considering these facts and the significance of queen bees, methods such as those pioneered by Doolittle, Miller, Smith, and swarming instincts were employed to mass rear and study the quality traits of *A. mellifera* queens.

Materials and Methods

The research was conducted at the apiary of Chaudhary

Table-1 : Correlation coefficient (r) between queen cell and neonate queen reared by Miller Method.

No. of finished queen cells/colony	No. of neonate queens emerged	Weight of queen (mg)	Duration for egg laying (days)	Colony strength	Brood area (cm ²)	Nectar area (cm ²)	Pollen area (cm ²)	Diameter of queen cell (mm)			Depth of queen cell (mm)	Honey yield (kg)
								Top	Mid	Bottom		
Percent number of cells accepted	0.997**	0.427	0.836	0.155	-0.621	0.941	0.934	0.732	-0.298	-0.403	-0.394	0.13
No. of finished queen cells/colony		0.361	0.826	0.189	-0.567	0.925	0.91	0.761	-0.271	-0.359	-0.403	0.181
No. of neonate queens emerged			0.532	-0.478	-0.956*	0.602	0.689	-0.005	-0.578	-0.802	-0.165	-0.481
Weight of queen (mg)				-0.389	-0.757	0.961*	0.923	0.843	-0.764	-0.777	-0.8	0.401
Duration for egg laying (days)					0.5	-0.189	-0.171	-0.133	0.891	0.821	0.657	-0.244
Colony strength (cm ²)						-0.798	-0.853	-0.288	0.708	0.886	0.402	0.235
Brood area (cm ²)							0.990*	0.76	-0.6	-0.686	-0.606	0.195
Nectar area (cm ²)								0.662	-0.566	-0.693	-0.51	0.055
Pollen area (cm ²)									-0.518	-0.397	-0.826	0.768
Top diameter (mm)										0.951*	0.864	-0.389
Mid diameter (mm)											0.702	-0.11
Bottom diameter (mm)												-0.783
Depth of queen cell (mm)												0.088

* p = 1%, ** p = 5%

Table-2 : Correlation coefficient (r) between different parameters viz. queen cells and queen in queen less colonies reared by Smith Method.

	No. of finished queen cells/colony	No. of neonate queens emerged	Weight of queen (mg)	Duration for egg laying (days)	Colony strength	Brood area (cm ²)	Nectar area (cm ²)	Pollen area (cm ²)	Diameter of queen cell (mm)			Depth of queen cell (mm)	Honey yield (kg)
									Top	Mid	Bottom		
Percent number of cells accepted	0.909	0.831	0.996**	-0.165	-0.951*	0.779	0.477	0.805	0.287	0.189	-0.913	-0.027	-0.797
No. of finished queen cells/colony		0.892	0.928	-0.561	-0.878	0.568	0.34	0.979*	0.636	0.311	-0.992**	0.292	-0.942
No. of neonate queens emerged			0.814	-0.484	-0.662	0.776	0.705	0.879	0.679	0.681	-0.942	0.519	-0.971*
Weight of queen (mg)				-0.214	-0.970*	0.72	0.404	0.832	0.311	0.142	-0.922	-0.032	-0.801
Duration for egg laying (days)					0.174	0.173	0.096	-0.718	-0.953*	-0.409	0.54	-0.778	0.661
Colony strength						-0.565	-0.184	-0.775	-0.203	0.094	0.843	0.201	0.681
Brood area (cm ²)							0.897	0.447	0.092	0.525	-0.647	0.07	-0.609
Nectar area (cm ²)								0.281	0.209	0.8	-0.454	0.37	-0.524
Pollen area (cm ²)									0.776	0.382	-0.969*	0.45	-0.961*
Top diameter (mm)										0.653	-0.652	0.887	-0.797
Mid diameter (mm)											-0.416	0.849	-0.607
Bottom diameter (mm)												-0.35	0.968*
Depth of queen cell (mm)													-0.572

* p = 1%, ** p = 5%

Table-3 : Correlation coefficient (r) between different parameters of *Apis mellifera* colonies reared by Doolittle Method.

	No. of finished queen cells/ colony	No. of neonate queens emerged	Weight of queen (mg)	Duration for egg laying (days)	Colony strength	Brood area (cm ²)	Nectar area (cm ²)	Pollen area (cm ²)	Diameter of queen cell (mm)			Depth of queen cell (mm)	Honey yield (kg)
									Top	Mid	Bottom		
Percent number of cells accepted	0.990*	0.569	0.795	-0.302	0.600	0.239	0.783	0.896	-0.254	0.062	-0.694	0.065	-0.692
No. of finished queen cells/colony		0.671	0.872	-0.426	0.707	0.373	0.709	0.927	-0.147	0.203	-0.635	0.161	-0.683
No. of neonate queens emerged			0.898	-0.763	0.949	0.898	0.218	0.831	0.615	0.811	-0.314	0.327	-0.611
Weight of queen (mg)				-0.800	0.961*	0.771	0.32	0.866	0.222	0.65	-0.304	0.497	-0.510
Duration for egg laying (days)					-0.905	-0.92	0.312	-0.418	-0.411	-0.901	-0.308	-0.858	-0.023
Colony strength						0.917	0.094	0.760	0.443	0.834	-0.124	0.586	-0.403
Brood area (cm ²)							-0.232	0.513	0.714	0.984*	0.133	0.614	-0.214
Nectar area (cm ²)								0.712	-0.298	-0.394	-0.968*	-0.567	-0.843
Pollen area (cm ²)									0.193	0.355	-0.735	-0.002	-0.865
Top diameter (mm)										0.764	0.065	0.045	-0.258
Mid diameter (mm)											0.282	0.641	-0.073
Bottom diameter (mm)												0.656	0.934
Depth of queen cell (mm)													0.49

* p = 1%, ** p = 5%

Table-4 : Correlation coefficient (r) between finished queen cell, cell size and weight of queen by Swarming Method.

	Duration for egg laying (days)	Colony strength	Brood area (cm ²)	Nectar area (cm ²)	Pollen area (cm ²)	Diameter of queen cell (mm)			Depth of queen cell (mm)	Honey yield (kg)
						Top	Mid	Bottom		
Weight of queen (mg)	0.761	0.619	-0.101	0.302	0.960*	0.751	-0.783	0.562	-0.538	-0.739
Duration for egg laying (days)		0.694	-0.076	0.688	0.715	0.796	-0.950*	-0.081	-0.931	-0.187
Colony strength			0.64	-0.022	0.39	0.187	-0.882	0.265	-0.789	-0.505
Brood area (cm ²)				-0.667	-0.373	-0.635	-0.216	0.207	-0.198	-0.272
Nectar area (cm ²)					0.451	0.83	-0.433	-0.554	-0.568	0.408
Pollen area (cm ²)						0.87	-0.657	0.484	-0.428	-0.626
Top diameter (mm)							-0.61	0.002	-0.539	-0.16
Mid diameter (mm)								-0.09	0.936	0.366
Bottom diameter (mm)									0.26	-0.959*
Depth of queen cell (mm)										0.022

* p = 1%, ** p = 5%

Sarwan Kumar Himachal Pradesh Agricultural University Palampur, Bee Research Station; Nagrota Bagwan (H.P.), India during the spring breeding season of the calendar year 2016-2017. The experimental site was located at an altitude of 907.31 m above mean sea level (amsl) and between 32°07' North latitude and 76°24' East longitude. Various materials and equipment, such as Langstroth hives, beekeeping tools, and scientific apparatus, were utilized for the study. The prerequisites for mass queen rearing involved maintaining two healthy *A. mellifera* mother colonies and establishing four cell builder colonies. Different methods, including Doolittle, Miller, Smith, and swarming instinct, were employed for mass queen rearing. The Doolittle method involved the preparation of artificial queen cell cups and the grafting of larvae. In the Miller method, queen cells were raised using frames with marked eggs, while the Smith method used rectangular wax foundation sheets for comb raising. The swarming instinct method induced natural swarming in queen-right cell builder colonies. Various observations, such as acceptance of eggs and larval grafts, number of sealed queen cells, size of queen cells, queen emergence, weight of neonate queens, and pre-oviposition period, were recorded and analyzed (Kamboj *et al.*, 2023). This comprehensive approach aimed to investigate and compare the efficiency of different mass queen rearing methods in beekeeping.

Results and Discussion

Analyzing the outcomes obtained from the diverse mass queen rearing methods, the study unveils critical insights into the comparative effectiveness of each technique and its impact on the overall performance of honey bee colonies.

Miller Method : The data analysis (Table-1) demonstrated a positive correlation ($r=0.997$, 5% significance level) between the percentage of accepted cells and the number of finished queen cells per colony. Additionally, the average weight of neonate queens, influenced by larger queen cells (correlation with diameters of top and mid parts, $r = 0.951$), exhibited a positive correlation with brood area ($r = 0.961$). The interconnectedness of higher brood area, larger queen cells, heavier queens, and increased nectar collection was evident through positive correlations ($r=0.990$). These findings align with Kahya *et al.* (2008) results.

Smith Method : As indicated in Table-2, a positive correlation ($r = 0.976$, 5% significance level) was found between the body weight of queens and the number of finished queen cells per colony. This correlation may be attributed to the ample number of nurse bees in the colony, nurturing queen larvae and resulting in comparatively larger queens. The positive correlation

between pollen area ($r = 0.979$) and the number of finished queen cells can be linked to the enhanced hoarding capabilities of the test colonies (refer to Table 4.9). These findings align with previous literature, including Gatoria *et al.* (2000), Kumar *et al.* (2000), and Akyol *et al.* (2008).

Doolittle Method

A significant positive correlation ($r=0.990$, 1% significance level) was observed between the percentage of accepted cells and the number of finished queen cells per colony (Table-3). Furthermore, the emergence of neonate queens was found to depend on colony strength ($r=0.995$), consistent with the works of Koc and Karacagolu (2011) and Tandon (2014). Larger queen cells produced better queens and demonstrated a positive correlation with brood area, aligning with Woyke (1971) findings.

Swarming Method : The analysis revealed a significantly positive correlation (r) between the duration taken for starting egg laying and brood area (0.960), in accordance with Woyke (1971). An early-mated queen was likely to start laying eggs sooner, resulting in more brood area in the colony, as supported by Akyol (2008). However, there was a negative correlation between pollen area and the depth, top, and bottom diameters of queen cells (Table-4, $r = -0.998$).

Conclusions

The Doolittle honey bee queen rearing method exhibited noteworthy advantages over other techniques, evidenced by the statistically earlier commencement of egg laying and a significantly higher honey yield. The colonies raised using the Doolittle method displayed consistent and statistically significant increases in colony strength during the January to March period. Moreover, a positive correlation was identified between the number of finished queen cells and the weight of queens reared, emphasizing the interconnectedness of these key parameters. The non-significant differences in pollen hoarding across all colonies throughout the year indicate a consistent performance in this aspect across the various queen rearing methods. In conclusion, the findings underscore the effectiveness of the Doolittle method in achieving early egg laying, robust colony strength, and enhanced honey yield, suggesting its potential as a preferable approach in honey bee queen rearing for improved colony performance.

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A Review of the Constraints in the Implementation of Soil Health Card (SHC) Scheme”

Sharma Shalini¹ and Sharma K.C.²

¹Department of Soil Science and Agricultural Chemistry, BHU, Varanasi, U.P.-221005

²Department of Extension Education, SKNAU, Jobner-Jaipur, Rajasthan-303329

Abstract

Understanding of soil health condition is essential to the sustainability and stability of entire ecosystem of farmland. To protect deterioration of soil and visualizing the importance of balanced nutrients in crop production the SHC scheme was launched in 2015. In the present study an attempt was made to review the literature related with constraints perceived by the respondents in the implementation of SHC Scheme. The important constraints faced by majority of the respondents were – difficulty in identifying micronutrient deficiency, calculation of fertilizer dose was difficult, the time taken between soil sampling and issuing cards to farmers was too high and so on.

Key words : Soil health card (SHC), respondents, micronutrients, fertilizers, constraints.

Soil is the basic component of agriculture which contains nutrients and provides them to plants for proper growth. Soil is key to the ecosystem functions, which supports the production of food, forestry products and human health. Healthy soils produce healthy crops that in turn nourish people and animals. In soil properties, soil health plays an important role in agricultural productivity, food quality, environmental resiliency and ecosystem sustainability (Sterens, 2018). Soil health restoration is often the first entry point to increase the productivity of food secure farms, which also affects global climate. That's why understanding soil health condition is essential to the sustainability and stability of the entire ecosystem of farmland (Xue *et al.* 2019). In present time the major challenge within sustainable soil management is to conserve ecosystem service delivery while optimizing agricultural yields. It is proposed that soil health is dependent on the maintenance of four major functions: carbon transformations; nutrient cycles; soil structure maintenance and regulation of pests and diseases (Kibblewhite *et al.* 2007).

Soil health and fertility is the basis for sustainable profitability of the farmers. Using optimal doses of fertilizers and cropping pattern as per the scientific recommendation is the first step towards sustainable farming. Soil testing is a science based and time-tested tool for assessment of soil fertility status and soil ailments and for nutrient amendment recommendations. Soil testing, as a tool for judicious fertilizer use, works on the principle of profitability, meaning if all other factors of production are at optimum and none of them limiting, there is all probability to obtain more profitable response to applied nutrients based on soil testing than those applied on ad hoc basis. In India, the current consumption of NPK ratio is 6.7:2.4:1, which is highly skewed towards

nitrogen as against ideal ratio of 4:2:1, India is spending nearly rupees seventy thousand crore on fertilizer subsidy every year. According to the estimates, subsidy amount is about Rs. 5000/ha of net cropped area and about Rs. 5100/farmer resulting in excessive use of fertilizers, especially NPK at the cost of micro-nutrients and manure. Hence, there is a need for balanced use of fertilizers. Keeping this in view Govt. of India has introduced Soil Health Card Scheme across India.

SHC Scheme is an analysis of quality of soil right from its functional characteristics to water and nutrient content and other biological properties. It contains corrective measures that a farmer should adopt to obtain a better yield. The SHC helps the farmers to get a well monitored report about the soil and they are guided by the experts to improve soil health. Injudicious and haphazard use of chemical fertilizers, low addition of organic matter and non-replacement of depleted micro and secondary nutrients over the years have resulted in nutrient deficiencies in soil (Brijraj *et al.* 2019). To avoid deterioration of soil in long run and visualizing the importance of balanced nutrients in crop production the Soil Health Card (SHC) Scheme was launched by honorable Prime Minister Narendra Modi on 19th February, 2015 at Suratgarh, Rajasthan. The scheme aims at issuing soil health cards to farmers in every three years so as to provide a basis to address nutritional deficiencies in the soil.

Soil Health Card help farmers to get good harvest by studying the quality of the soil. The card being a printed report given to the farmers once in three years for his land holding. The SHC contains all basic and crop wise recommendations of fertilizers or nutrients required for farms of different soil types. It also provides recommendations of other inputs in order to increase the

productivity of farms. It also leads to profiling of soil structure which will in turn help in diversification of crops as per the soil content of the area as well. After getting SHC, farmers have reduced N, P and K use, especially nitrogen use and increased micro nutrients use which helped them to increase the fertility. It helped farmers to diversify towards less input intensive crops from more input intensive crops. It also helped in the formulation of specific schemes like subsidized micronutrients from governments. Many constraints are being faced by the farmers and extension agencies in the implementation of SHC Scheme at the field level. An understanding of the constraints faced by the respondents may serve as a feedback to the planners, policy makers, extension personnel, scientist and development agencies to make suitable strategy in the implementation of the scheme. Looking to the above facts in mind the present study entitled, "A Review of the constraints in the implementation of Soil Health Card (SHC) Scheme" was carried out with the following objective:-

(1) To review the research studies carried out regarding constraints perceived by the respondents in the implementation of SHC Scheme.

A constraint is anything that prevents or limits an individual or a group to utilize any resources or information from tapping the intended effect of the information (Kumar *et al.*, 2019). Constraints can be of any type like personal or external in a social system. In this study the limiting factors faced by farmers while utilizing the soil health card and its information was reviewed.

Research Methodology

This study is based on secondary data. The sources of the data are published and unpublished sources like books, journals, articles, magazine articles, reports, publications, unpublished doctoral dissertations and the World Wide Web.

Review of Literature

Damisa and Igonoh (2007) expressed that lack of access to reliable and current information coupled with wide communication gaps between researchers and farmers were presently a major impediment to adoption of Integrated Soil Fertility Management (ISFM) by farmers in the western Kenya region.

Sanginga and Woome (2009) stated that low level of literacy among small holding farmers in Sub Saharan Africa (SSA) has been identified as a major constraint to effective communication and dissemination of soil fertility information, then, acting as a major impediment to its access by farmers.

Chouhan *et al.* (2012) reported the constraints faced by the farmers in adoption of recommendations included high cost, difficulty in adoption, low credibility of soil testing report and long distance to laboratory.

Patel and Chauhan (2012) in their study revealed that over whelming majority (91 per cent) of farmers expressed difficulty in identifying micronutrient deficiency due to unavailability of micronutrient status of soil. 88 per cent of them expressed difficulty in calculating fertilizer dose on the basis of nutrient status of soil. 84 per cent of them expressed that soil health cards were issued after harvesting of crops. 82 per cent expressed that time taken between soil sampling and issuing cards to the farmers was too high, 65 per cent expressed problem of unavailability of internet facility at village level and 23 per cent expressed that collection of soil sample was not done in the presence of farmers.

Patel (2013) found that constrains faced by the respondents in application of soil health card programme were- unavailability of micronutrient status of soil which ranked first with mean score (78.00 per cent) followed by difficulty in calculating fertilizer does on the basis of nutrient status of soil (73.33 per cent) and unable to operate internet (77.66 per cent).

Bennett and Cattle (2014) identified series of statements concerning impediments for the adoption of soil health management plans. These statements were separated into six broad categories: education and training impediments; agency and extension organizations based impediments; land use associated impediments; market impediments; economic impediments and personal and social impediments.

Chowdary and Theodore (2016) observed the foremost constraints expressed by the respondents in adoption of SHC were inadequate follow-up by extension agency (63.0 per cent), followed by no visible results (43.0 per cent), complex to adopt the recommendations (26.0 per cent), less knowledge (23.0 per cent), less benefit (14.0 per cent), lack of time (11.0 per cent), peers do not follow (9.0 per cent), unscientific method of collecting soil sample (9.0 per cent) and finally higher cost (3.0 per cent).

Kalamkar and Swain (2016) reported that in the soil testing farmers have faced several difficulties in applying recommended doses of fertilizers. Among these constraints, difficulty in understanding and following the instructions on SHCs regarding application of recommended doses, unavailability of technical advice on methods and time of fertilizer application, high prices of fertilizers and unavailability of required fertilizers in adequate quantity were the major ones. About 41 per cent

farmers stated the difficulty in understanding and 62 per cent were feeling that application of recommended doses as their major problem in applying recommended doses. About 35 per cent farmers stated higher price as their main constraints. While 31.3 per cent farmers stated lack of money to purchase fertilizers as their main constraints.

Bardolai and Das (2017) found the following problems in implementation of SHC scheme :

(i) In Assam there were about 27.02 lakh farmers, but no agency maintained authentic records of the benefited farmers with proper address and Land holding till date. Problems, many times arose in identifying the real owner of the farm for collection of soil samples, which ultimately posed difficulty in implementation of the SHC scheme.

(ii) Collection and analysis of soil sample, printing of SHC's and it's distribution seems to be an arduous task for the State Agriculture Department. This may be the reason for which the jobs were entrusted to a private agency.

(iii) Existing infrastructure of the state labs were not up to the mark to achieve the targets within the given timeline.

(iv) Initially, micronutrient analysis of the soil samples could not be undertaken in the state labs due to technical problems.

(v) Short supply of reagents often hampered a lot in analyzing the soil samples.

(vi) Lack of technical guidance and training programme to handle the Mini Soil Test Labs (Mridha Parikshak), were identified to be yet another problems for soil sample analysis.

(vii) Shortage of employees and frequent transfer of lab staffs was a major hindrance in accomplishing the work.

Grower *et al.* (2017) revealed that 32 per cent farmers told that no farmers training camp was organized emphasizing on the benefits of soil testing in their village. Also it was reported by seven percent respondents that they were not at all aware about the technique of taking soil sampling/testing procedure. Nearly five per cent respondents revealed that while taking soil sample proper method was not followed by the officials collecting soil sample from their fields and two per cent respondents also revealed that they were not involved in taking soil sample and soil test report delivery was delayed.

Patel *et al.*, (2017) concluded that the respondents (farmers) reported the following constraints faced in SHC scheme, they are as follows, 'understanding of soil testing was difficult' , 'delay in getting the test reports on time' ,

'difficulty in following test based fertilizer recommendation', 'no certainty in yield gain' and 'no proper and scientific guidance'.

Reddy (2017) concluded the constraints of Soil Health Card scheme as:

(i) Some farmers complained that the soil test values are not representative of their field and they also complained that the field staff has not collected soil samples in their presence.

(ii) Many farmers were unable to understand the content, hence unable to follow the recommended practices.

Barauh *et al.* (2018) expressed that farmers being very traditional in nature and with limited land holding cannot be expected to fully adopt the recommended dose of fertilizers within a year of receiving the soil health cards.

Jaiswal and Singh (2018) concluded that 75.83 per cent of the farmers were having problems in making SHC, 64.17 per cent, were having difficulty in calculating fertilizer dose on the basis of nutrient status of the soil, 55.83 per cent were saying that collection of soil sample was not done in presence of farmer, 52.50 per cent told that the time gap between soil samples taken and issuing cards was too long, 37.50 per cent received SHC after crop harvest, 32.50 per cent showed inability to understand all the information given in the card, 24.17 per cent said no subsidy on inputs required through government for improving the soil quality and 22.50 per cent told about irregularity of extension services.

Mukati *et al.* (2018) observed that large majority of the soil health card holders faced difficulty in calculating fertilizer dose on the basis of nutrient status of the soil (64.10 per cent). The respondents also responded that the task of collection of the soil sample was not done in the presence of farmers (55.56 per cent), time gap between soil samples taken and issuing cards were too high (51.28 per cent), received soil health cards after crop harvest (40.17 per cent), inability to understand all the information given in the card (25.64 per cent), no subsidy on inputs required by the government for improving the soil quality (20.51 per cent) and irregularity of extension services (17.09 per cent) which may restrict them to clear their doubts at the time of need .

Niranjan *et al.* (2018) revealed that the major problems reported by the majority of soil tested farmers were as follows , difficulty in calculating the required quantity of fertilizers as per SHC (87 per cent), followed by high price of fertilizers (79 per cent), lack of training (74 per cent), method of collecting ideal soil samples (56 per cent), lack of technical advice on method and time of fertilizers application (53 per cent), lack of capital to

purchase fertilizers (34 per cent), recommendation of SHC is not creditable (47 per cent), recommended fertilizers not available in adequate quantity in the local market (63 per cent), lack of knowledge about method of collecting ideal soil sample (56 per cent), soil testing laboratories are located far away (45 per cent), lack of knowledge regarding advantages of SHC (35 per cent) SHC not available on time (23 per cent) and soil testing not required for my field as crop yield is good (19 per cent).

Archana and Balasubramanian (2019) found that inability to understand all the information given in card was the first constraint with the mean score 96 percent followed by time gap between soil samples taken and issuing cards is too high (82.8 per cent), lack of proper scientific guidance (72 per cent), prices of fertilizers were high (63.3 per cent), non-availability of organic manure and bio-fertilizers (56.4 per cent) and non-availability of micronutrient fertilizers in market (49.2 per cent) were important constraints

Kumar *et al.* (2019) observed that the farmers faced several difficulties in getting and utilizing information of Soil Health card. Major Constraints were high time gap between soil samples taken and issuing cards, difficulty in understanding all the information given in the soil health card and calculating fertilizer dose on the basis of nutrient status of soil.

Soil Health card (SHC) is an analysis of the quality of the soil right from its functional characteristics to water and nutrient content and other biological properties. It helps the farmers to get a well mentored report about the soil and they are guided by the experts to improve soil health. The present study was an attempt to review the literature on the constraints faced by the respondents in the implementation of Soil Health Card scheme. Following important conclusions were drawn from the study :

1. Majority of respondents (farmers) expressed difficulty in identifying micronutrient deficiency due to unavailability of micronutrient status in soil.

2. Difficulty was faced in calculating fertilizer dose on the basis of nutrient status of soil.

3. Majority of respondents perceived that time taken between soil sampling and issuing cards to the farmers was too long.

4. A few respondents told that soil test values were not representative of their fields and they also complained that the field staffs have not collected soil samples in their presence.

5. Respondents also faced the problem like lack of training about SHC, lack of knowledge about method of collecting ideal soil sample, soil testing laboratories were

locating far away, lack of technical advice on method and time of fertilizers application and so on.

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Performance of Guava Varieties under Ambient Storage Conditions

Dinesh Kumar Kuldeep*, D.P. Sharma, Manmohan Singh Bhoriya, Maneesh Kumar and N.R. Rangare

JNKVV, Jabalpur, Madhya Pradesh, India

*Corresponding Author Email : dineshkuldeep88@gmail.com

Abstract

A lab experiment was conducted to evaluate the post-harvest quality of different guava cultivars under ambient storage conditions. Experiment was conducted at Post-harvest Laboratory of Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during the winters of 2012-14. Experiment comprises of fruits of eight varieties of guava viz., Lucknow -49, Lalit, Shweta, Allahabad Safeda, GB Pasand, Chittidar, Apple Colour, Banarsi Surkha with Complete Random Design and replicated thrice. The cultivar GB Pasand exhibited the least amount of degradation in terms of fruit weight and decay percentage, whereas cultivar Lucknow-49 demonstrated minimum loss in total soluble solids and L-ascorbic acid during storage. As the experiment progressed, TSS exhibited an increasing tendency whereas ascorbic acid showed a declining trend. Based on the results, it can be said that GB Pasand and Lucknow-49 were the promising cultivar chosen for the experiment in terms of quality and post-harvest shelf life.

Introduction

Guava (*Psidium guajava*), also referred to as the “apple of the tropics,” is a highly nutritious and antioxidant fruit crop (Tiwari et al., 2016 and Meena et al., 2021). Guava is an excellent source of vitamin C and pectin. Per 100 g of edible portion, guava has averagely 80–83% moisture, 2.45% acid, 3.5–4.45% reducing sugar, 3.97–5.23% non-reducing sugar, TSS 9.73–14.23, potassium 0.48%, and vitamin C 260 mg (Islam et al., 2008). It is also a great source of dietary fibers and minerals like potassium, manganese, magnesium, and phosphorus. Guavas are eaten with their seeds, which are high in fiber and omega fatty acids (Meena et al., 2021). High vitamin C (L-ascorbic acid) content makes it a powerhouse in combatting free radicals, which are essential foes in the cause of many degenerative diseases (Kadam et al., 2012). Increased intake of vitamin C and Lycopene has been linked to a lower risk of chronic diseases such as cancer, cardiovascular disease, and cataracts, most likely through antioxidant processes (Garcia et al., 2004 and Tiwari et al., 2017).

Guava postharvest losses are estimated to be 25-30%, owing to poor storage and postharvest handling (Krishna and Kabir, 2018). Rough handling causes guava damage, resulting in bruising and lesions that make it prone to microbial deterioration (Singh, 2011). Good handling procedures preserve guava quality and decrease postharvest losses. Many post-harvest techniques exist, but most of them are inappropriate for this attractive fruit since, like guavas, they are not typically peeled before consumption. Choosing superior variety with better post-harvest handling and a longer shelf life with less quality decline is a more practical approach.

Keeping this in view present investigation was carried out to study the post-harvest quality of guava under ambient conditions.

Materials and Methods

The experiment was conducted during 2013-14 at Post-Harvest laboratory, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, on eight cultivars of guava viz., Lucknow-49, Allahabad Safeda, Lalit, Shweta, Apple Colour, Chittidar, Banarasi Surkha and Gorakh Bilas pasand. Following complete randomized design (Panse and Sukhatme, 1985) with three replication and eight fruits as a unit in each replication, fruits of the promising and demanding eight different varieties of guava were collected from Raghuvanshi Farm, Babiyan-village, Chhapra, District-Varanasi, U.P. Mature fruits having greenish yellow colour were randomly plucked from ten trees of each cultivar. The trees were of uniform size and vigor and were kept under uniform laboratory condition during the experimental period. Eight fruits were taken of each cultivar and used for physical and chemical studies. These fruits were stored at ambient temperature ($25 \pm 2^\circ\text{C}$) and relative humidity 70-75% in CFB boxes. Data on physiological weight loss (%), decay loss (%), ascorbic acid (mg/100g) and total soluble solids ($^\circ\text{Brix}$) were taken and statistically analyzed at 5% level of significance. The Physiological weight loss during storage was determined by the weight differences at days 0, 5 and 10, which were then compared with initial day and expressed in percentage. The number of decayed fruits due to fungus or any micro-organisms infection was recorded at days 0, 5 and 10, which were compared with initial weight and calculated as a percentage of the total number of fruits.

Table-1 : Effect of varieties on physiological weight loss and decay of guava under ambient storage condition.

Variety	Physiological weight loss (%)			Decay (%)		
	Days after storage			Days after storage		
	5	10	Mean	5	10	Mean
Lucknow-49	2.42	5.29	3.85	8.40	22.10	15.25
Lalit	2.67	5.87	4.27	8.90	23.00	15.95
Shweta	4.90	10.17	7.53	16.20	44.10	30.15
Allahabad Safeda	2.76	6.07	4.42	9.20	26.50	17.85
GB Pasand	2.05	4.42	3.32	7.10	20.40	13.75
Chittidar	3.63	6.71	5.17	13.40	31.10	22.25
Apple Colour	3.53	6.51	5.02	12.30	28.50	20.40
Banarsi Surkha	3.76	8.81	6.29	14.40	34.10	24.25
Mean	3.21	6.73		11.24	28.73	
CD at 5%	V= 0.45, D= 0.33, TxD= 0.94			V= 2.20, D= 4.30, TxD= 8.94		

Table-2 : Effect of varieties on TSS of guava under ambient storage conditions.

Variety	TSS in degree Brix			Mean
	Days after storage			
	0	5	10	
Lucknow-49	13.580	13.618	13.645	13.614
Lalit	11.500	11.567	11.605	11.557
Shweta	12.400	12.475	12.540	12.472
Allahabad Safeda	13.190	13.233	13.567	13.330
GB Pasand	11.300	11.367	11.433	11.367
Chittidar	13.000	13.670	14.733	13.801
Apple Colour	11.200	11.267	11.367	11.278
Banarsi Surkha	12.500	12.667	13.27	12.812
Mean	12.000	12.243	12.701	
CD at 5%	V= 0.09, D= 0.06, TxD= 0.17			

Table-3 : Effect of varieties on L-ascorbic acid content of guava under ambient storage condition.

Variety	L-ascorbic acid (mg/100 g)			Mean
	Days after storage			
	0	5	10	
Lucknow-49	319.60	319.54	319.47	319.54
Lalit	196.00	195.88	195.74	195.87
Shweta	236.00	235.82	235.71	235.84
Allahabad Safeda	302.00	301.95	301.86	301.94
GB Pasand	210.00	209.90	209.81	209.90
Chittidar	290.00	289.78	289.60	289.79
Apple Colour	248.02	247.94	247.76	247.91
Banarsi Surkha	240.04	239.78	239.66	239.83
Mean	247.02	246.85	246.71	
CD at 5%	V= 4.88, D= 0.33, TxD= NS			

The total soluble solids and vitamin C were determined t days 0, 5 and 10 using the method of Anonymous (1984).

Result and Discussion

Physiological weight loss : Data on physiological weight loss indicated that guava varieties significantly affected this trait during storage (Table-1). Among all evaluated varieties GB Pasand shows minimum loss of weight (3.32%) which was statistically significant over Lucknow-49 (3.85 %), Lalit (4.27 %), Allahabad Safeda (4.42 %) and other cultivars. Maximum physiological

weight loss was observed in variety Shweta (7.53 %) followed by Banarsi Surkha (6.29%). There was a continuous loss in weight as storage duration increases. The differences in weight loss could be due to differences in the water vapour permeability for the varieties (Tiwari et al., 2017). Cultivar differences in the weight loss of red raspberry during storage have been reported earlier (Haffner et al., 2002).

Decay (%) : Data indicated that guava varieties significantly affected decay (%) during storage (Table-1).

Among all examined varieties GB Pasand shows minimum loss of weight (13.75%) which was statistically significant over Lucknow-49 (15.25 %), Lalit (15.95 %), Allahabad Safeda (17.85 %) and other cultivars. Maximum physiological decay % was observed in variety Shweta (30.15 %) followed by Banarsi Surkha (24.25%). The increase in decay incidence caused pathogens in guava fruit was also observed by Reyes and Paull (1995) when the fruit were transferred to ambient conditions (22 °C) after 9 days of air storage at 10, 15, and 20°C.

Total Soluble Solids (degree Brix) : Data on physiological TSS showed that guava varieties significantly affected this trait during storage (Table-2). Among all evaluated varieties shows Lucknow-49 has maximum TSS (13.645 degree Brix) which was statistically at par with Allahabad Safeda (13.567 degree Brix) and significant other cultivars. This might be due to the conversion of polysaccharides into monosaccharide or soluble sugar. Pectin in guava is mostly composed of D-galacturonic acid, thus the polysaccharide present in pectin breaks down and increases the amount of total soluble solids (Tiwari et al., 2016)

L-Ascorbic Acid (mg/100 g) : Ascorbic acid content revealed that under ambient storage conditions, guava varieties had a substantial impact on vitamin C content (Table-3). Lucknow-49 was found to have the highest ascorbic acid content (319.54 mg/100g) among all the studied varieties, and this difference was statistically significant when compared to other cultivars while stored at room temperature. The presence of the enzyme ascorbic acid oxidase may cause the oxidation or irreversible conversion of L-ascorbic acid into dehydro-ascorbic acid, which could account for the drop in ascorbic acid levels during storage. There has also been prior research indicating a significant variance in the ascorbic acid concentration of guava fruit between several kinds (Bashir and Abu-Goukh, 2003 and Tiwari et al. 2016).

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A Review on Physiological Responses of 1-Methylcyclopropene (1-MCP) on Horticultural Crops

Dinesh Kumar Kuldeep*, D.P. Sharma, Manmohan Singh Bhooriya, Maneesh Kumar and N.R. Rangare

Jawahar Lal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P., India

**Corresponding Author Email : dineshkuldeep88@gmail.com*

Abstract

1-MCP is a novel commercial chemical that suppresses ethylene action and can help many horticultural crops maintain their quality during storage and marketing. It protects horticultural crops from injuries caused by both exogenous application and the endogenous presence of ethylene. It delay ripening and softening, reduces respiration and chlorophyll degradation. In ornamental plants particularly cut standard and spray flowers 1-MCP increases vase life after harvesting. It shares structural similarities with the natural plant hormone ethylene. It is used commercially to slow the ripening of fruits. Delaying of ripening in papaya, peel colour retention in sweet orange, minimum fruit decay in mango and no change in ascorbic acid, total phenolic content and antioxidants in cabbage are noteworthy advantages of exogenous application of 1-MCP in horticultural crops. The primary focus of this review is to discuss physiological responses of 1-MCP on Horticultural crops in detail.

Introduction

1-Methylcyclopropene (1-MCP) is a cyclopropene derivative that is utilized as a synthetic plant growth regulator. It is structurally linked to the natural plant hormone ethylene and is used commercially to slow the ripening of fruit and to help keep cut flowers fresh. Methallyl chloride and phenyllithium, which serves as a base, react to produce 1-methylcyclopropene. Ethylene is a gas that acts at trace levels (typically between a few tenths and a few thousands ppm in the gas atmosphere) throughout a plant's life by stimulating or regulating processes such as climacteric fruit ripening, flower opening (dehiscence process), and leaf shedding (abscission process). 1-MCP works by tightly binding to the ethylene receptor in plants, hence blocking the actions of ethylene (competitive inhibitor). Growers, packers, and shippers utilize 1-MCP under the brand name Smart-fresh to prevent or delay natural ripening in the agriculture industry. More than 34 nations, including the European Union and the United States, have approved and allowed the use of 1-MCP in agricultural goods such as apples, kiwifruit, tomatoes, bananas, plums, persimmons, avocados, and melons. The primary goal of this review is to go over the physiological effects of 1-MCP on horticultural crops in depth.

Physiological Responses

Ethylene inhibitor : In the presence of 1-MCP, ethylene mediated responses (ripening and senescence of fruits, flowers, leaves and plant as a whole) are found to be retarded (Guillen *et al.*, 2007; Choi and Huber, 2008). It is effective to protect horticultural produce from both

exogenous and endogenous sources of ethylene (Celikel *et al.*, 2002). 1-MCP inhibit the production of ethylene in *Physalis peruviana* (Lopez *et al.*, 2021), *Durio zibethinus*, *Pyrus communis* L. cv. Berlett and *Solanum tuberosum*. However, inhibition of ethylene by exogenous application of 1-MCP depends upon the type of crop, cultivar, temperature, storage conditions, treatment duration, etc. 1-MCP inhibited the production of ethylene biosynthetic enzymes i.e. ACC oxidase, ACC synthase and associated mRNA accumulation consequently affecting ethylene production (Alabboud *et al.*, 2017).

Respiration : There is an inverse relationship between respiration rates and post-harvest life of horticultural commodities (Varoquaux and Ozdemir, 2005). Yang, 1995 reported that ripening of climacteric fruits is accompanied by autocatalytic increases in ethylene production and increase in the respiration rate of the fruit. It is well known increase in respiration is mediated through ethylene synthesis. Exogenous application of 1-MCP reduce respiration rate or delayed respiration increase (Blankenship and Dole, 2003). The efficacy of 1-MCP depends upon the stage of commodities and storage conditions. Tian *et al.*, 2000 reported that exogenous application of 1-MCP inhibited the ethylene-induced respiratory increase in early-harvested fruit, but not in late harvested fruits of strawberry (Tian *et al.*, 2000).

Softening : Exogenous application of 1-MCP delayed the softening of most of climacteric as well as non-climacteric horticultural crops. However, some crops were not responding well to its exogenous application. 1-MCP has been to be effective in delaying softening in *Pyrus communis* L. cv. Berlett (Escribano *et al.* 2017).

Chlorophyll degradation and colour change : Ethylene is a gaseous hormone and is associated with the degradation of chlorophyll and ripening. Exogenous application of 1-MCP reduce the chlorophyll degradation horticultural crops due to its inhibitory action against ethylene synthesis. This effect of 1-MCP on inhibition of peel degreening is especially beneficial for lime fruits, where retention of green colour desirable during storage and marketing (Jomori et al., 2003). This attribute is also beneficial for green and leafy vegetables. Portel et al., 1999 reported that 1-MCP application inhibited the process of degreening in *Citrus sinensis*. But in many studies it is reported 1-MCP treated fruits and vegetables at early stage of ripening showed significantly lower organoleptic characteristics than untreated fruits and vegetables even at the final ripe stage of tomato (Guillen et al., 2006). However, Salazar et al., 2018 reported sensory quality attributes were adequate in all cases, reaching a medium or high acceptability in the evaluation panel in 1-MCP treated kiwi fruits. 1-MCP also delay chlorophyll degradation in *Brassica oleracea* var. italic and *Selenicereus megalanthus* (Herrera, 2007).

Flower senescence and vase life : The states of freshness or senescence that affect flower longevity are directly associated with ethylene production in floral organs, such as petals and the gynoecium (Naing et al., 2022). Exogenous application of 1-MCP tightly blocks ethylene binding sites in floral tissues and suppresses the expression of the response genes. The beneficial effect of 1-MCP has been well documented in a range of cut flowers and ornamental plants.

Other physiological responses of 1-MCP in horticultural crops : Exogenous application of 1-MCP reduce the decline of protein in senescence of many horticultural crops like as coriander (Jiang et al., 2002). Development of aroma in fruits and flowers depend upon the synthesis of ethylene and some other physiological processes. Total volatiles were inhibited in 'McIntosh' and 'Delicious' cultivar of Apple when exogenously treated with 1-MCP (Rupasinghe et al., 2000). Fan et al., 2000 also reported delayed development of volatile alcohol and esters in 1-MCP treated apricots. Titratable acidity and sugar content of horticultural commodities also affected by exogenous application of 1-MCP. 1-MCP inhibited loss in acidity in tomato slices, while did not affect titratable acidity in apricots (Dong et al., 2002) and Red Chief cultivar of apples during storage (Mir et al., 2001).

Factor affecting the effectivity of 1-mcp on horticultural crops : 1-Methylcyclopropene (1-MCP) is an innocuous gas used at very low concentration (1 or nl) which inhibit ethylene action by blocking ethylene receptors. Currently, the application of 1-MCP on certain

horticultural commodities is not commercially feasible due to the variable effects associated with this technology. In this section, factors that influence the effectivity of 1-MCP in horticultural crops such as maturity stage, concentration of 1-MCP, genotypes, storage temperature and atmospheres, packaging material and application timing are critically discussed.

Maturity stage : Shelf life of horticultural produce directly correlated with the rate of respiration. In climacteric fruits and vegetables such as tomato, apple, mango, guava, etc., there is an increase in respiration rate and ethylene production before the onset of ripening which is a later stage of fruit maturation. Fruit ripening results from increased ethylene production due to higher expression of ethylene receptor genes and activation of their associated enzymes. Thus, ripening of climacteric fruits results in a decrease of the ethylene receptor protein in the cells. Expression of ethylene receptor gene increases with advanced maturity and ripening stage, indicating that immature and overripe fruits may have fewer ethylene receptors compare to mature green fruits. Application of 1-MCP is recommended to treat pre-climacteric matured fruits as it does not respond effectively to ripe or overripe fruits. Matured banana fruits are more sensitive to application of 1-MCP compared to less mature. Ripe fruits of banana and avocado do not respond to exogenous application of 1-MCP (Harish et al., 2023). Similarly, mature green tomato treated with 1000 nl l⁻¹ 1-MCP were store for 35 days with significant decreases in quality parameters. In case of non-climacteric horticultural commodities viz., grape, pineapple, citrus 1-MCP more effective at maturity stage. Therefore, the ethylene concentration present in the fruit tissues would help in determined the dosage of 1-MCP at commercial scale.

Concentration of 1-MCP : The effectiveness of 1-MCP also depends on its concentration which varies from commodity to commodity. Similarly, they vary with temperature, time of treatment and method of application. In 'Hachia' persimmon 1-MCP dose 625 nl/l gave better results regarding the lowest weight loss and decay development compared to 156.25 nl/l and 312.5 nl/l (Ali et al., 2017). Similarly, in 'Zorro hybrid' tomato, 500 and 1000 nl l⁻¹ 1-MCP reduced weight loss, softening and ethylene production compared to 125 and 250 nL L⁻¹ (Sabir et al., 2012). In Cocktail tomato treating the fruit with 1250 ppb of 1-MCP was determined to be the best for maintaining all quality criteria during storage compare to 625 ppb. These results indicate that the effectiveness of 1-MCP depends on its dose.

Genotypes : The efficacy of 1-MCP has been extensively investigated on different genotypes of the crop and confirmed that genotypes also influence its efficacy.

Different genotypes might have a different number of ethylene receptors and internal concentration of ethylene which affects the efficacy of 1-MCP (Zhang *et al.*, 2011). The thinner-skinned genotypes may have better 1-MCP absorption capacity than the thicker-skinned genotypes (Choe and Huber, 2008). Efficacy of 1-MCP might be also varies due to the chemical composition viz., insoluble dry matter content of the genotypes which modulate the influx of 1-MCP into the tissue (Chope *et al.*, 2007). Dong *et al.*, 2013 observed that diffusion of 1-MCP was rapid in spinach and choy leaves than in tomato.

Application methods : Application method of 1-MCP also influence its effectiveness on horticultural commodities. There are two states of 1-MCP that are applied exogenously to horticultural crops, i.e. gaseous and aqueous. In the gaseous phase, 1-MCP gas is released from aqueous dissolution in a sealed container with the produce. In this step, a small amount of water is added to the 1-MCP powder to allow it to ingress and diffuse into the produce. Whereas in aqueous state produce are submerged in a solution of 1-MCP. Most of the findings suggested that aqueous state requires more 1-MCP concentration compared to gaseous mode to be effective (Choi *et al.*, 2008 on tomato and avocado; Escribano *et al.*, 2017 on pear). Since the immersion time in aqueous mode (1–5 min) is less than that in gaseous mode (6–24 h), the diffusion rate is likely to be slow in aqueous mode (Choi *et al.*, 2009). Therefore, higher concentrations probably increase the rate of 1-MCP absorption in aqueous state. Despite these differences, an aqueous mode was more consistent in delaying the rate of ripening than gaseous 1-MCP in pear (Escribano *et al.*, 2017) and banana (Pongprasert and Srilaong, 2014). Limited information on aqueous 1-MCP efficacy on post-harvest quality of horticultural crops and comparative studies between states of application make it difficult to exploit the mode in the horticultural industry. However, application of 1-MCP in aqueous mode is faster and easier and does not require a sealed environment for application (Escribano *et al.*, 2017). However, features such as water tanks are required, which may the application of 1-MCP is less practical, especially in those commodities that are not hydro-cooled. This could be one of the reasons behind limited application of 1-MCP in aqueous states. Commercially, gaseous 1-MCP is used in various horticultural commodities due to known protocols and easy to use when dealing with huge quantity of horticultural commodities particularly in climacteric fruits. Aqueous 1-MCP has potential in industries where fruits are washed or hydro-cooled prior to packaging, as it would be easy and practical to combine 1-MCP with sanitizing solutions such as calcium chloride. Minh (2021) reported that the incorporation of CaCl_2 and 1-MCP created a

synergistic effect on the improved quality of watermelon fruit during ambient storage condition. The microbubble technology for uniform application of 1-MCP application has also been developed, but the high cost has limited its commercial use.

Duration of treatment : The duration of 1-MCP application is directly correlated to the efficacy of the treatment. However, little is known about the duration of exogenous application of 1-MCP on horticultural crops. In Kesar cultivar of mango, shelf life and the quality of fruit was having strong association with 1-MCP concentration and its exposure time (Sakhale *et al.*, 2018). In the Optima cultivar of carnation, a 6 h treatment of 1-MCP was more successful in ethylene inhibition than a 3 hours treatment (Asil *et al.*, 2013). However, Abadi *et al.* (2009) reported that 1-MCP was more efficient in inhibiting ethylene synthesis in Tempo cultivar of carnation when the treatment duration was 3 hours compared to 6 hours and 9 hours treatment durations. Therefore, it is inferred that different treatment duration required was also found to be associated with cultivars and 1-MCP concentrations.

Temperature during application and storage : The temperature during exogenous application of 1-MCP varies from crop to crop, even within varieties of a particular crop. 1-MCP was more effective when banana was treated at 25°C (Zhu *et al.*, 2015), whereas application of 1-MCP at low temperature (0°C) delay ripening in Ber cv. Sungold compared to 8°C temperature (Velardo-Micharet *et al.*, 2017). However, 1-MCP applied at 0 °C had no pronounced effect on 'Bartlett' pear (Villalobos-Acuña *et al.*, 2011). 1-MCP and storage temperature also synergistically extend the storage life and quality of horticultural produce. Xie *et al.*, 2014 reported 1-MCP treated pear fruits when stored at -1.1°C effectively reduce respiration rate, ethylene production and chlorophyll degradation compare to storage temperature of 1.1°C. However, higher firmness was retained at 1.1°C.

Storage atmosphere : In addition to storage temperature, the storage environment is also related to the efficacy of 1-MCP. The use of storage environments such as controlled atmosphere (CA), modified atmosphere packaging (MAP) and hypobaric storage have been shown to complement 1-MCP in increasing storage life and maintaining the quality of horticultural produce. MAP technology improve the efficacy of 1-MCP in case of mango (Vázquez-Celestino *et al.*, 2016) and banana (Ketsa *et al.*, 2013). Weber *et al.*, 2017 reported reduced ethylene production and the activity of the ACC oxidase enzyme in 1-MCP-treated 'Fuji Suprema' apple stored in dynamic controlled atmosphere (DCA) storage. However, more work is needed to investigate the

effect of 1-MCP in combination with different storage methods and other genotype.

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Effect of Different Sources of Organic Manure on Growth and Yield of Wheat (*Triticum aestivum* L.)

Navaldeep Kaur, P.K. Sharma, Mahipal Dudwal and Sunil Kumar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India

*Corresponding Author Email : sidhunaval0031@gmail.com

Abstract

A research study was carried out to evaluate effect of different sources of organic manure on growth, yield of wheat. In Randomized block design research trail were under taken in which total eight treatments viz FYM (24 t/ha), Vermi-compost (6 t/ha), Poultry manure (4 t/ha), FYM (24t/ha) + vermicompost (6 t/ ha), FYM (24 t/ha) + poultry manure (4 t/ha), Vermicompost (6 t/ha) + poultry manure (4 t/ha), FYM (24 t/ha) + vermicompost (6 t/ha) + poultry manure (4 t/ha) and control were evaluated. Among them treatment FYM (24 t/ha) + vermicompost (6 t/ha) + poultry manure (4 t/ha) were found best with plant height, Grain yield (kg/ha), Straw yield (kg/ha) and Harvest index (%) 79.11 at 90 DAS, 4312 (kg/ha), 6424 (kg/ha) and 38.093 %, respectively.

Key words : Wheat, organic manure, vermicompost, neem cake and poultry manure.

Introduction

Wheat (*Triticum aestivum* L.) belonging to one of the most diverse and substantial families, Poaceae, is the principal cereal crop for the majority of the world's population (Bos *et al.*, 2005). The approximate biochemical composition of wheat is 66-71.6% carbohydrates, 13-16.7% proteins, 2.5-3.1% fats, 2.5-3% crude fibre (Khan, 1984). The total area under wheat in world during 2021-22 was 220.76 million hectares with an annual production of 770.88 million tonnes and average productivity of 34919 kg/ha (Anonymous, 2021). The average productivity wheat in Rajasthan was 3926 kg ha⁻¹ (Anonymous, 2022). Organic sources of nitrogen like FYM, vermicompost, neem cake and poultry manure helps to improve the soil health and also sustain the productivity. So a research works under taken to evaluate the effect of organic manure on yield of wheat.

Materials and Methods

To evaluate the effect of various treatments combinations, observations on plant growth parameters, yield attributes and other aspects were recorded. The seeds of wheat variety 'HD-2851' were sown 10 October and observation were recorded according selected treatments or objectives.

Plant height : Five shoots from each plot was randomly selected and tagged for periodic recording of plant height. Plant height of individual shoot was measured in centimeter with the help of meter scale at various physiological stages at 30, 60, 90 DAS and at harvest from the base of plant at soil surface up to the tip of the last youngest leaf and up to the last tip of spike at harvest stage and thereafter mean value was computed.

Dry matter accumulation (g/m²) : Periodical changes in dry matter accumulation were recorded by cutting three randomly selected 0.5 m row length from the soil surface with the help of sickle from sample rows of each plot at 30, 60, 90 DAS and at harvest. The harvested plant material was air dried first and then in an oven at 60°C to constant weight. Total dry weight of plants was averaged to record dry matter accumulation/g/m².

Number of effective tillers (m²) at harvest and Number of grains/spike : The number of ear bearing tillers were counted in three randomly selected m row length from each plot at harvest and their average was taken as the number of effective tillers (m²). From the ten spikes of wheat, grains were separated, cleaned and counted and the mean value of grains per spikes was computed.

Grain yield or straw yield (kg/ha) : The total biomass harvested from each net plot was threshed manually and cleaned by winnowing. The grains so obtained were weighed in kg plot-1 and then converted into kg ha⁻¹. The straw yield kg per plot was obtained by subtracting the grain yield from biological yield per plot recorded and then converted into kg ha⁻¹.

Harvest index : The ratio of economic yield (grain yield) to the biological yield was calculated to estimate the harvest index and was expressed as percentage (Singh and Stoskoof, 1971).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Results and Discussion

Plant height at 30, 60, 90 DAS and at harvest : The data indicated that organic manures application had significant

Table-1 : Effect of different organic manures on plant height at different stages of growth of wheat.

S. No.	Treatments	Symbol	Plant height (cm)			
			at 30 DAS	at 60 DAS	at 90 DAS	at harvest
1.	Control	T ₁	9.60	35.32	54.32	62.32
2.	FYM(24 t/ha)	T ₂	10.10	43.25	66.25	74.25
3.	Vermicompost (6 t/ha)	T ₃	10.25	47.35	66.35	75.15
4.	Poultry manure (4 t/ha)	T ₄	11.42	49.32	67.32	79.32
5.	FYM (24t/ha) + vermicompost(6 t/ ha)	T ₅	11.50	45.58	69.58	81.58
6.	FYM (24 t/ha) + poultry manure (4 t/ha)	T ₆	11.89	48.50	70.50	80.50
7.	Vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₇	11.54	57.57	72.57	82.57
8.	FYM (24 t/ha) + vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₈	11.95	56.11	79.11	86.11
SEm+			1.24	2.42	3.24	3.89
CD (P = 0.05)			NS	6.57	9.72	11.67

Table-2 : Effect of different organic manures on dry matter accumulation (g/m²) of wheat.

S. No.	Treatments	Symbol	Plant height (cm)			
			At 30 DAS	at 60 DAS	at 90 DAS	at harvest
1.	Control	T ₁	70.82	311.55	556.57	814.55
2.	FYM (24 t/ha)	T ₂	84.35	319.48	668.50	964.48
3.	Vermicompost (6 t/ha)	T ₃	86.95	323.58	668.60	977.38
4.	Poultry manure (4 t/ha)	T ₄	87.35	325.55	769.57	1005.55
5.	FYM (24t/ha) + vermicompost(6 t/ ha)	T ₅	90.35	420.81	876.50	1080.81
6.	FYM (24 t/ha) + poultry manure (4 t/ha)	T ₆	88.25	424.73	856.35	1086.25
7.	Vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₇	92.35	428.80	900.31	1120.32
8.	FYM (24 t/ha) + vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₈	105.25	532.34	984.25	1186.35
SEm+			5.12	17.32	36.35	46.35
CD (P = 0.05)			15.41	52.13	109.41	139.51

effect on plant height at all the growth stages except 30 DAS. At 90 DAS, the maximum plant height (79.11 cm) was recorded in T₈, which was statistically at par with T₇ and T₆ and T₅. While the shortest plants (54.32 cm) was observed under control which was significantly lower than the all other treatments. At harvest stage, maximum plant heights (86.11 cm) were recorded in T₈, which was statistically at par with all treatments, except T₁, T₂ and T₃. However, the minimum plant height (65.32) was observed under control (T₁), which was significantly lower than the all other treatments except T₂. Rathore *et al.* (1995) also reported the increase in height and yield attributes of wheat with organic manure. These findings further showed conformity with then observations of Abdel *et al.* (2002) at Cairo, Egypt, who reported that root length, tiller number, plant height and dry matter accumulation increased by manuring wheat plants with vermicompost. Data presented in table-1.

Dry matter accumulation (g/m²) : At 90 DAS the maximum dry matter accumulation (1186.35 gm) was obtain in T₈, which was significantly at par with T₇, T₆ and T₅ and significantly higher than the remaining treatments. However, the minimum dry matter accumulation (814.55 gm) was observed under control (T₁), which was

significantly lower than the all other treatments except T₂. These findings were in accordance with Ghosh *et al.* (2004), Hadis *et al.* (2018), Cherr *et al.* (2006), Pezeshkpour *et al.* (2014), and Shishehbor *et al.* (2013). Data presented in table-2.

Number of effective tiller/m² : The data pertaining to mean number of effective tillers per m² influenced by different organic manure management. The effective tillers were significantly affected by organic manure practices. The treatment T₈ (FYM (24 t/ha) + vermin-compost (6 t/ha) + poultry manure (4 t/ha) resulted in higher effective tillers (435.36), which was at par with T₇ (Vermicompost (6 t/ha) + poultry manure (4 t/ha)). The lowest effective tillers were recorded under control treatment T₁ (295.36).

Grains per spike : The variations in number of grains per spike were significant in various organic manure management practices. The maximum numbers of grains per spike (37.82) was recorded in T₈, which was statistically at par to T₇, T₆ and T₅ but significantly superior than the remaining treatments. The minimum number of grains per spike (27.36) was found in control (T₁).

Spike length : The variations in spike length were

Table-3 : Effect of different organic manures on yield attributes (number of effective tillers/m² at harvest, grains/spike and spike length.

S. No.	Treatments	Symbol	Yield attributes		
			Number of effective tillers/m ² at harvest	Grains per spike	Spike length
1.	Control	T ₁	295.36	27.36	7.86
2.	FYM (24 t/ha)	T ₂	345.25	31.25	8.11
3.	Vermicompost (6 t/ha)	T ₃	351.25	32.25	8.23
4.	Poultry manure (4 t/ha)	T ₄	348.20	32.25	8.52
5.	FYM (24t/ha) + vermicompost(6 t/ ha)	T ₅	376..25	34.58	9.22
6.	FYM (24 t/ha) + poultry manure (4 t/ha)	T ₆	385.24	34.15	9.40
7.	Vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₇	396.5	35.20	9.38
8.	FYM (24 t/ha) + vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₈	435.36	37.82	10.11
SEm+			14.52	1.58	0.24
CD (P = 0.05)			43.56	4.64	0.72

Table-4 : Effect of different organic manures on yield attributes (grain yield (kg/ha), straw yield (kg/ha) and harvest index (%) of wheat.

S. No.	Treatments	Symbol	Yield		
			Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
1.	Control	T ₁	2900	4325	43.509
2.	FYM (24 t/ha)	T ₂	3382	4935	39.621
3.	Vermicompost (6 t/ha)	T ₃	3356	5124	38.762
4.	Poultry manure (4 t/ha)	T ₄	3408	5034	38.758
5.	FYM (24t/ha) + vermicompost (6 t/ ha)	T ₅	3765	5465	40.769
6.	FYM (24 t/ha) + poultry manure (4 t/ha)	T ₆	3756	5625	39.683
7.	Vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₇	3896	5564	40.723
8.	FYM (24 t/ha) + vermicompost (6 t/ha) + poultry manure (4 t/ha)	T ₈	4312	6424	38.093
SEm+			152	241	1.25
CD (P = 0.05)			456	723	NS

significant in various organic manure management practices. The maximum numbers of grains per spike (10.11) was recorded in T₈ and which was statistically at par to T₇ and T₆ but significantly superior than the remaining treatments. The minimum numbers of grains per spike (7.86) was found in control (T₁). These findings were in accordance with Ghosh et al. (2004), Hadis *et al.* (2018), Cherr *et al.* (2006), Pezeshkpour *et al.* (2014), and Shishehbor *et al.* (2013). Data presented in table-3.

Grain yield (kg/ha) and Straw yield (kg/ha) : The significant variation was noted in wheat grain yield under different organic manures management options. The maximum grain yield and straw yield (4312 kg/ha and 6424 kg/ha, respectively) was recorded under T₈ (FYM (24 t/ha) + vermicompost (6 t/ha) + poultry manure (4 t/ha)) and significantly higher than the remaining treatments except T₇. The lowest grain yield and straw yield (2900 kg/ha and 4325 kg/hac respectively) was recorded in control which was significantly lower than all other treatments. Yousefi and Sadeghi (2014) also observed that application of vermin-compost significantly

improves the yield and yield characters of wheat as compared to other organic sources.

Harvest index (%) : The organic manure treatments did not have any significant effect on harvest index. However, the highest harvest index (40.77 %) was recorded with treatment T₅ (FYM (24t/ha) +vermicompost (6t/ ha)). The lowest harvest index (180.6 kg/ha) was recorded under control treatment (T₁). Data presented in table-4.

Conclusions

From present study it is clear that foliar spray of treatment i.e foliar application of cow urine at 10% + vermi-wash at 10% is most effective to achieve maximum growth and yield attributes. Therefore efficient use of cow urine and vermi-wash provides a better alternative to the synthetic chemicals which are cause potential danger to the farmers or costly also.

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Influence of Microbial Enriched Vermicompost and Fertility Levels on Growth and Yield of Mustard [*Brassica juncea* (L.)]

Pallishree Biswal*, P.K. Sharma, N.K. Sharma and Sunil Kumar

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan, India

*Corresponding Author Email : pallishreebiswal1@gmail.com

Abstract

A field experiment was conducted during *Rabi* season of 2022-23 at Research Farm, Vivekananda Global University, Jaipur, to study the influence of microbial enriched vermicompost and fertility levels on growth and yield. The experiment was laid out in factorial randomized block design with three replications. The treatments consisting three levels of vermicompost (control, 1.0 and 2.0 t ha⁻¹) and three treatment of fertility levels (Control, 75% RDF and 100% RDF). The experimental results showed that application of vermicompost @ 2.0 t ha⁻¹ produced significantly higher plant height and dry matter accumulation at 80 DAS and at harvest, chlorophyll content, number of siliquea plant⁻¹, number of seeds siliquea⁻¹, seed yield, stover yield and biological yield over control and application of vermicompost @ 1.0 t ha⁻¹. While, different levels of vermicompost were failed to cause significant variation on plant stand at 20 DAS, plant height and dry matter accumulation at 40 DAS, test weight and harvest index. Results further showed that application of 100% RDF significantly increased the plant height and dry matter accumulation at 80 DAS and at harvest, chlorophyll content, number of siliquea plant⁻¹, number of seeds siliquea⁻¹, seed yield, stover yield and biological yield of mustard. However, plant stand at 20 DAS, plant height and dry matter accumulation at 40 DAS, test weight and harvest index was not changed significantly due to application of fertility levels. Therefore, application of enriched vermicompost @ 2.0 t ha⁻¹ and 100% RDF may be recommended for higher productivity of mustard crop.

Key words : Growth, fertility, vermicompost and yield.

Introduction

Globally, oil seed crops have the unique significance in recent era of energy crisis as they play prominent role in the agricultural industries and export trade. The oil seed cultivation scenario has undergone dramatic change in recent years wherein, they become a net foreign exchange earner leading to “Yellow revolution”. Indian mustard [*Brassica juncea* (L.) Czern & Coss] is a major *rabi* oilseed crop of the country and occupies a prominent place being next in importance to soybean and groundnut, both in area and production. It belongs to family Brassicaceae and have chromosome no. of $2n = 36$. Indian mustard gives edible oil which is used as cooking medium in North India. The seed and oil are used as condiment in the preparation of pickles and for flavouring curries and vegetables. The leaves of young plants are used as vegetable. The oil content in mustard seeds varies from 37 to 42 per cent and its oil is utilized for human consumption for cooking and frying purposes. It is also used in the preparation of vegetable ghee, hair oils, medicines, soap making, mixtures with mineral oils for lubrication and manufacture of greases.

Among the various constraints attributing to low productivity of mustard in arid and semi-arid region, the erratic nature of climate, unavailability or inefficient irrigation water and poor fertilizer management and poor soil physical conditions are the most important factors

which lead to low crop yield. Soil health deterioration is the prime threat to Indian agriculture which is being aggravated with excessive use of fertilizers particularly in less responsive soils which have low organic matter content. The improper use of inorganic fertilizer has led to think about the use of FYM, vermicompost, poultry manure; bio-fertilizers etc. in growing areas for sustainable production system but organic manure alone cannot produce the sufficient food for present population and other uses. Under these circumstances, integrated use of organic manures with inorganic fertilizers shown promising results not only in sustaining the productivity but have also proved effective in maintaining soil health and enhanced nutrient use efficiency.

Among 17 essential plant nutrients, N, P and K play the most important role in augmenting agriculture production which is required in the larger quantity of all the mineral nutrients absorbed by plant roots. Nitrogen is a major nutrient which provide lush green plant colour on account of increase in chlorophyll content required for the process of photosynthesis. It is also an important constituent of protoplasm and chlorophyll and associated with the activity of living cells. Likewise, the response to phosphorus is determined by soil phosphorus status, moisture availability and yield level attained. Phosphorus is the key element in the process of conservation of solar energy into chemical energy. The optimum supply of phosphorus to the plant stimulates root development and

growth thereby helps to establish seedling quickly and also reduces the harmful effect of excess nitrogen in plants. Potassium is also one of the major elements essential for growth, yield and quality of plant and it is thought to be essential for the formation and translocation of carbohydrates which needed in large quantities by most of the crops. There is a great scope for increasing the production of mustard by bringing more area under cultivation and increasing its productivity by applying organic manures with balanced inorganic fertilization and maintaining soil fertility status.

Materials and Methods

The experiment was conducted during *Rabi* 2021-22 at Research Farm, Vivekananda Global University, Jaipur. Geographically, the study area is located at 75°88'99" E longitude and 26°81'17" N latitude and this region falls under agro-climatic zone III A (Semi-arid Eastern Plain Zone) of Rajasthan. The seeds of variety giriraj were treated with bavistin @ 3 g kg⁻¹ seed to prevent seed borne disease. The crop was sown by "kera" method in rows spaced at 30 cm apart and plant spaced at 10 cm on 5 November 2022 using seed rate of 4 kg/ha. The experiment consisting of 9 treatment combinations was laid out in Factorial Randomized Block Design. Treatments details along with their symbols are presented in table-1.

Table-1 : Treatments details with their symbols.

S. No.	Treatment	Symbol
A. Vermicompost levels (t ha⁻¹)		
1.	Control	VC ₀
2.	1.0	VC ₁
3.	2.0	VC ₂
B. Fertility levels		
1.	Control	F ₀
2.	75 % RDF	F ₁
3.	100 % RDF	F ₂

Statistical analysis : Experimental data recorded in various parameters were statistically analyzed with the help of Fisher's analysis of variance technique (Panse and Sukhatme, 1985). The critical difference (CD) for the treatment comparisons was worked out wherever the variance ratio (F test) was found significant at 5% level of significance.

Results and Discussion

Effect of microbial enriched vermicompost on growth attributes : The data clearly stated that the growth attributes of mustard was affected significantly by application of vermicompost. Results revealed that application of vermicompost at 2.0 t ha⁻¹ significantly increased plant height and dry matter accumulation at 80 DAS and at harvest and chlorophyll content of mustard

over control and application of vermicompost at 1.0 t ha⁻¹ (Table-2). It is well established fact that the incorporation of organic matter not only acts as store house of major and micro-nutrients but is also known to influence favourably the physical, chemical and biological properties of soil. Effect of vermicompost on plant growth and productivity may be ascribed to its direct and indirect involvement in the availability of nutrients to crop plants. Addition of vermicompost acts as source of N, P and K to plants and has also been observed to increase organic carbon content in soil. The CEC of soil has also been reported to increase on account of increased organic matter content of soil. Increase in organic carbon content of soil due to vermicompost application results from microbial decomposition of organic matter leading to production of H₂CO₃ and other organic acids. Under the present study, plant analysis at harvest clearly reflected positive influence of vermicompost incorporation in enriching nutritional status of plant parts (seed and stover). Improvement in crop growth parameters under vermicompost incorporation is in close accordance with findings of Parihar *et al.* (2014), Kansotia *et al.* (2015), Gour *et al.* (2017), Kumar *et al.* (2018) and Yadav *et al.* (2018) in mustard.

Effect of microbial enriched vermicompost on yield attributes and yield : Application of 2.0 t vermicompost ha⁻¹ significantly improved yield attributes like number of siliqua/plant and number of seeds/siliqua in mustard (Table-3). This may be ascribed to overall improvements in vigour and crop growth as already stated in preceding paragraphs. Since, vermicompost contains almost all essential plant nutrients; its incorporation in soil promotes rapid vegetative growth, branching and leaf area thereby, increasing the sink size in terms of flowering, seed filling and size of seeds. The improved overall growth and profuse tillering due to vermicompost application coupled with transport of photosynthates towards reproductive structures on the other hand, might have increased the yield attributes. Significant increase in seed, stover and biological yield was recorded with application of 2.0 t vermicompost ha⁻¹. The significant increase in seed yield with addition of vermicompost might be due to their positive influence on maintaining balanced source - sink relationship which clearly evident from remarkable improvement in dry matter production, other growth parameters and yield attributes like number of siliqua plant⁻¹ and number of seeds siliqua⁻¹ which eventually resulted in increased seed yield. The increase in stover yield with application of 2.0 t vermicompost ha⁻¹ could be partly attributed to its direct influence on dry matter production of each vegetative part and indirectly through increased morphological parameters of growth (plant height and number of branches). Since, biological yield is

Table-2 : Effect of microbial enriched vermicompost and fertility levels on growth parameters of mustard.

Treatments	Plant population m ⁻¹ row length 20 DAS	Plant height (cm)			Dry matter accumulation (g/m ²)		
		At 40 DAS	At 80 DAS	At harvest	At 40 DAS	At 80 DAS	At harvest
Vermicompost (t ha ⁻¹)							
Control	9.16	47.03	140.59	155.58	80.58	130.00	193.37
1.0	9.46	48.82	167.11	190.08	83.89	158.07	246.73
2.0	9.66	50.49	182.39	213.52	85.98	181.63	272.07
SEm ±	0.28	1.30	4.62	4.99	2.62	3.89	5.67
CD (P=0.05)	NS	NS	13.84	14.97	NS	11.66	16.99
Fertility levels							
Control	9.28	47.67	136.76	149.50	81.63	132.76	201.98
75% RDF	9.43	48.85	168.23	194.52	83.86	160.76	242.93
100 % RDF	9.56	49.81	185.09	215.17	84.96	176.19	267.25
SEm ±	0.28	1.30	4.62	4.99	2.62	3.89	5.67
CD at 5%	NS	NS	13.84	14.97	NS	11.66	16.99
Interaction (N x Zn)							
CD at 5%	NS	NS	NS	NS	NS	NS	NS

Table-3 : Effect of microbial enriched vermicompost and fertility levels on yield and yield attributes of mustard.

Treatments	Chlorophyll content (mg g ⁻¹)	Yield attributes			Yield (kg ha ⁻¹)			
		Number of siliqua plant ⁻¹	Number of seeds siliqua ⁻¹	Test weight (g)	Seed	Stover	Biological	Harvest index (%)
Vermicompost (t ha ⁻¹)								
Control	7.14	115.52	10.43	4.57	1426	3401	4828	29.41
1.0	8.64	134.25	12.99	4.73	1676	3851	5527	30.38
2.0	9.62	150.09	14.49	4.79	1893	4179	6072	31.16
SEm ±	0.24	3.92	0.31	0.12	40	90	113	0.59
CD (P=0.05)	0.72	11.76	0.94	NS	120	270	340	NS
Fertility levels								
Control	7.19	112.58	10.65	4.60	1392	3282	4674	29.73
75% RDF	8.52	135.90	12.82	4.70	1713	3889	5603	30.50
100% RDF	9.68	151.38	14.43	4.78	1891	4260	6151	30.71
SEm ±	0.24	3.92	0.31	0.12	40	90	113	0.59
CD at 5%	0.72	11.76	0.94	NS	120	270	340	NS
Interaction (N x Zn)								
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

a function of seed and stover yields representing vegetative and reproduction growth of crop. The profound influence of vermicompost application on both these components of crop growth led to realization of higher biological yield. The results of the present investigation corroborate the findings of Singh *et al.* (2014), Kansotia *et al.* (2015), Thaneshwar *et al.* (2017) and Yadav *et al.* (2018) in mustard.

Effect of fertility levels on growth attributes : The findings of the present investigation showed that different fertility levels significantly enhanced the vegetative growth in terms of plant height, dry matter accumulation and chlorophyll content in mustard. The maximum value of these growth parameters was recorded with 100% of RDF which was significantly superior over control and 75% of

RDF (Table-2). The increase in growth parameters under application of 100% RDF may be due to better start and early seedling vigor under the optimum levels of inorganic sources of nutrient which indicates proper nutrients utilization during early growth stages of the crop. Increased nutrient status of the soil and more availability of the nutrients at initial stage under optimum moisture status in the soil provide favorable conditions for effective growth and development of the crop. Potassium helps in the protein synthesis, chlorophyll formation and increasing resistance against stress which might have improved growth and development of the plant. The faster availability of nutrients from adequate supply of inorganic fertilizers through-out the cropping period enhances the nutrient requirement of the crop and production of greater

number of photo-synthetically active leaves which might have led to higher production of carbohydrates and phyto-hormones which resulted in increased plant height and dry matter accumulation. The results are in close agreement with the finding of Bijarnia *et al.* (2017), Bisht *et al.* (2018), Kumar *et al.* (2018), Deepthi *et al.* (2020), Yogi *et al.* (2020) and Mokariya *et al.* (2021).

Effect of fertility levels on yield attributes and yield : In the present investigation, there was significant increase in yield attributes (number of siliqua and number of seeds siliqua⁻¹) and yields (seed, stover and biological) of mustard with different fertility levels. The maximum mean values were obtained with the application of 100% of RDF which was significantly superior to control and 75% of RDF (Table-3). The beneficial response of inorganic sources of nutrient on yield attributes and yield of mustard might be due to the availability of sufficient amount of plant nutrients throughout the growth period of crop resulting in better uptake of nutrients, plant vigor and improved yield. Higher fertility level induced greater translocation of photosynthates from leaves via stem to seed site i.e. siliqua and seed and these resulted in higher numbers of seeds. The results are in conformity with that of Tripathi *et al.* (2011), Kumawat *et al.* (2014), Kumar *et al.* (2016), Brar *et al.* (2016) and Sutaliya and Jakhar (2020). Application of higher rate of NPK markedly increased almost all the yield attributes and yield due to optimum plant development and better translocation of photosynthates to the site of spike formation. For these reasons better performance of maturity characters found associated with plants supplied with sufficient nutrient. The increase in yield may also be due to better uptake of nutrients from the soil which might have contributed to increased dry matter accumulation and number of tillers per plant ultimately enhanced seed and stover yield of mustard. Similar finding was reported by Vivek *et al.* (2009), Babar and Dongale (2011), Kansotia *et al.* (2013), Bijarnia *et al.* (2017), Kumar *et al.* (2017), Yogi *et al.* (2020) and Mokariya *et al.* (2021).

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Studies on Mitigation of Drought Effect through Foliar Spray of Chemicals on Soybean (*Glycine max* L. Merrill) under Rainfed Condition

Jitendra Marskole, V.D. Dwivedi, Vijay Agrawal and Anoop Kumar Rathore

Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, M.P.

Corresponding Author Email : jeetmarskole1@gmail.com

Introduction

Soybean (*Glycine max* L. Merrill) is one of the commercial crops in India. Soybean is a crop of multiple qualities, as it is both a pulse and oilseed crop. It contains 40 percent protein and 20 percent edible oil, besides minerals and vitamins. As per survey conducted by SOPA, the all India estimated production 12.98 million tonnes from an area of 12.03 million hectare with productivity of 1079 kg/ha. In Madhya Pradesh, the area under soybean cultivation is 6.26 million hectares with the production of 5.95 million tonnes. Although the ecological conditions of the state are congenial for soybean production, but the yield is substantially low (950 kg/ha), despite of the best management practices (SOPA, 2014).

Potassium (K) acts as a very essential and important nutrient for the plant growth and development. It is necessary in plants to improve the efficiency of photosynthesis and use of water. In soybean, deficiency of K causes so many problems and shows many deficiency symptoms in plants growth such as weaker straw, increased lodging and decrease in growth. Application of K to soybean plants under saline conditions enhances the growth of the plants and decreases the effect of salinity.

The effects of seed treatment (500 ppm) or foliar application of 1000 ppm thiourea (at 25 and 40 days after sowing) or a combination of these have been found effective on growth, yield, net photosynthesis and nitrogen metabolism of soybean (*Glycine max* L.) grown under rainfed conditions of the Indian arid zone. Thiourea application either as pre-sowing seed treatment or as foliar spray significantly increased plant height, leaf area, dry matter production and seed yield as compared to the untreated plants (Garg *et al.* 2006). However, maximum favourable effects were obtained with combined application of seed treatment and foliar spray. The beneficial effects of thiourea were attributed to its role in significantly increasing the net photosynthetic rates and the concentrations of total chlorophyll and starch in the leaves. Thiourea also reflected a positive role in enhancing nitrogen metabolism as it significantly

increased nitrate reductase activity and concentration of soluble protein in the treated plants. It has been found that seed treatment with thiourea followed by foliar spray could significantly improve growth, yield and water use efficiency of rainfed soybean under arid conditions due to enhanced photosynthesis and more efficient nitrogen metabolism (Garg *et al.* 2006).

Materials and Methods

A field experiment was conducted at AICRP for Dryland Agriculture, Kuthulia Farm College of Agriculture, Rewa (M.P.) during Kharif season 2015. A total of eight treatment combination, consisted of

T₁ : Control

T₂ : Water spray at 25-30 and 55-60 DAS

T₃ : Foliar spray of 1% KNO₃ solution at 25-30 and 55-60 DAS

T₄ : Foliar spray of 1% KCl solution at 25-30 and 55-60 DAS

T₅ : Foliar spray of thiourea @ 250g ha⁻¹ solution at 25-30 and 55-60 DAS

T₆ : T₅ + Trizophos insecticide @ 600 ml ha⁻¹ tank mix

T₇ : T₄ + Trizophos insecticide @ 600 ml ha⁻¹ tank mix

T₈ : T₃ + Trizophos insecticide @ 600 ml ha⁻¹ tank mix

These treatments were arranged in a randomized block design with three replications. The crop variety JS-20-29 was sown on 2nd July 2015 with the seed rate of 75 kg/ha at a 30 cm wide rows. Soybean crop was fertilized with 30:60:30 kg NPK/ha as basal dose in the form of urea, single super phosphate and muriate of potash, respectively. All the package of practices were followed as per the recommendations given by the university. The crop was harvested on 3rd October, manually with the help of sickles. Observations pertaining to plant population at 7 days after sowing, plant height (cm), number of leaves/plant, branches/plant at an interval of 20 days, pods/plant, seed/pod and seed index as well as yield were recorded and statistically analysed for interpretation of results.

Table-1 : Effect of treatments on no. of leaves and no. of branches per plant at different stages of crop growth.

Treatment	Number of leaves plant ⁻¹			Number of branches plant ⁻¹		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T ₁	7.09	16.01	13.80	2.12	2.92	3.57
T ₂	7.42	16.87	14.67	2.26	3.06	3.70
T ₃	7.92	19.34	17.47	2.39	3.43	4.08
T ₄	8.42	17.77	15.90	2.64	3.19	3.84
T ₅	7.76	18.02	15.82	2.43	3.23	3.85
T ₆	8.09	18.44	16.23	2.50	3.30	3.95
T ₇	8.52	19.40	17.20	2.64	3.44	4.10
T ₈	9.09	20.74	18.53	2.85	3.65	4.31
SEm±	0.38	0.68	0.51	0.12	0.13	0.13
CD (P=0.05)	1.16	2.12	1.57	0.39	0.40	0.41

Table-2 : Effect of treatments on yield attributes and yield of soybean

Treatment	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	Number of seeds plant ⁻¹	Seed index (g)	Seed yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
T ₁	23.60	2.40	56.64	12.68	679.65	2371.12
T ₂	29.98	2.53	75.40	12.78	904.76	2876.57
T ₃	34.22	2.65	87.42	13.07	1049.06	3390.39
T ₄	32.30	2.63	84.90	13.40	1018.76	2932.23
T ₅	29.99	2.57	79.37	13.53	952.38	2975.91
T ₆	35.51	3.20	113.04	13.46	1356.42	2953.96
T ₇	33.32	2.73	90.79	13.66	1089.47	3145.85
T ₈	37.18	3.13	115.91	14.13	1390.94	3170.22
SEm±	1.50	0.13	1.86	0.29	8.11	17.32
CD (P=0.05)	4.65	0.39	5.77	0.88	25.12*	53.68*

Results and Discussion

Data pertaining to growth parameters are given in Table-1. These parameters were significantly affected due to different treatments at all the growth stages of crops. As regards to the different treatments, it was observed that the maximum plant height of 25.5, 52.24, 74.83, cm and 76.20 cm was recorded at 20, 40, 60 DAS and harvest of crop, respectively under T₈ in which two sprays of 1% KNO₃ solutions was done at 25-30 and 55-60 DAS and trizophos@600 ml/ha closely followed by two foliar spray of thiourea@250g/ha at 25-30 and 55-60 DAS+trizophos@600 ml/ha. The number of leaves and branches/plant increased with the advancement of crop age. However, the maximization of leaves (20.74 and 18.53) and branches(3.65 and 4.31)/plant were recorded at 40 and 60 DAS respectively. Further advancement in age of crop plant from 40-60 DAS the leaves/plant decreased.

The treatments given to the experiment had significant effect on both the growth parameters viz., number of leaves as well as branches/plant. The highest counts of leaves(20.74%) and branches (4.31) were recorded under T₈ closely followed by T₇ and T₃. These

finds are in close conformity with the findings of Bly *et al.* (1990), Ramesh and Thirumurugan (2001).

Effect on yield attributes : Yield attributes viz. Pods/plant, seeds/pod and seed index were found significantly differ due to different treatments. The maximum values of yield attributing traits viz. No. of pods (37.18/plant), No. of seeds (3.13/pod) and seed index (14.13g) were recorded under T₈. Whereas, lowest count of pods/plant (23.60/plant), seeds/pods (2.40/pods) and seed index of 12.68g were recorded under control treatment. The treatment T₈, T₆ and T₃ found to be at par with each other for the number of pods/plant. Whereas, the treatments T₆ and T₈ in number of seeds/pod, T₈, T₇, T₆ and T₅ were found to be at par with each other for seed index. The spray of 1% KNO₃ as well as Trizophos at critical period of crop provide a better growth and protection to the plant might have better development of yield attributes. Similar results have also been reported by Sindhe and Jadhav (1995) and Rahul and Parth (2015).

Effects on yield : Production of grain is a complex phenomenon which is not only depends on genetic constitution of plant but also on the production measures followed. Yields data presented in Table 2 and showed that the highest seed and straw yields of 1390 kg/ha 3170

kg/ha were recorded under T8 (spray of KNO_3 twice at an interval of 25-30 days subsequently spray of Trizophos@600 ml/ha) proved superior over other treatments.

Whereas, the lowest yield of 679.65 and 2371 kg/ha were recorded under control plots. This is might be due to the severe competition for nutrients right from establishment of crop unto the end of crop growth. It leads to poor growth and development resulted in poor development of yield attributes under control plot. Whereas, treated plots (T7 and T8) attended lush growth due to better nutrition and elimination of insect incidence resulted in better development of yield attributes and consequently the higher yield. The result is in close agreement with the findings of Govindan and Thirumurugan (2000).

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Symbiotic Traits, Yield attributes S Uptake and Yield of Soybean in Black Soils of Madhya Pradesh

Diksha Vishwakarma* and S.C. Gupta

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, RAK College of Agriculture, Sehore, Madhya Pradesh-466001

***Email :** dikshavishwakarma55@gmail.com

Abstract

Field experiment on Sulphur enhanced SSP which contains about 16% S instead of 12% S in regular SSP was conducted on Soybean (*Glycine max.*L) in Black soils possessing 9.8 ppm Sulphur with four treatments viz. T₁- 60 kg P₂O₅/ha through regular SSP (45 kg S/ha), T₂- 60 kg P₂O₅/ha through S enhanced SSP (60 kg S/ha), T₃- 40 kg P₂O₅/ha through regular SSP (30 kg S/ha) and T₄- 40 kg P₂O₅/ha through S enhanced SSP (40 kg S/ha) with five replications in RBD in M.P. Nodulation and yield attributes viz. plant height, no of pods/plant, exhibited significant increase due to use of S enhanced SSP over regular SSP both at 40 and 60 Kg P₂O₅/ha application. As regards grain yield, treatment T₂- 60 kg P₂O₅/ha through S enhanced SSP (60 kg S/ha) could produce significantly higher yield (1430 kg/ha) over T₃- 40 kg P₂O₅/ha through regular SSP (30 kg S/ha) and T₄- 40 kg P₂O₅/ha through S enhanced SSP (40 kg S/ha) (1185 & 1270 kg/ha respectively). However T₂- 60 kg P₂O₅/ha through S enhanced SSP (60 kg S/ha) was statistically identical to T₁- 60 kg P₂O₅/ha through regular SSP (45 kg S/ha) in enhancing grain yield (1368 Kg/ha) of Soybean indicating fulfillment of S requirement of crop with both the sources (Regular SSP and S enhanced SSP) when phosphorous applied @60 kg P₂O₅/ha solely through either type of SSP. The yield enhancement by the use of S enhanced SSP over regular SSP (@ 40 kg P₂O₅/ha & 60 kg P₂O₅/ha levels) was 4.53 and 7.17% respectively. Grain yield enhancement by regular and S enhanced SSP @60 kg P₂O₅/ha over farmers practice of 40 kg P₂O₅/ha through regular SSP was 15.4 and 20.7% higher respectively. As regards S content and uptake in soybean grain and straw and also available S balance in soil after crop harvest, these were significantly affected due to S enhanced SSP over regular SSP both at 40 and 60 Kg P₂O₅/ha levels.

Key Words: Sulphur, S enhanced SSP, Nodulation, S content, S Uptake

Introduction

Soybean area, production and productivity in India and in M.P as reported in 2018 was 108.4 and 54.09 lakh hectares 109.3 and 58.18 million tonnes and 1009 and 1075 kg/ha respectively (www.sopa.org). Soybean yield in India as well as in M.P. is comparatively low as compared to world average productivity. This might be attributed to imbalance fertilization, poor BNF, improper management, high incidence of pest and diseases etc. Being legume as well as oil seed crop, Soybean needs balance nutrition. In recent years S deficiency has been widely seen and reported in many states of India (NAAS, 2018) including in M.P. Sulphur is recognized as the fourth major essential nutrient severely limiting crop production in India. Indian soils have widespread S deficiency to an extent of 46% (Shukla and Tiwari, 2016). In Madhya Pradesh, due to ease in application, farmers are mostly using DAP and NPK grade fertilizers in Soybean crop, which is not taking care of S application in soil, though S is required in soils as Soybean and pulses are continuously and dominantly grown in the state for 5 decades and deficiency also indicated in large number of soil samples in number of districts. Keeping this in view sulphur enhanced SSP

prepared by some manufacturer which contain 16% S instead of 12% S in regular SSP thought to be tested in soybean to fulfill its nutritional requirement for both P as well as S. Hence the present investigation was carried out to evaluate the efficacy of S enhanced SSP on growth, yield attributes, yield, Sulphur content and uptake in chickpea and also on available S in soil after crop harvest.

Materials and Methods

In order to assess the efficacy of S enhanced SSP in soybean in black soils a field experiment was conducted at research farm of RAK College of Agriculture, Sehore, M.P. during 2015-16 with four treatments viz. T₁- 60 kg P₂O₅/ha through regular SSP (45 kg S/ha), T₂- 60 kg P₂O₅/ha through S enhanced SSP (60 kg S/ha), T₃- 40 kg P₂O₅/ha through regular SSP (30 kg S/ha) T₄- 40 kg P₂O₅/ha through S enhanced SSP (40 kg S/ha), replicated 5 times in a RBD under black soils possessing a soil pH of 7.4, EC of 0.31 dSm⁻¹, organic carbon 0.42%, available NPK 215, 12.9 and 480 kg/ha and Sulphur 9.8 ppm. Nodulation study was conducted in 5 randomly uprooted plants using standard procedure. Available S in soil and plant determined by turbidity method using spectrophotometer by adopting standard procedures.

Table-1 : Effect of S enhanced SSP on nodulation, yield attributes and yield of Soybean (RVS 2001-4).

Treatments	Nodule number pl^{-1} At 45DAS	Nodule dry weight pl^{-1} (mg) at 45DAS	Plant height at maturity (cm)	No of branches pl^{-1} at maturity	No of pods pl^{-1}	No of seeds pod^{-1}	Leaf Area index	Grain yield Kg/ha	Straw yield Kg/ha	100 seed wt (g)
T ₁ . 60 Kg P ₂ O ₅ /ha through Regular SSP (45 Kg S/ha)	36.7	140	35.7	4.5	30.1	2.2	2.52	1368	2592	8.65
T ₂ . 60 Kg P ₂ O ₅ /ha through S enhanced SSP (60 Kg S/ha)	39.3	168	38.1	4.8	32.9	2.4	2.63	1430	2888	9.15
T ₃ . 40 Kg P ₂ O ₅ /ha through Regular SSP (30 Kg S/ha)	28.5	126	32.2	4.2	24.9	2.0	2.28	1185	2490	8.42
T ₄ . 40 Kg P ₂ O ₅ /ha through S enhanced SSP (40 Kg S/ha)	33.8	143	34.4	4.4	28.2	2.2	2.45	1270	2520	8.89
Sem	0.7	5.5	1.6	0.2	0.7		0.01	55.7	115	0.19
CD	1.6	13.0	NS	0.5	1.6		0.24	133.1	NS	NS

Note : N and K (20 and 20 Kg/ha) applied uniformly as per RDF in all the treatments.

Table-2 : Response of Soybean to S application at different levels of P application using regular and S enhanced SSP.

Treatments	Grain yield Kg/ha	% Increase in yield over Regular SSP	% increase in yield over farmers practice with regular SSP
T ₁ -60 Kg P ₂ O ₅ /ha through Regular SSP (45 Kg S/ha)	1368	-	15.4
T ₂ -60 Kg P ₂ O ₅ /ha through S enhanced SSP (60 Kg S/ha)	1430	4.53	20.7
T ₃ -40 Kg P ₂ O ₅ /ha through Regular SSP (30 Kg S/ha)	1185	-	-
T ₄ -40 Kg P ₂ O ₅ /ha through S enhanced SSP (40 Kg S/ha)	1270	7.17	7.1

*N and K (20 and 20 kg/ha) applied uniformly as per RDF in all the treatments.

Results and Discussion

Symbiotic Traits ,Yield attributes and Grain yield : The data recorded on symbiotic traits viz nodule number and nodule dry weight pl^{-1} and on yield attributes viz. no of branches pl^{-1} no of pods pl^{-1} , no of seed pod^{-1} leaf area index etc. exhibited significant increase due to use of S enhanced SSP over regular SSP both at 40 and 60 Kg P₂O₅ /ha application (Table1). As regards grain yield (Table-1), treatment T₂- 60 kg P₂O₅/ha through S enhanced SSP (60 kg S/ha) could produce significantly higher yield (1430 kg/ha) over T₃- 40 kg P₂O₅/ha through regular SSP (30 kg S/ha) and T₄- 40 kg P₂O₅/ha through S enhanced SSP (40 kg S/ha) (1185 & 1270 kg/ha respectively). However T₂- 60 kg P₂O₅/ha through S enhanced SSP (60 kg S/ha) was statistically identical to T₁- 60 kg P₂O₅/ha through regular SSP (45 kg S/ha) in enhancing grain yield (1368 Kg/ha) of Soybean indicating fulfillment of S requirement of crop with both the sources (Regular SSP and S enhanced SSP) when phosphorous applied @60 kg P₂O₅/ha solely through either type of SSP. The yield enhancement by the use of S enhanced SSP over regular SSP (@ 40 kg P₂O₅/ha & 60 kg P₂O₅/ha levels) was 4.53 and 7.17% respectively. Grain yield enhancement by regular and S enhanced SSP @60 kg P₂O₅/ha over farmers practice of 40 kg P₂O₅/ha through

regular SSP was 15.4 and 20.7% higher respectively (Table-2). As the soils of the experimental site possessing S below critical limit and as such enhanced availability of S from applied sources may have favorably affected the synthesis of S containing amino acids, protein and also other important physiological processes inside the plant system which enabled the crop to produce good nodulation growth, yield attributes and yield of Soybean. Results of similar kind were also reported by other workers with the application of Sulphur in crops. (Rao *et al.*, 2013 and Ganeshmurthy *et al.*, (2000).

Sulphur Content,Uptake and S in Soil After Harvest :

As regards to S content and uptake in soybean grain and straw and also available S balance in soil after crop harvest, these were significantly affected due to S enhanced SSP over regular SSP both at 40 and 60 Kg P₂O₅/ha levels (Graph 1&2). Since S enhanced SSP contains more S which might have added and supplies relatively more Sulphur to crop plants and hence comparatively more S content and uptake and also more available S in soils recorded under S enhanced SSP. Increase in S uptake and available S in soil due to increasing levels of S application has also been reported by other workers (Gokhale *et al*, 2005 and Majumdar *et al.*, 2001).

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Bio-Efficacy of Emamectin Benzoate Application Based on Damage Score Caused by Fall Armyworm *Spodoptera* (J.E Smith) in Maize

Bhanu Pratap Singh Hada, S. Ramesh Babu, Amit Kumar, Ankit Kumar and Hiraram

Department of Entomology, Rajasthan College of Agriculture, MPUAT, Udaipur-313001

Corresponding Author Email : bhanusa1431@gmail.com

Abstract

The present investigations on Bio-efficacy of Emamectin benzoate application based on Damage Score caused by Fall Armyworm *Spodoptera* (J.E Smith) in Maize was conducted during *Kharif*, 2022, at agronomy farm, Rajasthan College of Agriculture, Udaipur. Before the first application of Emamectin benzoate @ 5 % SG the mean number of plants showing Davis score 3 and 6. The lowest mean number (2.00) of plants showing Davis score 3 was observed in T₄-Emamectin benzoate 5% SG spray at 20% of plants with Davis Scale 3-type damage. Whereas the lowest mean no. of plant showing Davis scores 6 was observed in T₃-Emamectin benzoate 5% SG spray at 10% of plants with Davis Scale 3-type damage (1.67). The lowest mean no. of plant showing Davis scores 6 was observed in T₅-Emamectin benzoate 5% SG spray at 10% of plants with Davis Scale 6-type damage (0.33) after Ten days of first spray.

Key words : Bio-efficacy, Davis Score, Fall Armyworm, Damage score, Emamectin benzoate

Introduction

Maize (*Zea mays* L.) is the world's leading crop and is widely cultivated as cereal grain that was domesticated in Central America. It is one of the most versatile emerging crops having wider adaptability. Globally, maize is known as the queen of cereals because of its highest genetic yield potential. Maize is the only food cereal crop that can be grown in diverse seasons, ecologies and uses. Beside this maize have many types like normal yellow/ white grain, sweet corn, baby corn, popcorn, waxy corn, high amylase corn, high oil corn, quality protein maize, etc. Apart from this, maize is an important industrial raw material and provides a large opportunity for value addition.

Spodoptera frugiperda (Lepidoptera: Noctuidae), sometimes known as the fall armyworm, is an invasive polyphagous damaging insect pest that has been blamed for maize losses all over the world (Clark *et al.*, 2007; Nabity *et al.*, 2011). It's a pest native to tropical and subtropical America that's economically damaging, very migratory and has a high reproductive capability (Prasanna *et al.*, 2018). This pest was first identified in Africa in 2016 as an invasive pest (Goergen *et al.*, 2016), being a highly transboundary migratory pest (Otim *et al.*, 2021). It can cover a large geographic area in a short period. In 2018, this pest was identified as an invasive pest in several Asian nations, including Yemen, India, Thailand, Myanmar, Sri Lanka (Liu *et al.*, 2019) and Bangladesh (Chhetri and Acharya, 2019) where its spread was documented. Infestation levels by larvae of FAW can cause a 15–73% reduction in maize yield (Cruz

and Turpin, 1982). However, the incorrect use of chemical pesticides by resource-poor rural growers may result in toxic exposure for farm workers (McConnell and Hruska, 1993) as well as significant environmental damage (Tinoco-Ojanguren and Halperin, 1998). Owing to the development of pest populations with varying degrees of resistance, FAW has become increasingly economically important (Pacheco-Covarrubias, 1993).

Materials and Methods

Field Experiment : The experiment was carried out at the Instructional farm of Rajasthan College of Agriculture, MPUAT Udaipur. Plot of the maize hybrid was laid out in a randomized block design, with seven treatments and three replications. Each plot was comprise 5 rows, 3 m long and was irrigated as needed. Plot within each block was separated from one another by 0.5 meters. The decision as to when Emamectin benzoate insecticide should be applied was based on three different criteria: (i) the number of captured adult male moths in pheromone traps, (ii) the percentage of plants showing Davis scale 3-type damage and (iii) the number of plants showing Davis Scale 6–type damage. More specifically, the treatments were (Cruz *et al.* 2012).

I. Insecticide application: 10 d after the pheromone trap catches three *S. frugiperda* adult moths (first trap 1).

II. Two insecticide applications: the first one (first trap 1) and the second application after the capture of three *S. frugiperda* adults, initiating the counting in the trap on the fifth day after the first insecticide application.

III. Insecticide application at 10% of plants with Davis Scale 3-type damage.

Table-1 : Efficacy of first insecticide application on different Davis score.

Treatment	Davis score (0-9)			
	Before Spraying		After 10 Days	
	Davis Score 3	Davis Score 6	Davis Score 3	Davis Score 6
T ₁ -Insecticide application: 10 d after the pheromone trap catches three <i>S. frugiperda</i> adult moths (first trap 1).	2.667	3.000	1.333	0.667
T ₂ -Two insecticide applications: the first one (first trap 1) and the second application after the capture of three <i>S. frugiperda</i> adults, initiating the counting in the trap on the fifth day after the first insecticide application.	2.333	2.000	1.333	1.000
T ₃ -Insecticide application at 10% of plants with Davis Scale 3-type damage.	3.000	1.667	0.667	0.667
T ₄ -Insecticide application at 20% of plants with Davis Scale 3—type damage.	2.000	2.000	1.667	0.333
T ₅ -Insecticide application at 10% of plants with Davis Scale 6-type damage.	2.667	2.667	1.000	1.000
T ₆ -Insecticide application at 20% of plants with Davis Scale 6—type damage.	2.333	2.000	1.333	1.000
T ₇ -Untreated Control.	3.000	2.333	4.000	4.333
SEm ±	0.55	0.40	0.43	0.40
CD %	NS	NS	1.33	1.23

Table-2 : Efficacy of second insecticide application on different Davis score.

Treatment	Davis score (0-9)	
	After 10 Days	
	Davis Score 3	Davis Score 6
T ₁ -Insecticide application: 10 d after the pheromone trap catches three <i>S. frugiperda</i> adult moths (first trap 1).	4.333	4.000
T ₂ -Two insecticide applications: the first one (first trap 1) and the second application after the capture of three <i>S. frugiperda</i> adults, initiating the counting in the trap on the fifth day after the first insecticide application.	1.333	1.000
T ₃ -Insecticide application at 10% of plants with Davis Scale 3-type damage.	1.333	1.000
T ₄ -Insecticide application at 20% of plants with Davis Scale 3—type damage.	1.667	1.000
T ₅ -Insecticide application at 10% of plants with Davis Scale 6-type damage.	0.667	0.333
T ₆ -Insecticide application at 20% of plants with Davis Scale 6—type damage.	1.000	1.667
T ₇ -Untreated Control.	6.000	6.000
SEm ±	0.35	0.39
CD %	1.07	1.20

IV. Insecticide application at 20% of plants with Davis Scale 3—type damage.

V. Insecticide application at 10% of plants with Davis Scale 6-type damage.

VI. Insecticide application at 20% of plants with Davis Scale 6—type damage.

VII. Untreated Control.

Observation : Evaluations of the number of insects captured in the traps as well as the percentage of plants with Davis Scale 3 and 6—type damage was made weekly. To determine the infestation level based on the type of damage in each corresponding plot, two rows of maize were chosen at random. The percentage of infested plants was determined visually in these rows, and spraying was initiated when the optimum point was reached. An infestation was determined for all treatments before each

insecticide application in each experimental plot, and the number of insect pest larvae per plant in a sample of 10 plants was counted.

Statistical analysis : Data from the experiment was analyzed by one-way analysis of variance (ANOVA). Treatment means was compared using the Scott–Knott test ($P = 0.05$) (Scott and Knott 1974). Before running the ANOVA, test was conducted to determine whether the data set met the necessary assumptions.

Results and Discussion

Efficacy of first spray of insecticide application based on Davis score

Before the first spray : The data presented in the Table-1 and depicted in Fig.-1 reveals that the mean Davis score 3 and 6 was ranged 2.00 to 3.00 and 1.67 to 3.00, respectively. The lowest mean Davis score 3 was

observed in T₄- Insecticide application at 20% of plants with Davis Scale 3 type damage) (2.00) followed by T₂-Two insecticide applications: the first one (first trap 1) and the second application after the capture of three *S. frugiperda* adults, initiating the counting in the trap on the fifth day after the first insecticide application and T₆- Insecticide application at 20% of plants with Davis Scale 6-type damage were found at par (2.33), while, highest Davis Score 3 was found in untreated control. Whereas the lowest Davis score 6 was observed in T₃- Insecticide application at 10% of plants with Davis Scale 3-type damage (1.67) followed by T₂- Two insecticide applications: the first one (first trap 1) and the second application after the capture of three *S. frugiperda* adults, initiating the counting in the trap on the fifth day after the first insecticide application, T₄- Insecticide application at 20% of plants with Davis Scale 3-type damage and T₆- Insecticide application at 20% of plants with Davis Scale 6-type damage were found at par (2.00). While highest mean Davis score 6 was found in T₁- Insecticide application: 10 d after the pheromone trap catches three *S. frugiperda* adult moths (first trap 1). (3.00).

Ten days after the first spray : The data showed in the Table-1 and depicted in Fig.-2 reveals that the mean Davis score 3 and 6 was ranged 0.67 to 4.00 and 0.33 to 4.33, respectively. The lowest mean Davis score 3 was observed the lowest mean Davis score 3 was observed in T₄- Insecticide application at 20% of plants with Davis Scale 3-type damage) (0.67) followed by T₅- Insecticide application at 10% of plants with Davis Scale 6-type damage (1.00), while, highest Davis Score 3 was found in untreated control. Whereas the lowest Davis score 6 was observed in T₄- Insecticide application at 20% of plants with Davis Scale 3-type damage (0.33) followed by T₁- Insecticide application: 10 d after the pheromone trap catches three *S. frugiperda* adult moths (first trap 1) and T₃- Insecticide application at 10% of plants with Davis Scale 3-type damage were found at par (0.667). While highest mean Davis score 6 was in untreated control.

Efficacy of second insecticide application based on Davis score

Ten days after the second spray : The data showed in the Table-2 and depicted in Fig.-3 reveals that on mean Davis score 3 and 6 was ranged 0.67 to 6.00 and 0.33 to 6.00, respectively. The lowest mean Davis score 3 was observed in T₅- Insecticide application at 10% of plants with Davis Scale 6-type damage (0.667) followed by T₆- Insecticide application at 20% of plants with Davis Scale 6-type damage (1.00) while, highest Davis Score 3 was found in untreated control. Whereas the lowest Davis score 6 was observed in T₅- Insecticide application at 10% of plants with Davis Scale 6-type damage (0.33) followed

by T₂- Two insecticide applications: the first one (first trap 1) and the second application after the capture of three *S. frugiperda* adults, initiating the counting in the trap on the fifth day after the first insecticide application, T₃- Insecticide application at 10% of plants with Davis Scale 3-type damage and T₄- Insecticide application at 20% of plants with Davis Scale 3-type damage were found at par (1.00). While highest mean Davis score 6 was found in untreated control. The similar finding of the present studies is in partially agreement with finding of Sharma *et al.* 2023 reported that Emamectin benzoate sprayed maize plants also has lower scoring, i.e., 4.25 after chlorantraniliprole. Kumar *et al.* 2020 was recorded that, Emamectin benzoate show 25.58% and 15.8% leaf damage 14 days after first and second spray, respectively. Similarly finding show, there was a slow reduction in the damage symptoms in the Emamectin Benzoate-treated plots with the average damage scoring scale ranging from 2-3 (few small and ragged holes on upper leaves and whorl) (Karki *et al.*, 2023). Similar finding of Davis scores were between 2 and 4, with the lowest numbers observed in the positive control (Emamectin benzoate) Babendreier *et al.* 2020.

lowest damage rates was found in the Ema Star treatments (48 g/l Emamectin benzoate + 64 g/l acetamiprid 48 g/l Emamectin benzoate + 64 g/l acetamiprid) (Agboyi *et al.* The present studies are in partially agreement with findings of Sisay *et al.* (2019), Dhobi *et al.* (2020), Kumar and Mohan (2020), Sagar *et al.* (2020) and Suthar *et al.* (2020) who also reported the damage score reduction through insecticidal application against fall armyworm.

The findings of present investigation certain close conformity with the earlier findings of Lee *et al.* (2017) who reported that the application of insecticide was based on different criteria *Viz.*, the number of trap-caught moths in a Delta-type trap with a commercial sex pheromone sex pheromone lure placed in the center of the target area, soon after plant emergence; the percentage of plants exhibiting pinhole-type damage (10 % or 20 %) and the percentage of plants exhibiting shot hole-type damage (10 % or 20 %) compared to a check plot without any control measures.

Conclusions

Fall Armyworm (*Spodoptera frugiperda* (J. E. Smith)) is highly destructive pest which feeds on maize plant throughout the season. It is gain resistance against numerous insecticides, so the application of chemical insecticides should be based on damage score or ETL is must. The tested insecticide Emamectin benzoate @5 % SG given good result when it was applied based on damage score.

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Seasonal Incidence of Girdle beetle, *Obereopsis brevis* in Soybean [*Glycine max* (L.) Merrill]

Devesh Parmar^{1*}, H.R. Chaudhary², B.K. Patidar², H.P. Meghwal² and Laxman Singh Saini³

¹Department of Entomology, RCA, MPUAT, Udaipur, Rajasthan

²Department of Entomology, AU, Kota, Rajasthan

³Department of Entomology, SKNAU, Jobner, Rajasthan

*Corresponding Author Email : 0909deveshparmar@gmail.com

Abstract

The present investigation on "Seasonal Incidence of girdle beetle in Soybean [*Glycine max* (L.) Merrill]" was conducted during *kharif*, 2019 at Agricultural Research Station, Ummedganj, Agriculture University, Kota. The results revealed that the occurrence of girdle beetle was initiated during second week of August. The girdle beetle infestation found in increasing trend during periodical observations and reached its peak in first week of October. The correlation study reveals that the girdle beetle infestation was significantly negative correlated with rainfall. Girdle beetle has been observed predominant insect pest and its infestation increases as the crop stages up to 26.20 per cent.

Key words : seasonal, incidence, girdle beetle, correlation, peak, infestation, per cent, predominant.

Introduction

Soybean [*Glycine max* (L.) Merrill] is one of the most important oilseed commercial crop of India. It is world's most useful and cheapest sources of protein (Akinyele and Harshbarger, 1983), vitamins, minerals, carbohydrate and other ingredients. Soybean is a legume crop mainly but seeds widely used as oilseed. It contains 40% protein, well balanced in essential amino acids; 20% oil, rich in poly unsaturated fats specially Omega 6 and Omega 5 fatty acids; 6-7% total minerals; 5-6% crude fiber and 17-19% carbohydrates (Chauhan and Joshi, 2005). Madhya Pradesh, Maharashtra and Rajasthan covers an area 52.4, 39.3, and 9.3 lakh ha, respectively. The Rajasthan state stands third occupying the soybean area and second in productivity (1244 kg/ha). The crop covers 92 to 93 per cent area and production by these three states Madhya Pradesh, Maharashtra and Rajasthan (Anonymous, 2018).

There are many problems in cultivation of soybean in India as well as Rajasthan, as all stages of this crop are prone to heavy infestation by insect-pest complex. The crop is infested by more than 275 insect pests throughout its growth stage from germination to maturity (Babu *et al.*, 2017). In India, 20 insect species have been recorded major pests infesting soybean crop (Singh and Singh, 1990). Among borers, girdle beetle (*Obereopsis brevis* Swed.) is predominant, among defoliators, tobacco caterpillar (*Spodoptera litura* Fabricius) and green semiloopers (*Chrysodeixis acuta* Walker) are predominant. Immature stages (larva or caterpillar) of both tobacco caterpillar and green semilooper damage

the crop mostly at vegetative stage and in severe case, it completely defoliates the crop resulting drastic yield loss. *Spodoptera litura* larvae even damage to soybean pods also (Chaturvedi *et al.*, 1998 and Singh *et al.*, 2000). Therefore, the present study of the insects-pests and their relative occurrence with reference to different crop stages was conducted, to determine the management strategy pertaining to their nature of damage at most vulnerable or susceptible crop stage so that feasible and economic control measure can be determined for their effective and economic management in the crop.

Materials and Methods

The field experiment to investigate the Seasonal Incidence of girdle beetle in Soybean [*Glycine max* (L.) Merrill]" was conducted during *kharif*, 2019 at Agricultural Research Station, Ummedganj, Kota. The experiment was laid out in plots measuring 4.2 m x 5 m (21 m²) replicated thrice. Soybean variety JS-335 was sown in the second week of July, *kharif* 2019 after onset of monsoon which is a general practice of sowing in the region adopting all agronomical practices required for raising the crop. Observation of girdle beetle, *obereopsis brevis* was recorded from "earmarked one meter row length area" at five places plot wise weekly started at 7 days of germination. The total as well as infested plants were counted and per cent infestation was worked out :

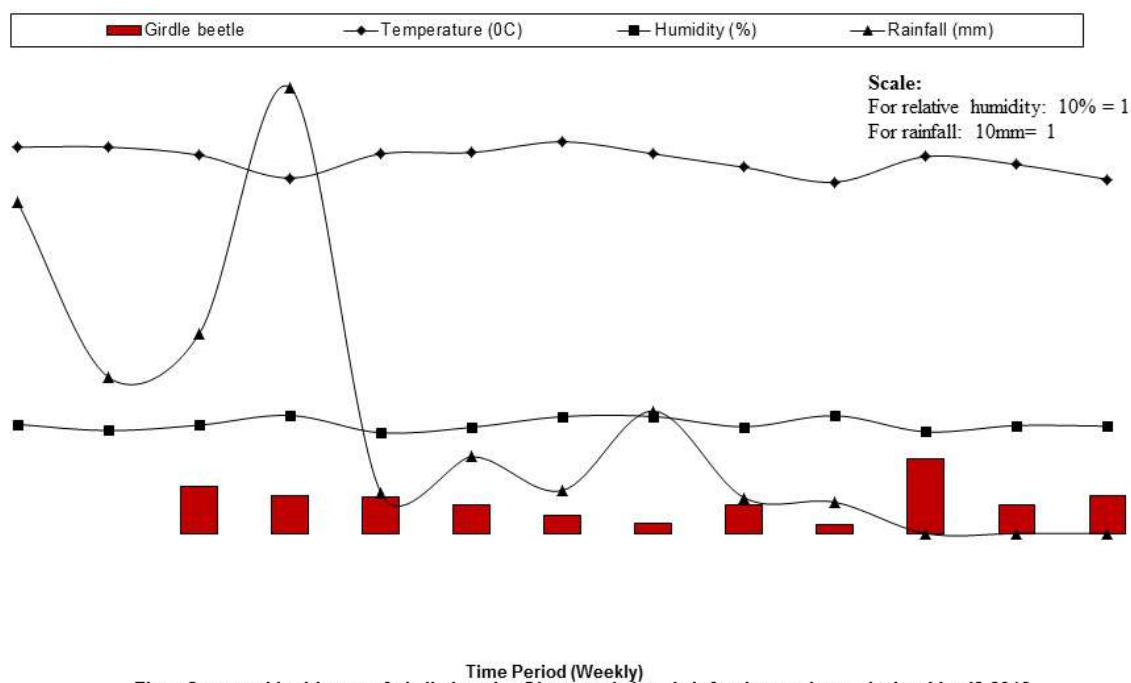
$$\text{Per cent infestation} = \frac{\text{Number of plant infested}}{\text{Total numbers of plants}} \times 100$$

Simple correlation was worked out between the population of insect pests and abiotic factors by the Karl

Table-1 : Seasonal incidence of girdle beetle, *Obereopsis brevis* infesting soybean during kharif, 2019.

SMW No.	Period From - To	Mean temp. (°C)	Mean relative humidity (%)	Rainfall (mm)	Girdle beetle, <i>Obereopsis brevis</i> (% infested plant)	Girdle beetle, <i>Obereopsis brevis</i> (% infested plant in particular week)
30	23 July – 29 July	28.7	81.0	246.0	0.00	0.00
31	30 July – 05 Aug	28.7	76.4	116.0	0.00	0.00
32	06 Aug -12 Aug	28.1	80.5	148.5	3.44	3.44
33	13 Aug -19 Aug	26.4	87.7	331.0	6.21	2.77
34	20 Aug -26 Aug	28.2	74.8	30.0	8.96	2.75
35	27 Aug – 2 Sep	28.3	78.9	57.0	11.04	2.08
36	03 Sep – 09 Sep	29.1	86.9	32.0	12.41	1.37
37	10 Sep – 16 Sep	28.2	86.9	91.0	13.11	0.70
38	17 Sep – 23 Sep	27.2	79.3	26.5	15.18	2.07
39	24 Sep – 30 Sep	26.1	87.5	23.2	15.87	0.69
40	1 Oct.- 7 Oct.	28.0	75.5	0.0	21.37	5.50
41	8 Oct – 14 Oct	27.4	80.2	0.0	23.44	2.07
42	15 Oct – 21 Oct	26.3	79.7	0.0	26.20	2.76
Coefficient of correlation (r) for population and mean atm. temp.					-0.496	-
Coefficient of correlation (r) for population and mean RH					-0.020	-
Coefficient of correlation (r) for population and total rainfall					-0.721*	-

* Significant at 5% level of significance

Fig. : Seasonal incidence of girdle beetle, *Obereopsis brevis* infesting soybean during kharif, 2019

Pearson's coefficient of correlation formula (Steel and Torry, 1980) :

$$r_{xy} = \frac{\frac{\sum XY}{n} - \frac{\sum X}{n} \frac{\sum Y}{n}}{\sqrt{\left(\frac{\sum X^2}{n} - \frac{(\sum X)^2}{n} \right) \left(\frac{\sum Y^2}{n} - \frac{(\sum Y)^2}{n} \right)}}$$

Where,

r_{xy} = Simple correlation coefficient

X = Variable i.e. abiotic component.

(Average temperature, relative humidity and total rainfall)

Y = Variable i.e. mean number of insect pests per plant

n=Number of observations.

The correlation coefficient (r) values were subjected to the test of significance using t-test :

$$t = \frac{r}{\sqrt{1-r^2}} \sqrt{n-2} \sim t_{n-2} \text{ d.f.}$$

The calculated t-value obtained was compared with tabulated t-value at 5% level of significance.

Results and Discussion

The incidence of girdle beetle commenced in the second week of August with 3.44 per cent infested plants. The maximum infestation of girdle beetle was observed (5.5%) during first week of October. The overall girdle infestation in soybean crop was recorded as 26.20 per cent. The per cent girdle beetle infestation exhibited negatively significant correlation with mean rainfall ($r = -0.721$), while, negatively non significant correlation with temperature ($r = -0.496$) and mean relative humidity ($r = -0.020$). The results corroborate the findings of Shrivastava *et al.* (1972) girdle beetle damaged the soybean plants to the extent of 13.7 to 42.2 per cent from August to October. Kumar *et al.* (2019), who reported that the infestation of girdle beetle started in 2nd week of August, when crop was 35 days old with 3.08 per cent plant infestation. However, number of infested plants were slowly increased and reached to 9.20 and 15 per cent in 4th week of August and last week of September.

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Effect of Soil and Foliar Application of Urea and Nano Urea in Nutrient Uptake and Content of Wheat (*Triticum aestivum* L.)

Mahipal Singh Choudhary^{1*}, S.K. Intodia¹, Manju Choudhary² and Suman Dhayal¹

¹Department of Agronomy RCA, Udaipur, MPUAT, Udaipur, Rajasthan

²Department of Agronomy, Anand Agricultural University Anand, Gujarat

*Corresponding Author Email : mahipalsinghchoudhary13@gmail.com

Abstract

The current experiment on wheat crop was conducted at Rajasthan College of Agriculture, Udaipur, Rajasthan during *rabi* season of the years 2021-22 and 2022-23 on different recommended doses of nitrogen through soil and foliar application of urea and nano urea to check the nutrient content and uptake on wheat crop. The experiment carried out in split plot design, consisted of five main plots of soil application and five subplots of foliar application and replicated thrice. Results revealed that higher content and uptake of nitrogen, phosphorus and potassium by grain and straw of wheat was recorded under soil application of 125% RDN which gave similar result with soil application of 100% RDN and superior over soil application of 75, 50% RDN and control. Foliar spray of nano urea at 25-30 and 45-50 DAS being at par with foliar spray of urea at 25-30 and 45-50 DAS, achieved significantly higher nutrient content and uptake by grain and straw. Minimum uptake was recorded under foliar spray of nano urea at 25-30 DAS, foliar spray of urea at 25-30 DAS and control.

Key words : Nano urea, nitrogen, nutrient uptake, soil application, foliar application

Introduction

Wheat (*Triticum aestivum* L.) is the important and widely grown cereal crop of the world and known as “King of cereals” because of its wider adaptability and pre-eminent productivity as it can be cultivated in many areas with heterogeneous types of weather, elevation or soil. In terms of acreage and production, wheat is India’s second most significant food crop, after rice. Wheat contains a high amount of nutrients, including 70% carbohydrate, 10%–12% protein, 2.0% fat, 1.8% minerals, 2.2% crude fiber, and trace amounts of vitamins A, B6 and C but during the milling process, most of the nutrients removes with the bran and germ (Britannica, 2021). Thirty-three per cent of the world’s population eats wheat, and India is a country well-known for producing and consuming wheat. In India, over 75% of the wheat cultivated is used to make chapatti or flat unleavened bread made from whole wheat flour; the remaining wheat is used to make other baked goods including cakes, biscuits, and bread (Hemalatha *et al.*, 2013). Despite this large increase in population, some parts of the world are still experiencing a hunger crisis due to a lack of food grains. The challenge of increasing wheat production is daunting because the wheat cropping system is currently constrained by climatic fluctuations, poor soil health and an increased risk of disease and insect-pest epidemic outbreaks. Although conventional fertilizer application to boost productivity and profitability has led to higher nutrient consumption, which ultimately results in low nutrient use efficiencies, lower profits, and increased environmental issues, nutrient management

has played a significant role in achieving self-sufficiency in food-grain production (Pampolino *et al.*, 2012). N, P and K fertiliser use efficiencies are rarely greater than 30-35%, 18-20% and 35-40%, respectively and have been consistent for several decades. The extent of multi-nutrient deficiencies is increasing year by year, which is closely related to crop losses of approximately 25-30%. Nutrient deficiencies in the nation are approximately 90, 80, 50, 41, 49 and 33% for N, P, K, S, Zn and B, respectively. Therefore, the nation will need to provide a 40–45 Mt supply of nutrients from all sources by 2025 and there is need to assess the nutrient content and uptake in crop, so this study has been done to analyze the effect of soil applied and foliar applied urea and nano urea fertilizers on crop nutrient content and uptake.

Materials and Methods

A field experiment was conducted during *rabi* season of the years 2021-22 and 2022-23 under climatic and edaphic condition of Udaipur (Rajasthan). This area is located at 74° 42' E longitude and 24° 35' N latitude with an altitude of 581.13 m above mean sea level and in Rajasthan’s NARP agro-climatic zone IVa, which includes the Aravalli Hills and Sub-Humid Southern Plains. The experiment was carried out in split plot design with five-soil applications in main plots (Control, 50%, 75%, 100 and 125% RDN) and five foliar applications in sub plots (Control (Water Spray), Nano urea application at 25-30 DAS, Nano urea application at 25-30 DAS and 45-50 DAS, Urea application @ 4% at 25-30 DAS, Urea application @ 4% at 25-30 and 45-50 DAS) and replicated

thrice. Foliar spray of nano urea @ 2.5 ml L⁻¹ and urea @ 4% (with 500 litre water ha⁻¹) was done at 25 and 45 DAS as per treatments. The plot size was 5.0 m × 3.0 m = 15.0 m² and the crop variety was Raj-4079. The soil of the experimental site was clay-loam in texture and slightly alkaline in reaction. The soil was found medium in available nitrogen and phosphorus and high in available potassium.

Nitrogen content (%) : Nitrogen was determined by digesting 0.5 gm sample material with 10 ml conc. sulphuric acid. Total N was determined by Kjeldahl method as outlined by (Piper, 1966).

Phosphorus content (%) : Phosphorus was determined by digesting 0.5 g sample material with triple acid mixture of HNO₃, HClO₄ and H₂SO₄ in the ratio of 10:4:1 and developing colour using a portion of the digest following Vanado-molybdate yellow colour method (Jackson, 1973). The intensity of colour was measured using Spectronic 20 spectrophotometer at a wavelength of 470 nm.

Potassium content (%) : Potassium was determined by digesting 0.5 g sample material with triple acid mixture of HNO₃, HClO₄ and H₂SO₄ in the ratio of 10:4:1 and analysis of suitable aliquot of digested material –It was done with the help of Flame photometer (Jackson, 1973).

Nutrient uptake : The nutrient uptake (N, P and K uptake) by crop was calculated by multiplying the per cent nutrient content in seed and straw with their respective dry matter and expressed as kg ha⁻¹.

Results and Discussion

Nitrogen content

Soil application : Table-1 indicates that, when compared to the application of 75, 50% RDN and control, application of 125% RDN significantly increased the nitrogen content in wheat grain and straw. Additionally, it was statistically at par with 100% RDN in both the experimentation year and on a pooled basis.

Foliar spray : The N content in grain and straw with two foliar sprays of nano urea at 25-30 DAS and 45-50 DAS was found to be significantly higher than that of the control (water spray) and one foliar spray of nano urea at 25-30 DAS by 1.61, 1.76 and 8.41 per cent in grain and 3.42, 4.47 and 15.76 per cent in straw, respectively, on a pooled mean basis. It performed similarly to two urea sprays at 25–30 DAS and 45–50 DAS. Additionally data reveals that grain and straw by two foliar sprays of urea at 25-30 DAS and 45-50 DAS had a significantly higher N content than one nano urea spray at 25-30 DAS, one urea spray at 25-30 DAS and control on pooled mean basis. This can be due to the fact that nano-fertilizers have bigger surface

areas and particles that are smaller than the pore sizes (5 to 50 nm) of plant leaves, which can improve nutrient penetration into plant tissues from the treated surface. The results corroborate with findings of Patidar *et al.* (2022).

Phosphorus content

Soil application : Application of 125% RDN being at par with application of 100% RDN and significantly superior over rest of the treatments recorded higher phosphorus content in grain and straw during both the year of experimentation and on pooled basis as shown in table-2.

Foliar spray : Foliar application of nano urea and urea significantly increased in phosphorus content in grain and straw during both the years and on pooled basis. Two foliar spray of nano urea at 25-30 DAS and 45-50 DAS recorded significantly higher phosphorus content in grain and straw over one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and water spray (control) by 2.62, 3.25 and 12.36 in grain and 3.45, 3.47 and 7.14 in straw per cent, respectively in pooled mean basis. It was at par with two spray of urea at 25-30 DAS and 45-50 DAS. The data also reveals that application of two foliar sprays of urea at 25–30 DAS and 45–50 DAS had significantly higher phosphorus content in grain and straw than one urea foliar spray at 25–30 DAS, one urea foliar spray at 25–30 DAS and control. The phosphorus content in grain and straw by the application of one foliar spray of nano urea at 25–30 DAS was also found to be significantly higher than that of the control treatment (water spray) in 2021–22, 2022–23 and on a pooled basis, respectively.

Potassium content

Soil application : When comparing the potassium content of wheat grain and straw at different levels of soil application of nitrogenous fertilizer, 125% RDN showed a significantly higher potassium content than 75, 50% RDN and control. However, the results were statistically comparable to those of 100% RDN during 2021–22 and 2022–23 and on a pooled data basis. However, pooled data indicates that over 75, 50% RDN and control, the potassium content in grain and straw was increased by 3.06, 5.27 and 11.82 per cent in grain and 3.53, 5.53 and 15.66 per cent in straw, respectively due to application of 125% RDN. Higher plant absorption and better nitrogen translocation as a result of improved nutritional status in the rhizosphere and plant system could explain the results. Since the concentration of a nutrient in a crop plant, as well as the crop's output of grain and straw affect the nutrient's uptake. Sharma *et al.* (2022) and Rawal *et al.* (2022) findings were also show similar results.

Foliar spray : Data presented in table 3 reveals that foliar

Table-1 : Effect of RDN and foliar application of nano-urea and urea on nitrogen content in grain and straw of wheat.

Treatments	Nitrogen content in grain (%)			Nitrogen content in straw (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Soil Application						
Control (No Nitrogen)	1.828	1.857	1.843	0.431	0.457	0.444
50% RDN (Half N as basal and half N at first Irrigation)	1.953	1.981	1.967	0.474	0.500	0.487
75% RDN (Half N as basal and half N at first Irrigation)	1.974	2.003	1.989	0.485	0.511	0.498
100% RDN (Half N as basal and half N at first Irrigation)	2.018	2.047	2.032	0.499	0.525	0.512
125% RDN (Half N as basal and half N at first Irrigation)	2.023	2.052	2.037	0.504	0.530	0.517
SEm±	0.012	0.013	0.009	0.004	0.003	0.002
C.D. at 0.05	0.040	0.044	0.027	0.012	0.010	0.007
Foliar spray						
Control (water Spray)	1.850	1.879	1.865	0.431	0.457	0.444
Nano urea application at 25-30 DAS	1.975	2.004	1.990	0.484	0.510	0.497
Nano urea application at 25-30 DAS and 45-50 DAS	2.008	2.036	2.022	0.501	0.527	0.514
Urea application @ 4% at 25-30 DAS	1.972	2.001	1.987	0.479	0.505	0.492
Urea application @ 4% at 25-30 DAS and 45-50 DAS	1.991	2.020	2.005	0.498	0.524	0.511
SEm±	0.011	0.011	0.008	0.003	0.003	0.002
C.D. at 0.05	0.032	0.031	0.022	0.010	0.009	0.006

Table-2 : Effect of RDN and foliar application of nano-urea and urea on phosphorus content in grain and straw of wheat.

Treatments	Phosphorus content in grain (%)			Phosphorus content in straw (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Soil Application						
Control (No Nitrogen)	0.439	0.465	0.452	0.151	0.164	0.157
50% RDN (Half N as basal and half N at first Irrigation)	0.474	0.500	0.487	0.164	0.176	0.170
75% RDN (Half N as basal and half N at first Irrigation)	0.482	0.508	0.495	0.169	0.182	0.176
100% RDN (Half N as basal and half N at first Irrigation)	0.496	0.522	0.509	0.178	0.191	0.185
125% RDN (Half N as basal and half N at first Irrigation)	0.501	0.528	0.515	0.180	0.193	0.187
SEm±	0.003	0.003	0.002	0.002	0.002	0.001
C.D. at 0.05	0.011	0.010	0.007	0.005	0.006	0.004
Foliar spray						
Control (water Spray)	0.440	0.466	0.453	0.162	0.175	0.168
Nano urea application at 25-30 DAS	0.483	0.508	0.496	0.168	0.181	0.174
Nano urea application at 25-30 DAS and 45-50 DAS	0.496	0.523	0.509	0.173	0.186	0.180
Urea application @ 4% at 25-30 DAS	0.480	0.506	0.493	0.167	0.180	0.174
Urea application @ 4% at 25-30 DAS and 45-50 DAS	0.495	0.521	0.508	0.172	0.185	0.179
SEm±	0.002	0.002	0.001	0.001	0.001	0.001
C.D. at 0.05	0.005	0.005	0.003	0.004	0.003	0.002

application of nano urea and urea significantly increased the potassium content in grain and straw of wheat during both the years and on pooled basis. In comparison to one foliar spray of nano urea at 25-30 DAS, one foliar spray of nano urea at 25-30 DAS and water spray (control), two times foliar spraying of nano urea at 25-30 DAS and 45-50 DAS was observed to have a considerably greater potassium content in grain and straw on a pooled mean basis and it was statistically at par with two urea spray at

25–30 DAS and 45–50 DAS. Data further shows that the two foliar spray of urea at 25-30 DAS and 45-50 DAS recorded higher potassium content in grain and straw and significantly superior over one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and control. The potassium content of grain and straw with one foliar spray of nano urea at 25–30 DAS was also found to be significantly higher than control in 2021–22, 2022–23 and on a pooled basis, respectively.

Table-3 : Effect of RDN and foliar application of nano-urea and urea on potassium content in grain and straw of wheat.

Treatments	Potassium content in grain (%)			Potassium content in straw (%)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Soil Application						
Control (No Nitrogen)	0.471	0.493	0.482	1.455	1.484	1.469
50% RDN (Half N as basal and half N at first Irrigation)	0.499	0.525	0.512	1.596	1.624	1.610
75% RDN (Half N as basal and half N at first Irrigation)	0.510	0.536	0.523	1.627	1.655	1.641
100% RDN (Half N as basal and half N at first Irrigation)	0.523	0.549	0.536	1.680	1.709	1.694
125% RDN (Half N as basal and half N at first Irrigation)	0.526	0.553	0.539	1.684	1.714	1.699
SEm±	0.004	0.004	0.003	0.013	0.014	0.010
C.D. at 0.05	0.013	0.014	0.009	0.043	0.047	0.029
Foliar spray						
Control (water Spray)	0.482	0.507	0.495	1.530	1.558	1.544
Nano urea application at 25-30 DAS	0.506	0.531	0.519	1.612	1.641	1.626
Nano urea application at 25-30 DAS and 45-50 DAS	0.520	0.546	0.533	1.648	1.678	1.663
Urea application @ 4% at 25-30 DAS	0.503	0.528	0.516	1.605	1.633	1.619
Urea application @ 4% at 25-30 DAS and 45-50 DAS	0.518	0.543	0.530	1.647	1.675	1.661
SEm±	0.003	0.003	0.002	0.008	0.008	0.006
C.D. at 0.05	0.008	0.008	0.006	0.024	0.023	0.016

Table-4 : Effect of RDN and foliar application of nano-urea and urea on N uptake by grain and straw by wheat.

Treatments	N uptake (kg ha ⁻¹)					
	Grain			Straw		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Soil Application						
Control (No Nitrogen)	57.52	60.62	59.07	14.63	16.46	15.55
50% RDN (Half N as basal and half N at first Irrigation)	78.91	84.32	81.61	21.90	24.00	22.95
75% RDN (Half N as basal and half N at first Irrigation)	94.28	97.57	95.92	27.72	30.00	28.86
100% RDN (Half N as basal and half N at first Irrigation)	107.81	110.93	109.37	31.71	33.88	32.79
125% RDN (Half N as basal and half N at first Irrigation)	108.27	112.04	110.16	32.83	34.82	33.82
SEm±	1.94	1.93	1.37	0.59	0.65	0.44
C.D. at 0.05	6.34	6.29	4.11	1.93	2.13	1.32
Foliar spray						
Control (water Spray)	77.53	80.83	79.18	21.31	23.16	22.24
Nano urea application at 25-30 DAS	89.92	93.87	91.90	25.92	28.03	26.97
Nano urea application at 25-30 DAS and 45-50 DAS	96.99	100.22	98.61	28.28	30.49	29.38
Urea application @ 4% at 25-30 DAS	88.39	92.32	90.36	25.47	27.51	26.49
Urea application @ 4% at 25-30 DAS and 45-50 DAS	93.95	98.23	96.09	27.82	29.98	28.90
SEm±	1.33	1.19	0.89	0.47	0.42	0.32
C.D. at 0.05	3.81	3.39	2.51	1.35	1.19	0.89

Nitrogen Uptake (In Grain)

Soil application : The data presented in table-4 revealed that wheat grain N uptake increased significantly with 125% RDN over 75, 50% RDN and control and statistically at par with 100% RDN during 2021–22, 2022–23 and on pooled basis. On a pooled data basis, the increase in N uptake due to application of 125% RDN was 14.85, 34.98, and 86.49 per cent over 75, 50% RDN and control, respectively. Similarly, wheat grains exhibit significantly

higher N uptake when exposed to 100% RDN over 75, 50% RDN and control. Further data analysis, 50% RDN also significantly increased in N uptake by grain of wheat over control by 38.16 per cent. The correlation studies authenticate positive relation between grain yield and nutrient uptake by crop. Sharma *et al.* (2022) and Rawal *et al.* (2022) noted comparable results.

Foliar spray: On a pooled mean basis, it was found that foliar application of nano urea at 25-30 DAS and 45-50

Table-5 : Effect of RDN and foliar application of nano-urea and urea on P uptake by grain and straw by wheat.

Treatments	P uptake (kg ha ⁻¹)					
	Grain			Straw		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Soil Application						
Control (No Nitrogen)	13.84	15.19	14.51	5.10	5.89	5.50
50% RDN (Half N as basal and half N at first Irrigation)	19.18	21.33	20.25	7.55	8.46	8.01
75% RDN (Half N as basal and half N at first Irrigation)	23.02	24.75	23.89	9.67	10.68	10.17
100% RDN (Half N as basal and half N at first Irrigation)	26.52	28.29	27.40	11.33	12.33	11.83
125% RDN (Half N as basal and half N at first Irrigation)	26.83	28.87	27.85	11.74	12.70	12.22
SEm±	0.50	0.53	0.36	0.21	0.25	0.17
C.D. at 0.05	1.63	1.73	1.09	0.70	0.82	0.50
Foliar spray						
Control (water Spray)	18.48	20.07	19.27	8.03	8.87	8.45
Nano urea application at 25-30 DAS	22.03	23.87	22.95	9.00	9.94	9.47
Nano urea application at 25-30 DAS and 45-50 DAS	23.99	25.78	24.88	9.81	10.81	10.31
Urea application @ 4% at 25-30 DAS	21.52	23.35	22.43	8.92	9.84	9.38
Urea application @ 4% at 25-30 DAS and 45-50 DAS	23.38	25.36	24.37	9.63	10.60	10.11
SEm±	0.30	0.31	0.22	0.20	0.18	0.13
C.D. at 0.05	0.85	0.90	0.61	0.57	0.52	0.38

Table-6 : Effect of RDN and foliar application of nano-urea and urea on K uptake by grain and straw by wheat.

Treatments	K uptake (kg ha ⁻¹)					
	Grain			Straw		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
Soil Application						
Control (No Nitrogen)	14.85	16.10	15.48	49.34	53.34	51.34
50% RDN (Half N as basal and half N at first Irrigation)	20.17	22.36	21.27	73.66	77.90	75.78
75% RDN (Half N as basal and half N at first Irrigation)	24.37	26.13	25.25	92.92	97.09	95.00
100% RDN (Half N as basal and half N at first Irrigation)	27.94	29.75	28.85	106.66	110.13	108.39
125% RDN (Half N as basal and half N at first Irrigation)	28.13	30.18	29.15	109.72	112.61	111.17
SEm±	0.56	0.58	0.40	2.01	2.09	1.45
C.D. at 0.05	1.83	1.89	1.21	6.55	6.82	4.35
Foliar spray						
Control (water Spray)	20.27	21.89	21.08	75.74	79.03	77.39
Nano urea application at 25-30 DAS	23.08	24.92	24.00	86.23	90.04	88.14
Nano urea application at 25-30 DAS and 45-50 DAS	25.16	26.89	26.02	93.09	97.17	95.13
Urea application @ 4% at 25-30 DAS	22.54	24.37	23.45	85.39	89.07	87.23
Urea application @ 4% at 25-30 DAS and 45-50 DAS	24.43	26.46	25.44	91.85	95.76	93.81
SEm±	0.33	0.34	0.23	1.61	1.45	1.09
C.D. at 0.05	0.93	0.96	0.66	4.61	4.15	3.06

DAS significantly increased the uptake of nitrogen in grains compared to one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and control by 7.65, 9.13, and 24.54 per cent, respectively. It was statistically at par with two spray of urea at 25-30 DAS and 45-50 DAS.

In straw

Soil application: Higher N uptake by straw of wheat was recorded with soil application of 125% RDN as compared to soil application of 75 and 50% RDN and control, which was at par with soil application of 100% RDN during both

the individual years as well as on pooled basis. The magnitude of increase due to 125% RDN was 17.19, 47.36 and 117.49 per cent over soil application of 75 and 50% RDN and control respectively on pooled data basis. Similarly, 100% RDN also has the significant effect on higher uptake of N by straw of wheat over 75, 50% RDN and control.

Foliar spray: Foliar application of nano urea and urea significantly enhanced in N uptake by straw of wheat during both the years and on pooled basis. Significantly higher N uptake by straw was found under foliar application of nano urea at 25-30 DAS and 45-50 DAS over one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and only water spray by 8.94, 10.91 and 31.10 per cent, respectively in pooled mean basis. It was at par with two spray of urea at 25-30 DAS and 45-50 DAS.

Phosphorus Uptake (In Grain)

Soil application : Data in table 5 shows that 125% RDN recorded significantly higher P uptake which was equivalent to soil applications of 100% RDN and superior over rest of the treatments during both the individual years as well as on pooled basis. The magnitude of increase due to 125% RDN was 16.58, 37.53 and 91.94 per cent over soil application of 75 and 50% RDN and control respectively on pooled data basis. Similarly, 100% RDN also has the significant effect on uptake of P by grain of wheat over 75, 50% RDN and control.

Foliar spray : Foliar application of nano urea and urea significantly increased the P uptake by grain during both the years and on pooled basis. Significantly higher P uptake by grain was found under foliar application of nano urea at 25-30 DAS and 45-50 DAS over one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and only water spray by 8.41, 10.92 and 29.11 per cent, respectively in pooled mean basis. It was at par with two spray of urea at 25-30 DAS and 45-50 DAS.

In straw

Soil application : P uptake by straw of wheat influenced significantly with application of 125% RDN over rest of the treatments and being at par with 100% RDN during 2021-22, 2022-23 and on pooled basis. The magnitude of increase due to 125% RDN was 20.16, 52.56 and 122.18 per cent over 75, 50% RDN and control, respectively on pooled data basis. Similarly, 100% RDN also recorded significant increased uptake of P by straw of wheat over 75, 50% RDN and control.

Foliar spray: Foliar application of nano urea at 25-30 DAS and 45-50 DAS was found significantly higher P uptake by straw over one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and

control by 8.87, 9.91 and 22.01 per cent, respectively in pooled mean basis. It was at par with two spray of urea at 25-30 DAS and 45-50 DAS.

Potassium Uptake (In Grain)

Soil application : K uptake by grain of wheat was significantly increased by soil application of 125% RDN which was at par with soil application of 100% RDN and superior over rest of the soil applied RDN during 2021-22, 2022-23 and on pooled data basis. The magnitude of increase due to soil application of 125% RDN was 15.44, 37.05 and 88.31 per cent over soil application of 75, 50% RDN and control, respectively on pooled basis. Similarly, soil application of 100% RDN was also recorded higher uptake of K by grain of wheat over soil application of 75, 50% RDN and control by 14.26, 35.64 and 86.37 per cent, respectively. Data further revealed that soil application of 75% RDN was recorded significantly higher K uptake by grain of wheat over soil application of 50% RDN and control. K uptake by grain of wheat was also significantly increased with soil application of 50% RDN over control.

Foliar spray : Foliar application of nano urea at 25-30 DAS and 45-50 DAS was found significantly higher K uptake by grain over one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and control by 8.42, 10.96 and 23.43 per cent, respectively in pooled mean basis. It was statistically at par with two spray of urea at 25-30 DAS and 45-50 DAS.

In straw

Soil application : Maximum K uptake by straw recorded with soil application of 125% RDN over rest of the treatments and being at par with 100% RDN during 2021-22, 2022-23 and on pooled basis. K uptake by straw of wheat in soil application of 125% RDN increased by 17.02, 46.70 and 116.54 per cent over 75, 50% RDN and control, respectively on pooled basis. The soil application of 100% RDN was also observed significantly higher K uptake by straw over soil application of 75, 50% RDN and control. The soil application of 75% RDN was also observed significantly higher K uptake by straw over soil application of 50% RDN and control.

Foliar spray : Foliar application of nano urea at 25-30 DAS and 45-50 DAS was found significantly higher K uptake by straw over one foliar spray of nano urea at 25-30 DAS, one foliar spray of urea at 25-30 DAS and control by 7.93, 9.06 and 22.92 per cent, respectively in pooled mean basis. It was at par with two spray of urea at 25-30 DAS and 45-50 DAS. The application of nano fertilizer may expose the plant nutrient (NPK) to a greater surface area, which may enhance the fixation of plant nutrient of nanoparticle, minimizing losses and releasing it at a later stage of crop growth when needed. This may

account for the nano fertilizer's superior potassium uptake over conventional fertiliser. These outcomes line up with Khaled *et al.* (2021), Kanno *et al.* (2022).

Conclusions

According to this study, wheat has greater amount of nutrient after soil application of 125% RDN which found to have significantly higher nitrogen, phosphorus and potassium content and uptake in grain and straw remain on par with the 100% RDN soil application. However, Among the foliar applications, there were outstanding increases in the content and uptake of nitrogen, phosphorus and potassium in grain and straw when using nano urea in foliar spray at 25-30 and 45-50 DAS compared to the other treatments.

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Effect of Silica and Microbial Consortia on Growth, Yield and Economics of Tomato (*Solanum lycopersicum* L.)

Neha Meena^{1*}, H.L. Bairwa¹, S. Pilania¹, V. Saharan², Gajanand Jat³, R.P. Meena⁴ and Anamika Meena¹

¹Department of Horticulture, RCA, MPUAT, Udaipur, Rajasthan

²Department of MBBT, MPUAT, Udaipur, Rajasthan

³Department of Soil Science and Agricultural Chemistry, MPUAT, Udaipur, Rajasthan

⁴CoA, Dungarpur, MPUAT, Udaipur, Rajasthan

*Corresponding Author Email : neha.masar2020@gmail.com

Abstract

The present investigation entitled “Effect of Silica and microbial consortia on growth, yield and economics of Tomato (*Solanum lycopersicum* L.)” was carried out at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur. The twelve treatments for the tomato crop were evaluated with three replications under randomized block design. Variety “USM- Kareena (Hybrid)” of tomato was used in this experiment. The results exhibit the significant effect of various treatments on growth, yield and economics of tomato. The growth parameters viz., maximum plant height at 60 DAT, 90 DAT and at harvesting (63.60 cm, 91.90 cm and 126.60 cm), respectively, leaf area index (3.93), number of branches (8.12), 50% flowering (54.12), minimum days to harvest (77.39), stem diameter (1.55 cm) was obtained in treatment T₁₂ (RDF(NPK) 50% +Silica 50 kg ha⁻¹ + silica solubilising bacteria +NPK consortium). Similarly, yield attributes and yield namely maximum number of fruits per plant (18.21), fruit weight (86.88 g), fruit volume (93.33 cc), specific gravity (1.07 g/cc), yield per plant (1.55 kg) and yield per ha (61134 kg ha⁻¹) was recorded with treatment T₁₂ (RDF (NPK) 50% +Silica 50 kg ha⁻¹ + silica solubilising bacteria +NPK consortium).

Key Words : Silica, microbial consortia, growth, yield, economics, tomato, NPK consortia

Introduction

India's diverse climate ensures the availability of all varieties of fresh fruit and vegetable. It ranks 2nd in vegetable production in the world, after China. As per NHB (3rd Advance estimates) published by NHB, during 2021-22, India produce 204.84 million metric tonnes of vegetables. (Anonymous, 2022)

The tomato, or *solanum lycopersicum* L. is a vegetable crop grown annually all over the world and is a member of the Solanaceae family. Tomato is termed as “functional food” due to rich in antioxidants such as carotenoids, vitamin C, phenolics and tocopherols (Ranieri *et al.* 2004). Consumption of fresh tomatoes and tomato products restrict the development of different types of cancer (Giovannucci 1999). Antioxidants play a potential role in scavenging free radicals and prevent many degenerative and chronic diseases, such as cancer, cardiovascular diseases, cataract, digestive tract tumour's, hypertension, diabetes, obesity and immunity system dysfunctions (Canene-Adams *et al.* 2005). Lycopene is the principle carotenoid (> 80% of the total carotenoid) present in fully red-ripe tomato fruits and is responsible for the characteristic red colour (Shi and Le-Maguer 2000). and a high nutritive, a good source of vitamins A and B as well as an excellent source of vitamin

C. It is delicious, relieves constipation and has a pleasant taste (Ronga *et al.*, 2018).

Tomatoes covers approximately 4.73 million hectares area and produces 163.96 million tonnes globally (Anonymous, 2016). In India, tomato is ranked third after potato and onion with world's second most popular crop after potatoes having second only to China with an average production of 20366 MT with acreage of 841 M ha of yearly production (Anonymous, 2022). Its area and production in Rajasthan were 20504 hectares and 232864 tonnes, respectively. The district of Udaipur has its area and production to the tune of 189 ha and 1928 M.T, respectively (Anonymous, 2022).

Silicon is known to affect the availability of nutrients in soils and effectiveness with which plants utilize nutrient. Studies revealed that silicon application dramatically accelerated rice growth and raised the crop's grain and straw yields (Zhang *et al.*, 2021). Furthermore, silicon (Si) is required for the structural rigidity of cell walls, when plants have a passive or selective absorption or they are poor accumulators as Solanaceae, the proportion of silicon taken and present in the plants is lower than 1%, yet its presence can provide significant benefits to the plant before it faces biotic and abiotic challenges. Si also undoubtedly strengthens plant defence against a variety of biotic and abiotic stresses (Zhang *et al.*, 2017). Despite

being widely present in soil, most silica sources are poorly soluble and not available to plants. To make silica available to plants, Silica solubilising bacteria (SSB) have an important role in increasing the available silica (Brindavathy *et al.*, 2012).

Bio fertilizer NPK consortia have become more popular recently. The bio NPK consortium is a one-stop solution for all of a crop's macronutrient (N, P, and K) needs. The use of Bio NPK consortia @ 3-5 ml for root dipping therapy can reduce soil, water and air pollution while increasing growth and production while saving up to 25% on N, P, and K chemical fertilizer. It is used as seed treatment (3-5 ml kg⁻¹), soil application (1 l ha⁻¹), seedling treatment (3-5 ml l⁻¹) and with drip irrigation (1 l ha⁻¹) (Vagela *et al.*, 2019). It is becoming increasingly clear that when a microbial consortium of two or more interacting microorganisms is involved, additive or synergistic result can be expected. They boost soil fertility, encourage diversity and interaction with other beneficial microbes hinder the growth and infectious action of potential pathogens and generally preserve the sustainability of the systems with increased yields of certain crops (Santoyo *et al.*, 2021). Instead of utilizing separate bio fertilizers for each nutrient, consortium bio fertilizers ensure the mineralization and solubilisation of many nutrients with a single application by combining a mixed population of plant growth-promoting rhizobacteria in a single inoculum unlike the earlier practices of using separate biofertilizers for each nutrient with carrier based consortium bio fertilizer, plant growth promoting rhizobacteria are more useful (Babu *et al.*, 2020). Keeping in view the above facts and importance of silica, SSB, microbial consortia on crop development and yield, a field experiment entitled "Effect of silica and microbial consortia on growth and yield of tomato (*Solanum lycopersicum* L.)" was carried out during kharif season, 2022 to assess effect of silica and microbial consortia on growth and yield and economics of tomato (*Solanum lycopersicum* L.).

Materials and Methods

The experiment entitled "Effect of Silica and microbial consortia on growth, yield and economics of Tomato (*Solanum lycopersicum* L.)" was carried out at Horticulture Farm, Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur. The twelve treatments for the tomato crop were evaluated with three replications under randomized block design. The twelve treatments consists of T₁ (Control), T₂ (RDF NPK (200:100:80), T₃ (Silica 100kg ha⁻¹), T₄ (NPK consortia), T₅ (Silica Solubilizing Bacteria), T₆ (RDF (NPK) 50% + Silica 100kg ha⁻¹), T₇ (RDF (NPK) 50% + Silica solubilizing bacteria), T₈ (RDF (NPK) 50% + NPK consortia), T₉ (RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica Solubilizing

Bacteria), T₁₀ (RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium), T₁₁ (RDF (NPK) 50% + Silica Solubilizing Bacteria + NPK consortia) and T₁₂ (RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica Solubilizing Bacteria + NPK consortia).

Crop was grown as per standard package of practices recommended by State Horticulture Department of Rajasthan. Variety "USM- Kareena (Hybrid)" of tomato was used in this experiment. The plots of 2.0 m x 2.0 m size were prepared. Basal dose of RDF and Silica were calculated as per treatment and mixed in the soil one week prior to transplanting. Four weeks old seedling were transplanted at the spacing of 50 cm x 50cm as per layout in the evening hours followed by quick light irrigation. Tomato harvesting was started at 60-65 days after transplanting. Harvesting was done by hand picking methods.

Leaf area was calculated using portable leaf area meter (Li-3000) and measured at the time of fruiting and average leaf area was measured and expressed as cm² /plant. Specific gravity of the fruit was worked out by dividing the weight of the fruit by the volume of the same fruit and was expressed as gram per cubic centimetre. Chlorophyll content of leaves was determined using Chlorophyll meter SPAD-502. In order to evaluate the most profitable treatment combination, economics of different treatments were worked out in terms of net returns and net returns per rupee investment. First of all, cost of cultivation was calculated then a gross return was estimated on the basis of the total yield (kg) per ha. The data recorded for the evaluation of different parameters was statistical analyzed using standard procedure for ANOVA of Randomized Block Design in order to test the significance of experimental results. The analysis of variance was done by the method suggested by Fisher (1954) and using analysis as described by Panse and Sukhatme (1995).

Results and Discussion

Effect of silica and microbial consortia on growth attributes of tomato

Plant height : The data showed that application of T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium presented in Table 1, the maximum plant height of 63.60, 91.90, 126.62 cm was recorded at 60, 90 DAT and at harvest respectively with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum was found with T₁-control. Plant height with application T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium was found significantly higher over rest of the treatments. The plant height at harvesting with treatment

Table-1 : Effect of Silica and microbial consortium on plant height (cm) of tomato.

Treatments	Plant height (cm)		
	60 DAT	90 DAT	At harvest
T ₁ : Control	41.75	65.18	95.85
T ₂ : RDF NPK (200:100:80)	52.70	73.37	116.37
T ₃ : Silica 100kg ha ⁻¹	49.78	71.22	114.67
T ₄ : NPK consortium	44.81	69.80	106.93
T ₅ : Silica solubilizing bacteria	42.80	65.62	97.95
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	55.37	75.48	119.85
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	54.40	75.40	116.95
T ₈ : RDF (NPK) 50% + NPK consortium	55.18	76.80	121.27
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	56.20	82.03	122.60
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	58.00	84.67	124.68
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	56.00	78.80	121.60
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	63.60	91.90	126.62
S. Em±	3.00	3.59	5.36
CD at 5%	8.81	10.53	15.73
CV %	9.90	8.20	8.05

Table-2 : Effect of Silica and microbial consortium on growth attributes of tomato.

Treatments	Stem Diameter	Leaf area index	Number of branches	Days to 50% flowering	Days to first fruit harvest
T ₁ : Control	1.12	3.68	5.81	64.32	91.97
T ₂ : RDF NPK (200:100:80)	1.50	3.71	6.96	63.12	90.26
T ₃ : Silica 100kg ha ⁻¹	1.43	3.62	6.92	63.23	90.42
T ₄ : NPK consortium	1.44	3.60	6.68	61.08	87.35
T ₅ : Silica solubilizing bacteria	1.45	3.60	6.64	60.32	86.25
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	1.52	3.75	7.12	59.10	84.52
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	1.51	3.72	7.03	59.37	84.89
T ₈ : RDF (NPK) 50% + NPK consortium	1.51	3.72	7.11	60.90	87.08
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	1.53	3.76	7.46	58.74	84.00
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	1.54	3.76	7.49	58.08	83.05
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	1.52	3.73	7.32	59.03	84.41
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	1.55	3.77	8.12	54.12	77.39
S. Em±	0.03	0.09	0.32	1.74	2.36
CD at 5%	NS	NS	0.94	5.09	6.94
CV %	3.54	4.07	7.90	5.00	4.76

T₁₂ was 1.51, 3.15 and 24.28 per cent higher than T₁₀, T₉ and T₁, respectively.

Stem Diameter (cm) : It is revealed from the data presented in the Table-2 that application of T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium produced maximum stem diameter (1.55 cm) and minimum (1.12cm) was found with T₁ control. Stem diameter (1.55 cm) in T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium failed to show any significant effect on stem

diameter though, it was higher over T₁₀ (1.54 cm), T₉ (1.53 cm), T₁₁ (1.52cm) treatments.

Leaf area index : Evaluation of data Table-2 shows that application of different treatments failed to show any significant effect on the leaf area index. Though maximum leaf area index at (3.93) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (3.68) was found with T₁-control.

Table-3 : Effect of silica and microbial consortium on yield attributes of tomato.

Treatments	No. of fruits per plant	Fruit diameter (cc)	Fruit volume (cc)	Specific gravity (g/cc)
T ₁ : Control	14.67	4.38	77.38	1.02
T ₂ : RDF NPK (200:100:80)	16.05	4.77	81.48	1.03
T ₃ : Silica 100kg ha ⁻¹	15.98	4.62	80.93	1.04
T ₄ : NPK consortium	15.51	4.16	80.04	1.03
T ₅ : Silica solubilizing bacteria	15.13	4.16	81.05	1.03
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	16.98	5.10	88.29	1.06
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	16.37	5.04	85.48	1.04
T ₈ : RDF (NPK) 50% + NPK consortium	16.63	5.06	85.76	1.04
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	17.67	5.18	88.35	1.06
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	17.85	5.25	90.64	1.06
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	17.37	5.20	89.27	1.05
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	18.21	5.27	93.33	1.07
S. Em±	0.69	0.18	1.65	0.00
CD at 5%	2.03	0.54	4.84	0.01
CV %	7.27	6.52	3.35	0.72

Table-4 : Effect of Silica and microbial consortium on yield and economics of tomato.

Treatments	Av. Wet. of fruit (g)	Av. Yield plant ⁻¹ (kg)	Yield (kg ha ⁻¹)	GR (ha ⁻¹)	NR (Rs.ha ⁻¹)	B:C Ratio
T ₁ : Control	6.02	1.15	45803	538,200	396,560	2.80
T ₂ : RDF NPK (200:100:80)	78.72	1.26	49304	590,823	440,843	2.94
T ₃ : Silica 100kg ha ⁻¹	78.17	1.25	49821	582,905	440,453	3.09
T ₄ : NPK consortium	77.99	1.21	48587	566,280	423,840	2.98
T ₅ : Silica solubilizing bacteria	79.00	1.20	47924	560,711	418,271	2.94
T ₆ : RDF (NPK) 50% + Silica 100kg ha ⁻¹	83.33	1.40	55988	655,058	508,436	3.47
T ₇ : RDF (NPK) 50% + Silica solubilizing bacteria	82.00	1.35	53843	631,800	485,190	3.31
T ₈ : RDF (NPK) 50% + NPK consortium	82.28	1.37	54792	641,066	494,456	3.37
T ₉ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria	83.03	1.47	58925	687,960	540,944	3.68
T ₁₀ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + NPK consortium	85.33	1.50	59917	702,000	554,984	3.77
T ₁₁ : RDF (NPK) 50% + Silica solubilizing bacteria + NPK consortium	84.70	1.45	57854	677,258	529,848	3.59
T ₁₂ : RDF (NPK) 50% + Silica 50kg ha ⁻¹ + Silica solubilizing bacteria + NPK consortium	86.88	1.53	61134	728,269	580,453	3.93
S. Em±	1.69	0.08	3464.47			
CD at 5%	4.97	0.23	10161.00			
CV %	3.60	10.12	11.18			

Number of branches : Fertilising the tomato crop with various treatment viz., RDF (NPK) 50%, Silica 50 kg ha⁻¹, Silica solubilizing bacteria, NPK consortium exposed a positive and significant effect on number of branches per plant at harvest (Table-2). Maximum number of branches (8.12) was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (5.81) was found with T₁ control. T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK

consortium produced 7.75, 12.43 and 28.44 per cent higher number of branches over T₁₀, T₉ and T₁, respectively.

Days taken to 50% flowering : The application of various treatment significantly reduced the time to 50% flowering. Data presented in Table-2 showed that a earliest 54.12 days were taken to 50% flowering was recorded under T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium. However, the maximum days

taken for 50% flowering 64.32 days with no application of various fertiliser and consortia were found with T₁-control.

Days to first fruit harvest : The application of various treatment significantly reduced the time to for first picking presented in Table 2. The earliest time for first picking 77.39 days under the application of T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium. However, the maximum days taken for first picking 91.97 days was found with T₁ -control.

Improvement in plant growth *i.e.* plant height, leaf area index, number of branches per plant at final harvest, days to flowering, stem diameter and days to harvest of tomato by the conjunction use of NPK, microbial consortium, silica solubilizing bacteria and silicon might have resulted in better nutritional environment in the rhizosphere as well as in the plant system. Zhang *et al.*, 2021 also revealed that Si plays important roles in plant growth and development of the plants. High rates of microbial transformation due to the availability of organic carbon for heterotrophic organisms, hydraulic conductivity, buffering effect, improved soil aggregation, aeration, release of organic acids, etc., which act as stimulants for crop nutrient supply during microbial decomposition and enable the crop to utilise nutrients, may be responsible for the maximum value of growth parameters. These results are in consonance with the findings of Babu *et al.*, 2017. Further, Subbaiah *et al.* (2018) also supported the findings. Further, these results are in close conformity with the findings of Alam *et al.* (2010), Avhad *et al.* (2016) and Angadi *et al.* (2017).

Yield attributes

Number of fruits per plant : Data presented in the Table-3 that number of fruits per plant influenced significantly and produced maximum number of fruits per plant (18.21) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (14.63) was found with T₁-control. T₁₂ produced 19.43, 10.10 and 1.97 per cent higher number of fruits per plant as compared to T₁, T₇ and T₉, respectively.

Fruit diameter (cm) : Perusal of data given in Table-3 indicated that maximum fruit diameter (5.27) was recorded under treatment T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (4.38) was found with T₁-control. Fruit diameter (5.27 cm) in T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium found significantly higher over T₁₀-RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium) (5.25), T₁-control (4.38) and other treatments.

Fruit volume (cc) : Perusal of data given in Table-3 indicated that fruit volume was significantly influenced by application of different treatments. Maximum fruit volume of 93.33 cc was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (77.38) was found with T₁ -control.

Specific gravity : Perusal of data given in Table-3 indicated that specific gravity has significantly influenced by application of different treatments. Maximum specific gravity of 1.07 g/cc was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium and minimum (1.02 g/cc) was found with T₁-control.

Yield and economics

Average weight of fruits (g) : The result of data analysis presented in Table-4 indicated that different treatments increased the fruit weight. Maximum fruit weight (86.88 g) was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (76.02 g) were found with T₁-control. Fruit weight under T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium (86.88 g) found significantly higher over T₁₀-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + NPK consortium) (85.33 g) and T₉-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria (83.03 g) and T₁-control (76.02 g) and other treatments.

Average yield per plant (kg) : The supplementation of tomato crop for recommended dose N, P, K with microbial consortium had shown positive and significant effect on crop yield per plant, presented in Table 4 Maximum yield (1.55 kg) was recorded with T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (1.15 kg) was found with T₁control. Yield per plant under T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium (2.57 kg) found significantly higher over T₁₀-RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium) (1.50 kg) and T₉-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria (1.47 kg) and T₁-control (1.15 kg) and other treatments. Average yield per plant produced under T₁₂ found to be 25.8, 5.16 and 3.22 per cent higher than T₁, T₉ and T₁₀, respectively.

Yield per hectare (kg ha⁻¹) : A perusal of data given in Table-4 revealed that maximum yield per hectare (61818.6 kg) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum (45802.7 kg) was found with T₁-control. Yield under T₁₂ found significantly higher over T₉ -RDF (NPK) 50% + Silica 50 kg ha⁻¹) (58688.0kg) and T₂-RDF (NPK) (50536.1) and T₁-Control (45802.7 kg). The yield per hectare recorded under T₁₂ was 5.06 and 25.9 per cent higher than T₁ and T₉, respectively.

Economics of treatment : Data pertains to economics of tomato for per hectare area under open conditions was affected by various treatments are shown in table-4. Treatment T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and T₁₀-RDF (NPK) 50% + Silica 50kg ha⁻¹ + NPK consortium) gave net return of ₹565453 and ₹552013 and minimum net return of ₹392251 was recorded with T₁ (Control). However, maximum B:C (3.93) was recorded with T₁₂-RDF (NPK) 50% + Silica 50kg ha⁻¹ +Silica solubilizing bacteria + NPK consortium and minimum B:C (2.73) with T₁ (Control).

The application of RDF (NPK) 50% + Silica 50kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium may result in higher values of all yield attributing parameters due to nutrient supply by combination of fertilisers along with microbial consortium during initial growth period and sustained supply of nutrient and congenial conditions by NPK and induced tolerance against biotic and abiotic stress by Silicon by lowering down the absorption of sodium by plants as supported by Sanchez *et al.*, 2012. The increased commercial production of tomato treated with nano silica is attributable to more and heavier fruits per plant. On tomato, an increase in crop output with Si supplementation has already been established by Kleiber *et al.*, 2015.

Furthermore, increased plant development provides more sites for photosynthesis and the transfer of photosynthates from source to sink (leaves to fruits) has been discovered by Tekale *et al.* (2017). Inorganic sources provide all major and minor growth nutrient and also improve physico-chemical and biological properties of soil which helps plant root to proliferates, resulting in larger coverage of rhizosphere area and better up take of nutrients. Higher fruit weight might be due to solubilization effect of plant nutrients by addition of microbial consortium leading to increased uptake of N, P and K as observed by Bhattarai 2011. Singh *et al.* (2017) found that the application of organic manures had the highest impact on the quantity of fruits per plant and output per hectare in tomato.

Conclusions

Based on results, it can be concluded that among the various treatments T₁₂-RDF (NPK) 50% + Silica 50 kg ha⁻¹ + Silica solubilizing bacteria + NPK consortium as found superior in different growth attributes viz., plant height 60, 90 and at harvesting DAT, number of branches, days to 50% flowering, chlorophyll content of leaf and stem diameter, different yield attributes viz. number of fruits per plant, fruit diameter, fruit weight and fruit volume, yield per plant, yield per hectare, net returns and B:C of tomato.

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Constraints Faced by the Farmers in Adaptation of Climate Change Related to Agriculture Activities in Udaipur District of Rajasthan

Sumit Kumar Yadav¹, F.L. Sharma², S.S. Sisodia¹, Narendra Kumar Choudhary¹ and Devendra Singh¹

¹Department of Extension Education, RCA, Udaipur, Rajasthan

²BN College, Udaipur, Rajasthan

*Corresponding Author Email : syadav12150@gmail.com

Abstract

The present study was undertaken in Udaipur district of Rajasthan state in order to identify constraints faced by the farmers in adaptation of climate change related to agriculture activities. A sample of 120 respondents from two tehsils (Girwa & Kotra) and eight villages (Alsigarh, Karget, Pai, Panduna, Mamer, Asawara, Samoli and Ghata) were taken on the basis of random sampling technique. The study revealed that poor supply of electricity for use of drip and sprinkler irrigation system, small size and fragmented land holding, inadequate knowledge about climate change, lack of credit facilities for adaptation of crop and livestock strategies, high cost of farm inputs, irregular extension service for adaptation of agril. strategies, lack of technical guidance about climate change, dependence on monsoon, non-availability of irrigation facility, Poor access to information resources and Lack of access to weather forecasting technology were the important constraints faced by the farmers in adaptation of agriculture activities due to climate change.

Key words : Climate, adaptation, constraints, agriculture.

Introduction

Climate change is one of the biggest challenges facing in the world today. The Intergovernmental Panel on Climate Change (IPCC) was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to assess climate change based on the latest science. Recent climate changes and climate variations are beginning to have effects on many natural and human systems. An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gases fluxes in terrestrial ecosystems.

Climate is one of the inputs for agricultural growth and survival of related population. Total annual crop losses in the world agriculture are mainly due to direct weather impacts. Increase in atmospheric carbon dioxide (CO₂) and other greenhouse gases viz. methane (CH₄), nitrous oxide (N₂O) and chloro fluoro Carbons (CFC) due to fossil fuel burning, rapid industrialization and deforestation create a layer in the atmosphere and prevent the long wave radiation emitted by earth which otherwise would have escaped to space. As a result, the average global temperatures are increasing. Increase in global temperature results in changes in the general circulation and thereby climate change. Agriculture sector reveals high sensitivity and resilience to climate change.

Looking to the effect of climate change in agriculture and allied fields the present study aimed to identify the

constraints faced by farmers in adaptation to agriculture activities in Udaipur district of Rajasthan.

Research Methodology

The present study was conducted in Udaipur district of Rajasthan state during the year 2020-2021 with a total of 120 respondents selected from two tehsils and eight villages. 15 respondents were selected from each village. To identify the constraints, a schedule was prepared with the help of agriculture experts. Data were collected with the help of interview schedule. Face to face interview technique was used for collection of information from respondents. For identifying constraints, mean per cent score was calculated and accordingly ranks were assigned on the basis of severity of constraints.

Results and Discussion

This part of the report deals with the constraints faced by the farmers in adaptation of various strategies due to climate change. An effort was made to find out the priority wise constraints faced by the farmers. For the convenience, 16 suitable constraints identified and calculated by mean per cent score and ranked accordingly. The results were presented in Table-1.

The data in the Table-1 reveal that Poor supply of electricity for use of drip and sprinkler irrigation system was expressed as most important constraint by the farmers with MPS 95.28 and ranked first in rank hierarchy. It was further observed that Small size and fragmented land holding and Dependence on monsoon were the next

Table-1 : Extent of constraints presented by the respondents. n = 120

S. No.	Constraints	Girwa		Kotra		Total	
		MPS	Rank	MPS	Rank	MPS	Rank
1.	Inadequate knowledge about climate	96.11	I	88.89	I	91.67	IV
2.	Lack of technical guidance about climate change	92.78	V	83.89	V	87.50	VIII
3.	Non-availability of drought tolerance varieties	91.11	VI	78.89	VI	84.19	VIV
4.	Dependence on monsoon	93.33	IV	95.56	IV	93.89	III
5.	Lack of access to weather forecasting technology	86.11	XI	76.11	XI	80.56	XII
6.	Difficulty in shifting cropping patterns	67.22	XVI	70.00	XVI	68.06	XVI
7.	Small size and fragmented land holding	95.00	III	96.67	III	95.00	II
8.	Lack of credit facilities for adaptation of crop and livestock strategies	88.33	VIII	94.44	VIII	90.56	V
9.	Irregular extension service for adaptation of strategies	87.78	VIV	90.56	VIV	88.06	VII
10.	Poor access to information resources	83.89	XII	80.56	XII	81.67	XI
11.	High cost of farm inputs	88.89	VII	89.44	VII	88.33	VI
12.	Non-availability of timely farm inputs	81.11	XIV	76.09	XIV	77.78	XIV
13.	Non-availability of irrigation facility	87.22	X	82.22	X	83.89	X
14.	High cost of efficient irrigation systems	82.22	XIII	74.44	XIII	78.33	XIII
15.	Poor supply of electricity for use of drip and sprinkler irrigation system	95.56	II	96.11	II	95.28	I
16.	Delay in settlement of crop insurance claim	77.78	XV	70.56	XV	73.89	XV

MPS = Mean Per Cent Score

important constraints perceived by the farmers with the extent of 95.00 and 93.89 MPS and ranked second and third, respectively.

Table further shows that next significant constraints perceived by the farmers were Inadequate knowledge about climate, Lack of credit facilities for adaptation of crop and livestock strategies, High cost of farm inputs with the extent of 91.67, 90.56 and 88.33 MPS and ranked fourth, fifth and sixth, respectively in the order of constraints.

Analysis of table also reveals that Irregular extension service for adaptation of strategies, Lack of technical guidance about climate change and Non-availability of drought tolerance varieties were realized as important constraints with 88.06, 87.50 and 84.19 per cent and ranked seventh, eighth and ninth, respectively with regard to adaptation of agricultural strategies due to climate change.

The constraints namely Non-availability of irrigation facility, Poor access to information resources and Lack of access to weather forecasting technology were faced by the farmers with the extent of 83.89, 81.67 and 80.56 MPS and ranked tenth, eleventh and twelfth, respectively.

It was further noted that High cost of efficient

irrigation systems, Non-availability of timely farm inputs and Delay in settlement of crop insurance claim were perceived by the farmers with the extent of 78.33, 77.78 and 73.89 MPS, respectively. Whereas, difficulty in shifting cropping patterns was the least important constraint opinioned by the farmers with 68.61 MPS.

From the table it was found that the extent of constraints faced by farmers of Girwa Tehsil was from 96.11 to 67.22 MPS, while in case of Kotra Tehsil, it was 88.89 to 70.00 MPS. Hence, it can be concluded that the constraints faced by the respondents of both the tehsils were more or less similar level.

These results are similar with the findings of Ananthnag *et al.* (2014) who revealed that in personal constraint that majority of farmers (60.00%) expressed that small land holdings (due to nuclear families and low annual income) was the major constraint, followed by in institutional constraint, poor extension service on climate risk management was the major constraint (72.00%) and lastly in technical constraint, non-availability of drought tolerant varieties was the major constraint (71.00 %). Regmi and Bhandari (2013) also reported that there are limits to adaptation, which are caused by barriers of available technology, knowledge and institutional farm work.

Conclusions

From the above discussion it can be concluded that Poor supply of electricity for use of drip and sprinkler irrigation system, Small size and fragmented land holding and Dependence on monsoon, Inadequate knowledge about climate, Lack of credit facilities for adaptation of crop, livestock strategies, High cost of farm inputs were the important constraints perceived by the farmers in adaptation of agriculture and livestock strategies in the study area.

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N, P and K Uptake and Content in Sorghum and Associated Weeds Influenced by Weed Management Practices

Tejpal Piploda^{1*}, Arvind Verma¹, M.K. Kaushik¹, Roshan Choudhary¹, Dharm Pal Singh² and Amit Dadheech³

¹Department of Agronomy, R.C.A., Udaipur, Rajasthan

²Department of Soil Science and Agricultural Chemistry, R.C.A., Udaipur, Rajasthan

³Department of Genetics and Plant Breeding, R.C.A., Udaipur, Rajasthan

*Corresponding Author Email : tejpalpiploda2022@gmail.com

Abstract

A field experiment was conducted at the Instructional Farm of Agronomy, Rajasthan College of Agriculture, MPUAT, Udaipur during *kharif* 2022 to assess the effect of weed management practices on nutrient content and uptake in grain sorghum and associated weeds. The experiment consisted of twelve treatments *i.e.*, atrazine 750 g ha⁻¹ PE *fb* 2,4-D ethyl ester 500 g ha⁻¹ PoE, atrazine 750 g ha⁻¹ PE *fb* 2,4-D dimethylamine salt 750 g ha⁻¹ PoE, atrazine + mesotrione (RM) 438 g ha⁻¹ PoE, atrazine + mesotrione (RM) 656 g ha⁻¹ PoE, atrazine 500 g ha⁻¹ + topramezone 18.9 g ha⁻¹ EPoE (Tank mix), atrazine 500 g ha⁻¹ + topramezone 25.2 g ha⁻¹ EPoE (Tank mix), atrazine 500 g ha⁻¹ PE *fb* mechanical weeding at 30 DAS, bentazone 960 g ha⁻¹ PoE, atrazine 500 g ha⁻¹ PE, atrazine 500 g ha⁻¹ PE *fb* bentazone 960 g ha⁻¹ PoE, two hand weeding at 20 DAS and 40 DAS and weedy check. The lowest total N depletion (3.34 kg ha⁻¹), P (0.48 kg ha⁻¹) and (4.26 kg ha⁻¹) by weeds was recorded under atrazine 500 g ha⁻¹ + topramezone 25.2 g ha⁻¹ EPoE (Tank mix). Whereas, weedy check recorded highest depletion of N (54.56 kg ha⁻¹), P (8.04 kg ha⁻¹) and K (67.38 kg ha⁻¹) by weeds at harvest.

Key words : *Sorghum*, weeds, nutrient uptake, nutrient content, weed management.

Sorghum (*Sorghum bicolor* (L.) Moench) 'jowar' is the fifth most important cereal in the world followed by wheat, rice, maize and barley and it is the major staple diet of the people of the semi-arid tropics (Ottman and Olsen, 2009). In India, the area and production under sorghum were 4.24 million hectares and 4.78 million tonnes during 2020-21 (DoES, DA&FW, 2021). Among the Indian states, Rajasthan is the leading nutri/coarse cereal producer, accounting for 26.54 (5.84 million ha) and 16.44 per cent (7.06 million tonnes) of total area and production in 2018-19 (DoES, 2019) respectively. The presence of weeds during the critical period reduced sorghum yield to 15-40 per cent. The chemical method of weed control has become efficient, time saving and cheaper with the introduction of herbicides (Vinayaka *et al.*, 2020). Unchecked weed growth in sorghum removed 29.94-51.05, 5.03-11.58 and 48.74-74.34 kg ha⁻¹ nitrogen, phosphorus and potassium, respectively, from the soil (Satao and Nalamwar 1993). Weeds compete with crops for water, nutrients and other growth factors and in the absence of effective control measures, weeds remove a considerable quantity of applied nutrients resulting loss in yield and conditions become severe under its scarcity (Sangwan *et al.*, 2019 and Zargar *et al.*, 2020). Improving nutrient-use efficiency (NUE) by reducing nutrient losses is a critical step towards increasing soil fertility and agricultural productivity of dry land farming. It is possible to

increase the NUE and productivity of crops by timely controlling the weed growth (Pandey *et al.*, 2001 and Ayneband *et al.*, 2012). The present study was conducted to assess the effect of weed management practices on nutrient concentration and uptake in grain sorghum and associated weeds.

Materials and Methods

A field investigation was carried out during *kharif* 2022 at the Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur. The soil of experimental site was non-saline (electrical conductivity: 0.76dSm⁻¹) alkaline (8.1 pH) sandy clay loam soil was rated as medium for organic carbon (0.61%), available N and K (286.4 and 354.4 kg ha⁻¹) and high for available P (21.2 kg ha⁻¹). The experiment comprising 12 weed management treatments *i.e.*, atrazine 750 g ha⁻¹ PE *fb* 2,4-D ethyl ester 500 g ha⁻¹ PoE, atrazine 750 g ha⁻¹ PE *fb* 2,4-D dimethylamine salt 750 g ha⁻¹ PoE, atrazine + mesotrione (RM) 438 g ha⁻¹ PoE, atrazine + mesotrione (RM) 656 g ha⁻¹ PoE, atrazine 500 g ha⁻¹ + topramezone 18.9 g ha⁻¹ EPoE (Tank mix), atrazine 500 g ha⁻¹ + topramezone 25.2 g ha⁻¹ EPoE (Tank mix), atrazine 500 g ha⁻¹ PE *fb* mechanical weeding at 30 DAS, bentazone 960 g ha⁻¹ PoE, atrazine 500 g ha⁻¹ PE, atrazine 500 g ha⁻¹ PE *fb* bentazone 960 g ha⁻¹ PoE, two hand weeding at 20 DAS and 40 DAS and weedy check was laid out in randomized complete block design (RCBD)

Table-1 : Effect of weed management on nutrient content (nitrogen, phosphorus and potassium) in weeds at harvest.

S. No.	Treatments	Nutrient content (%)					
		Nitrogen		Phosphorus		Potassium	
		Monocot weeds	Dicot weeds	Monocot weeds	Dicot weeds	Monocot weeds	Dicot weeds
1.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D Ethyl ester 500 g ha ⁻¹ PoE	1.862	2.175	0.257	0.300	2.184	3.092
2.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D dimethylamine salt 750 g ha ⁻¹ PoE	1.866	2.178	0.258	0.308	2.187	3.095
3.	Atrazine + Mesotrione (RM) 438 g ha ⁻¹ PoE	1.870	2.191	0.263	0.311	2.199	3.108
4.	Atrazine + Mesotrione (RM) 656 g ha ⁻¹ PoE	1.872	2.196	0.265	0.315	2.205	3.113
5.	Atrazine 500 g ha ⁻¹ + Topramezone 18.9 g ha ⁻¹ EPoE (Tank mix)	1.869	2.188	0.261	0.305	2.197	3.105
6.	Atrazine 500 g ha ⁻¹ + Topramezone 25.2 g ha ⁻¹ EPoE (Tank mix)	1.873	2.201	0.266	0.325	2.209	3.118
7.	Atrazine 500 g ha ⁻¹ PE fb Mechanical weeding at 30 DAS	1.855	2.155	0.254	0.278	2.164	2.995
8.	Bentazone 960 g ha ⁻¹ PoE	1.875	2.208	0.267	0.328	2.216	3.125
9.	Atrazine 500 g ha ⁻¹ PE	1.868	2.183	0.259	0.298	2.192	3.102
10.	Atrazine 500 g ha ⁻¹ PE fb Bentazone 960 g ha ⁻¹ PoE	1.876	2.218	0.269	0.319	2.219	3.128
11.	Two hand weeding at 20 DAS and 40 DAS	1.851	2.144	0.251	0.311	2.153	2.982
12.	Weedy check	1.879	2.265	0.275	0.345	2.223	3.132
	SEm±	0.053	0.060	0.008	0.012	0.076	0.106
	CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table-2 : Effect of weed management on nutrient uptake (nitrogen, phosphorus and potassium) by weeds at harvest.

S. No.	Treatments	Nutrient uptake (kg ha ⁻¹)								
		Nitrogen			Phosphorus			Potassium		
		Mono cot weeds	Dicot weeds	Total	Mono cot weeds	Dicot weeds	Total	Mono cot weeds	Dicot weeds	Total
1.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D Ethyl ester 500 g ha ⁻¹ PoE	9.66	5.88	15.53	1.33	0.81	2.15	11.32	8.36	19.68
2.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D dimethylamine salt 750 g ha ⁻¹ PoE	10.13	6.40	16.53	1.40	0.90	2.30	11.87	9.09	20.97
3.	Atrazine + Mesotrione (RM) 438 g ha ⁻¹ PoE	6.51	4.32	10.83	0.92	0.61	1.53	7.66	6.13	13.78
4.	Atrazine + Mesotrione (RM) 656 g ha ⁻¹ PoE	4.45	3.36	7.81	0.63	0.48	1.11	5.22	4.76	9.98
5.	Atrazine 500 g ha ⁻¹ + Topramezone 18.9 g ha ⁻¹ EPoE (Tank mix)	5.34	3.87	9.21	0.75	0.54	1.28	6.28	5.49	11.77
6.	Atrazine 500 g ha ⁻¹ + Topramezone 25.2 g ha ⁻¹ EPoE (Tank mix)	2.01	1.34	3.34	0.28	0.20	0.48	2.36	1.90	4.26
7.	Atrazine 500 g ha ⁻¹ PE fb Mechanical weeding at 30 DAS	2.57	1.48	4.04	0.35	0.19	0.54	2.98	2.05	5.04
8.	Bentazone 960 g ha ⁻¹ PoE	8.47	5.59	14.05	1.21	0.83	2.04	10.01	7.91	17.92
9.	Atrazine 500 g ha ⁻¹ PE	11.63	6.80	18.42	1.61	0.93	2.54	13.64	9.66	23.30
10.	Atrazine 500 g ha ⁻¹ PE fb Bentazone 960 g ha ⁻¹ PoE	7.33	4.74	12.07	1.05	0.68	1.74	8.70	6.68	15.38
11.	Two hand weeding at 20 DAS and 40 DAS	3.58	2.16	5.74	0.49	0.31	0.80	4.16	3.01	7.17
12.	Weedy check	38.30	15.96	54.26	5.61	2.43	8.04	45.31	22.07	67.38
	SEm±	0.465	0.258	0.627	0.057	0.041	0.079	0.568	0.383	0.839
	CD (P=0.05)	1.364	0.757	1.838	0.168	0.119	0.233	1.666	1.123	2.460

Table-3 : Effect of weed management on nutrient content (nitrogen, phosphorus and potassium) in sorghum at harvest.

Sr. No.	Treatments	Nutrient content (%)					
		Nitrogen		Phosphorus		Potassium	
		Grain	Stover	Grain	Stover	Grain	Stover
1.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D Ethyl ester 500 g ha ⁻¹ PoE	1.707	0.612	0.359	0.191	0.488	1.659
2.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D dimethylamine salt 750 g ha ⁻¹ PoE	1.697	0.608	0.355	0.189	0.485	1.649
3.	Atrazine + Mesotrione (RM) 438 g ha ⁻¹ PoE	1.689	0.597	0.348	0.181	0.479	1.629
4.	Atrazine + Mesotrione (RM) 656 g ha ⁻¹ PoE	1.681	0.596	0.344	0.180	0.477	1.622
5.	Atrazine 500 g ha ⁻¹ + Topramezone 18.9 g ha ⁻¹ EPoE (Tank mix)	1.695	0.602	0.351	0.182	0.481	1.635
6.	Atrazine 500 g ha ⁻¹ + Topramezone 25.2 g ha ⁻¹ EPoE (Tank mix)	1.675	0.590	0.342	0.179	0.474	1.612
7.	Atrazine 500 g ha ⁻¹ PE fb Mechanical weeding at 30 DAS	1.713	0.622	0.362	0.193	0.491	1.669
8.	Bentazone 960 g ha ⁻¹ PoE	1.672	0.589	0.341	0.177	0.474	1.612
9.	Atrazine 500 g ha ⁻¹ PE	1.695	0.603	0.352	0.185	0.483	1.642
10.	Atrazine 500 g ha ⁻¹ PE fb Bentazone 960 g ha ⁻¹ PoE	1.663	0.583	0.338	0.175	0.471	1.601
11.	Two hand weeding at 20 DAS and 40 DAS	1.723	0.664	0.368	0.195	0.494	1.680
12.	Weedy check	1.498	0.566	0.330	0.173	0.469	1.595
	SEm±	0.044	0.019	0.008	0.005	0.012	0.046
	CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table-4 : Effect of weed management on nutrient uptake (nitrogen, phosphorus and potassium) by sorghum at harvest.

S. No.	Treatments	Nutrient Uptake (kg ha ⁻¹)								
		Nitrogen			Phosphorus			Potassium		
		Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
1.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D Ethyl ester 500 g ha ⁻¹ PoE	57.95	62.34	120.29	12.20	19.46	31.65	16.58	169.01	185.59
2.	Atrazine 750 g ha ⁻¹ PE fb 2,4-D dimethylamine salt 750 g ha ⁻¹ PoE	56.28	60.43	116.71	11.73	18.76	30.49	16.02	164.04	180.06
3.	Atrazine + Mesotrione (RM) 438 g ha ⁻¹ PoE	32.33	34.32	66.65	6.61	10.42	17.03	9.17	93.47	102.64
4.	Atrazine + Mesotrione (RM) 656 g ha ⁻¹ PoE	28.25	29.90	58.15	5.77	8.98	14.75	8.02	81.77	89.79
5.	Atrazine 500 g ha ⁻¹ + Topramezone 18.9 g ha ⁻¹ EPoE (Tank mix)	30.62	32.31	62.93	6.23	9.81	16.04	8.69	88.31	97.01
6.	Atrazine 500 g ha ⁻¹ + Topramezone 25.2 g ha ⁻¹ EPoE (Tank mix)	24.26	25.52	49.78	4.93	7.68	12.61	6.87	70.25	77.12
7.	Atrazine 500 g ha ⁻¹ PE fb Mechanical weeding at 30 DAS	65.89	76.68	142.57	14.24	22.66	36.90	19.14	195.17	214.31
8.	Bentazone 960 g ha ⁻¹ PoE	33.81	35.78	69.58	6.95	10.85	17.80	9.56	97.67	107.23
9.	Atrazine 500 g ha ⁻¹ PE	53.75	57.43	111.18	11.18	17.60	28.78	15.36	156.71	172.07
10.	Atrazine 500 g ha ⁻¹ PE fb Bentazone 960 g ha ⁻¹ PoE	37.11	39.56	76.67	7.69	11.94	19.63	10.56	107.41	117.97
11.	Two hand weeding at 20 DAS and 40 DAS	62.93	68.57	131.50	13.27	21.25	34.52	18.04	183.79	201.83
12.	Weedy check	12.86	14.58	27.44	2.83	4.44	7.27	4.03	41.07	45.10
	SEm±	3.682	2.157	5.112	0.846	0.635	1.377	1.192	7.001	7.730
	CD (P=0.05)	10.798	6.327	14.994	2.480	1.862	4.038	3.495	20.534	22.672

with 3 replications. The crop was sown manually on 2nd July in 2022 in rows 45 cm apart at an intra-row spacing of 15 cm and was later thinned to one plant per stand at 15 DAS. Fertilizers, viz., 80 kg N, 40 kg P₂O₅ and 40 kg K₂O ha⁻¹ were applied as recommended for grain sorghum in the area. Application of herbicides was done as per treatment using 500 litres of spray fluid. N, P and K contents (%) were estimated in crop and weeds after harvest. The N, P and K contents in sorghum (grain and stover) and weed samples were estimated by micro-Kjeldhal, Vanadomolybdo-phosphoric yellow colour and flame photometer methods, respectively (Jackson 1973). The percentage content was then multiplied by the total biomass produced for estimation of nutrient uptake. All the parameters were subjected for statistical analysis and interpretation as per Gomez and Gomez (1984).

Results and Discussion

Weed density and dry weight : The experiment field was infested with grassy and broadleaved weeds. The prominent weed species were *Echinochloa colonum*, *Eleusine indica* L., *Digera arvensis* L., *Commelina benghalensis*, *Physalis minima* L. and *Setaria glauca* found at 30 DAS and 60 DAS during *kharif* 2022 in Sorghum field. Dry weight of weeds significantly affected by weed management practices. Significantly the lowest dry weight and density of weeds was recorded with application of atrazine 500 g ha⁻¹ + topramezone 25.2 g ha⁻¹ EPoE (Tank mix) which was at par with atrazine 500 g ha⁻¹ PE *fb* mechanical weeding at 30 DAS and it was followed by two hand weeding at 20 and 40 DAS. These results are corroborated with findings of Priya *et al.* (2014), Sujathamma *et al.* (2015), Thakur *et al.* (2016), Swapnil *et al.* (2016) and Verma *et al.* (2022).

Grain and stover yield : The highest grain yield (3875.86 kg ha⁻¹) was recorded in atrazine 500 g ha⁻¹ PE *fb* mechanical weeding 30 DAS. However, it was at par with two hand weeding at 20 and 40 DAS (3647.39 kg ha⁻¹), atrazine 750 g ha⁻¹ PE *fb* 2,4-D Ethyl ester 500 g ha⁻¹ PoE (3394.43 kg ha⁻¹) and atrazine 750 g ha⁻¹ PE *fb* 2,4-D dimethylamine salt 750 g ha⁻¹ PoE (3315.95 kg ha⁻¹) whereas, the lowest grain yield plant⁻¹ (1141.67 kg ha⁻¹) was recorded in weedy check. The highest stover yield was observed in atrazine 500 g ha⁻¹ PE *fb* mechanical weeding 30 DAS (11627.59 kg ha⁻¹) which was at par with two hand weeding at 20 and 40 DAS (11021.02 kg ha⁻¹).

Nutrient content and their depletion by weeds : The effect of weed management practices on N, P and K concentration in weeds was found non-significant (Table-1). Weeds consume more nutrients than they need for their growth, and may accumulate higher mineral nutrient concentrations than crop plants (Kaur *et al.*, 2018). Weed management practices significant influenced

on the N, P and K depletion by weeds. Weedy check removed 54.26 kg N, 8.04 kg P and 67.38 kg K ha⁻¹ from the soil (Table-2). Satao and Nalamwar (1993) also reported that unchecked weed growth in sorghum depleted a lot of soil nutrients. Data further reveals that uptake of nitrogen by monocot (2.01 kg ha⁻¹), dicot (1.34 kg ha⁻¹) and total (3.34 kg ha⁻¹), P by monocot (0.28 kg ha⁻¹), dicot (0.20 kg ha⁻¹) and total (0.48 kg ha⁻¹), and K by monocot (2.36 kg ha⁻¹), dicot (1.90 kg ha⁻¹) and total (4.26 kg ha⁻¹) weeds was observed minimum under atrazine 500 g ha⁻¹ + topramezone 25.2 g ha⁻¹ EPoE (Tank mix) (T6). The decrease in the depletion of N, P and K by weeds under this treatment was due to good control of weeds resulted lowest dry weight of weed, which corroborated with the findings of Mishra *et al.* (2014), Bhuva *et al.* (2018), Chaudhary *et al.* (2018), Lakra and Husain (2020) and Mahto *et al.* (2020).

Nutrient content and their uptake by crop : The data presented in Table-3 shows that there is non-significant effect of weed management practices on nitrogen, phosphorus and potassium content of sorghum grain and stover. Different weed management treatments significantly influenced the N, P and K uptake in grain and straw as well as total uptake of these nutrients by sorghum (Table 4). In weedy check plot, weeds competed with sorghum for nutrients and depleted larger amount of N, P and K from the soil and left less nutrients available for the crop uptake (Mishra *et al.*, 2014). The maximum total (grain + stover) nitrogen uptake was recorded under atrazine 500 g ha⁻¹ PE *fb* mechanical weeding 30 DAS (142.57 kg ha⁻¹) and it was at par with two hand weeding at 20 and 40 DAS (131.50 kg ha⁻¹). Data further indicates that atrazine 500 g ha⁻¹ PE *fb* mechanical weeding 30 DAS recorded maximum total (grain + stover) phosphorus uptake (36.90 kg ha⁻¹) by sorghum. Atrazine 500 g ha⁻¹ PE *fb* mechanical weeding 30 DAS accounted for highest gains in total (grain + stover) potassium uptake (214.31 kg ha⁻¹) which was found to be statistically at par with two hand weeding at 20 and 40 DAS (201.83 kg ha⁻¹). Results are corroborated with the research results of Mishra *et al.* (2014), Sinodiya and Jha (2014), Verma *et al.* (2018), Kumar *et al.* (2019) and Vinayaka *et al.* (2020).

Conclusions

Therefore, it can be inferred that uncontrolled weed growth significantly competes with sorghum and depletes a substantial amount of nutrients from the soil during the *kharif* season. Consequently, it is essential to combine various weed management practices, including chemical and physical methods like mechanical and hand weeding, to enhance sorghum's nutrient utilization efficiency and overall productivity. Since weeds contain a considerable quantity of nutrients, the weeds removed manually can be

utilized for composting and mulching purposes to preserve soil moisture in dry land conditions.

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Effect of Phosphorus and Molybdenum Fertilization on Yield Attributes and Yield of Chickpea (*Cicer arietinum* L.)

Vikash Dhaka¹, Devi Lal Dhaker^{1*}, O.P. Sharma¹, Harish Kumar Bijarnia¹, Manjeet Dhaka¹, Pradeep Dhaka¹ and Jitendra Singh²

¹Department of Agronomy, School of Agriculture, Suresh Gyan Vihar University, Jaipur, Rajasthan

²Department of Agronomy, School of Agriculture, Apex University, Jaipur, Rajasthan

*Corresponding Author Email : devilal.dhaker09@gmail.com

Abstract

A field experiment was conducted at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur during *rabi* season of 2022-23. The factorial experiment was laid out in randomized block design with three replications consisting of twelve treatment combinations by using four levels of Phosphorus (0, 20, 40 and 60 kg/ha) and three levels of Molybdenum (0, 0.5 and 1.0 kg/ha). Results revealed that application of Phosphorus @ 40 kg/ha and Molybdenum @ 1.0 kg/ha considerably enhanced the number of pods/plant, number of seeds/pod, seed, straw and biological yield of chickpea compared to control and other treatments of Phosphorus or Molybdenum.

Key words : Phosphorus, molybdenum, chickpea, yield and treatments.

Introduction

Chickpea (*Cicer arietinum* L.) is also known as gram and Bengal gram. There is a growing demand for chickpea due to its nutritional value as seeds of chickpea contain 20-22% protein, 60-62% carbohydrate, 5% fat and are rich in calcium and iron. Mostly chickpea is grown in South Asia, which accounts for more than 75% of the world chickpea area. India is the largest producer, importer and consumer of the pulses in the world, accounting for 25% of the global production, 15% trade, and 27% consumption; as sizeable population in the country still depends on vegetarian diets to meet its protein requirement (Ali and Kumar, 2007). In India, it is cultivated in an area of 10.91 m ha with the production of 13.75 m ha and productivity of yield of 892 kg/ha. Major states in chickpea production are Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka, Gujarat and Andhra Pradesh (Anonymous, 2022). In Rajasthan, it is cultivated in 6.15 m ha with the production of 4.31 m tonnes and the productivity of 701 kg/ha.

Application of phosphorus to legume is more important than other nutrients because it is a major plant nutrient and required for various metabolic processes such as cell division and development of cell, energy transport, signal transduction, macro molecular biosynthesis, photosynthesis and respiration. Phosphorus is an essential constituent of nucleic acids such as ribonucleic acid (RNA) and deoxy ribonucleic acid (DNA), adenosine diphosphate (ADP) and adenosine triphosphate (ATP), nucleoproteins, amino acids, proteins, phosphatides, phytin, several co-enzymes viz.,

thiamine, pyrophosphate and pyridoxyl phosphate (Verma *et al.*, 2015). The application of phosphorus @ 40 kg/ha produced significantly highest number of pods/plant, number of seeds/pod, seed yield, straw yield and biological yield of chickpea over control and 20 kg/ha phosphorus and at par with 60 kg P₂O₅/ha phosphorus (Balai *et al.*, 2017).

Molybdenum is an important micro-nutrient leading to poor seed yield of pulses in molybdenum deficient soils. It is an essential component of the enzyme nitrate reductase, which catalyses the conversion of NO₃⁻ to NO₂⁻. Molybdenum is a structural component of enzyme nitrogenase which is actively involved in atmospheric nitrogen fixation by root nodule bacteria in leguminous crops. Molybdenum concentration in legume nodules can be 10 times higher than in leaves (Yadav *et al.*, 2017). It also acts in enzymes, which bring about oxidation reduction reaction, especially the reduction of nitrate to ammonia prior to amino acids and protein synthesis in the cells of plant. Molybdenum is essential for the process of symbiotic and non-symbiotic nitrogen fixation. Molybdenum is also known to have an indirect role in increasing the oxygen content and availability of oxygen for root growth, therefore, the higher leghaemoglobin content may be due to greater oxygen concentration in and around the root system. It increases the chlorophyll content in leaves, thereby increasing photosynthetic space in the plant. Therefore, deficiency of molybdenum is considered as one of the constraints in the optimum production of pulse crops (Liu *et al.*, 2020). Kumar and Sharma (2005) found that application of molybdenum @ 1.0 kg/ha, being at par with 1.5 kg Mo/ha, significantly

Table-1 : Effect of phosphorus and molybdenum on growth parameters of chickpea.

Treatments	Plant height (cm)		Dry matter accumulation (g/ plant)	
	80 DAS	120 DAS	80 DAS	120 DAS
Phosphorus (kg/ha)				
0	40.93	51.03	6.82	10.43
20	49.13	64.72	8.05	12.68
40	53.05	70.72	8.81	13.90
60	53.51	71.28	8.88	14.39
SEm $\pm$	1.29	1.84	0.22	0.35
CD (P=0.05)	3.77	5.39	0.64	1.02
Molybdenum (kg/ha)				
0	42.91	53.46	7.03	10.73
0.5	50.34	66.43	8.27	13.27
1.0	54.22	73.43	9.12	14.56
SEm $\pm$	1.11	1.59	0.19	0.30
CD (P=0.05)	3.27	4.67	0.56	0.89

Table-2 : Effect of phosphorus and molybdenum on yield attributes of chickpea.

Treatments	Yield attributes		
	Number of pods/plant	Number of seeds/pod	Test weight (g)
Phosphorus (kg/ha)			
0	24.63	1.49	145.52
20	28.42	1.79	149.82
40	31.44	1.99	152.03
60	31.64	2.01	153.93
SEm $\pm$	0.83	0.07	4.85
CD (P=0.05)	2.44	0.19	NS
Molybdenum (kg/ha)			
0	25.27	1.58	147.52
0.5	29.64	1.83	150.43
1.0	32.19	2.04	153.02
SEm $\pm$	0.72	0.06	4.20
CD (P=0.05)	2.11	0.17	NS

NS=Non-significant

Table-3 : Effect of phosphorus and molybdenum on yields of chickpea.

Treatments	Yield (kg/ha)			Harvest index (%)
	Seed	Straw	Biological	
Phosphorus (kg/ha)				
0	1648	2863	4512	36.42
20	1967	3273	5240	37.49
40	2192	3646	5838	37.53
60	2258	3762	6020	37.47
SEm ±	63	108	155	0.55
CD (P=0.05)	185	317	456	NS
Molybdenum (kg/ha)				
0	1704	2968	4672	36.40
0.5	2044	3413	5457	37.41
1.0	2300	3777	6078	37.87
SEm ±	55	94	135	0.48
CD (P=0.05)	160	274	395	NS

NS=Non-significant

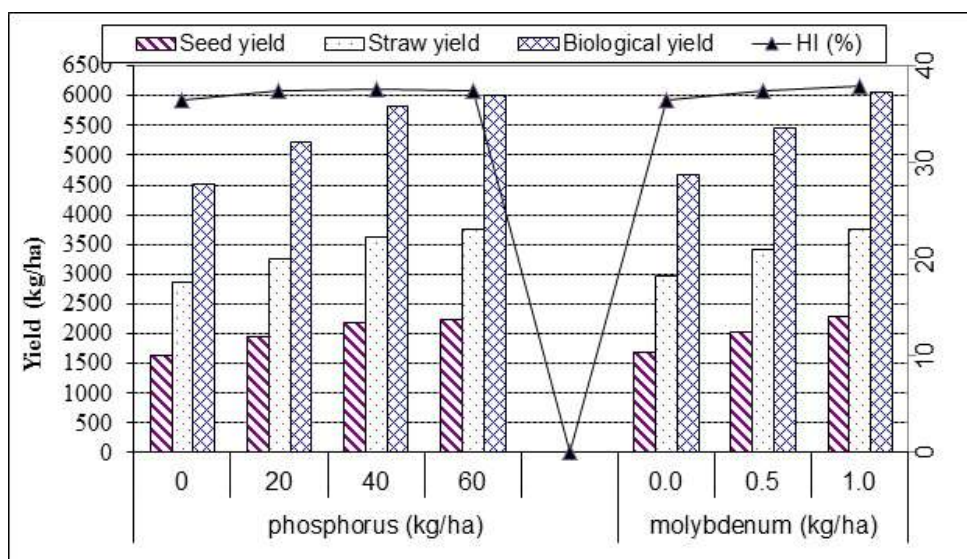


Fig.-1 : Effect of phosphorus and molybdenum on yields of chickpea.

increased the number of pods/plant, number of seeds/pod, test weight, seed and stover yield of chickpea over control and 0.5 kg/ha.

Materials and Methods

The experiment was conducted during *rabi* 2022-23 at Research Farm, School of Agriculture, Suresh Gyan Vihar University, Jaipur. The region's climate is typically semi-arid and marked by temperature extremes in both the summer and the winter. The temperature can go as high as 46°C in the summer and as low as - 1.0°C in the winter. The soil of experimental field contains low organic carbon (0.22%), available N (180.66 kg/ha), available phosphorus (21.08 kg/ha) and available potassium (245.23 kg/ha). Field experiment was laid out in factorial randomized block design with three replications by using four levels of Phosphorus (0, 20, 40 and 60 kg/ha) and 3 levels of Molybdenum (0, 0.5 and 1.0 kg/ha) thereby making 12 treatments combinations. The variety CSJ-515 of chickpea was sown in first week of November at a spacing of 30 cm × 10 cm by using recommended seed rate of 80 kg/ha. The recommended dose of fertilizer nitrogen (20 kg/ha) was applied through urea. The phosphorus and molybdenum was applied at the time of sowing through DAP and sodium molybdate as per treatment and mixed well in the soil. Five plants mean plot were selected and tagged to record the observation on growth and yield parameters. The data observed on different parameters were analyzed by following the standard procedure of analysis of variance technique as described by Gomez and Gomez (1984) at 5% level of significance.

Results and Discussion

The data presented in table-1, 2, 3 and fig.-1 results

showed that plant vegetative growth, yield attributes and yield of chickpea was considerably enhanced with the application of different levels of phosphorus and molybdenum.

Effect of Phosphorus : Graded levels of phosphorus application significantly increased the plant height and dry matter accumulation at different growth stages of crop. Significantly maximum plant height (53.51 and 71.28 cm at 80 and 120 DAS) and dry matter accumulation (8.88 and 14.39 g/plant at 80 and 120 DAS) was recorded with the application of phosphorus up to 60 kg/ha which was significant over 0 and 20 kg/ha but remained at par with 40 kg/ha. This increase in plant height and dry matter accumulation might be due to the better nutrients availability at the critical stage of crop which facilitates better nutrient transfer and accumulation of dry matter. These findings are in line with Singh *et al.* (2021).

Application of phosphorus up to 60 kg/ha gave significantly higher yield attributes such as number of pods per plant (31.64) and number of seeds per pod (2.01) as compared to 0 and 20 kg/ha phosphorus. However, it was at par with 40 kg/ha phosphorus. Considerable higher grain yield (2258 kg/ha), straw yield (3762 kg/ha) and biological yield (6020 kg/ha) was obtained with increasing level of phosphorus up to 60 kg/ha but statistically at par with 40 kg P₂O₅/ha. While, 40 kg phosphorus/ha also had significant effect over 0 and 20 kg/ha phosphorus. Test weight and harvest index was found non significant with graded levels of phosphorus. These attributes might be due to higher levels of inorganic fertilizers increasing efficiency of photosynthesis and activity of enzymes that is responsible for energy transformation. Rehan *et al.* (2018) also found similar results in their experiment. Thus, application of

phosphorus might have resulted in increased carbohydrate accumulation and their remobilization to reproductive parts of the plant, being the closest sink and hence, resulted in increased flowering, pod development and seed formation (Nadeem *et al.*, 2018).

Effect of Molybdenum : Results further showed that application of molybdenum @ 1.0 kg/ha significantly increased the plant height and dry matter accumulation at 80 and 120 DAS over control and 0.5 kg molybdenum/ha. Significantly maximum plant height of 54.22 and 73.43 cm and dry matter accumulation of 9.12 and 14.56 g/plant at 80 and 120 DAS was recorded respectively, with the application of molybdenum @ rate of 1.0 kg/ha. The significant improvement in these characters might also be due to the fact that molybdenum is a component of the enzyme nitrogenase which is essential for the process of symbiotic nitrogen fixation. It is also present in nitrate reductase which is responsible for the reduction of nitrates to ammonia prior to amino acid and protein synthesis in the plant cells causing better growth in terms of plant height and dry matter production (Ahmad *et al.*, 2021).

Yield attributes and yield of crop was improved with graded levels of molybdenum. Higher number of pods/plant (32.19) and number of seeds/pod (2.04) was recorded when 1.0 kg/ha molybdenum was applied and significant over lower levels of molybdenum. Significantly maximum seed yield (2300 kg/ha), straw yield (3777 kg/ha) and biological yield (6078 kg/ha) of chickpea were obtained with the increasing levels of molybdenum up to 1.0 kg/ha. However, it was significantly superior than 0 and 0.5 kg/ha. This might be due to its role in N-fixation and growth hormone metabolism. Molybdenum has unique role in enhancing nitrogen fixation thereby increasing its availability to the plants for efficient growth and development of plants in terms of photosynthetic area which enhanced the photosynthesis and synthesis of other metabolites for plant use (Liu *et al.* 2020). The positive influence on nutrient uptake appears to be due to improved growth and nutritional environment in plant system. The improvement in uptake of nutrients seems to be the fact that the uptake of nutrients is function of nutrient content and yield of the crop and increased crop yield also increases the uptake of nutrients in crop (Khan and Prakash 2013).

Conclusions

Based on one year experimentation, it was concluded that application of phosphorus up to 60 kg/ha and molybdenum @ 1.0 kg/ha improved crop growth and yield attributes and gave crop yields as compared to lower level of fertilizers. Hence, application of 40 kg/ha phosphorus and 1.0 kg/ha molybdenum is recommended for higher productivity of chickpea.

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Stability Analysis for Quality Parameters in Bread Wheat [*Triticum aestivum* (L.) em. Thell]

Manisha Kumari^{1*}, Hemlata Sharma¹, Amit Dadeech¹, Abhay Dashora¹ and Manisha Verma²

¹Department of Genetics and Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur-313001, Rajasthan

²Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur-313001, Rajasthan

*Corresponding Author's Email : manisha70b@gmail.com

Abstract

To estimate how stable the wheat's quality attributes were, a 10 x 10 diallel design with 45 crosses (not including reciprocals) was used. For Rabi 2020–21, a randomized block design was used to examine fifty-seven genotypes in three replications at three different locations. These genotypes consisted of ten parents, forty-five crosses, and two checks. When compared to G x E, the genotypic variance was found to be significant in a pooled analysis of variance spanning three environments. Bartlett's test also revealed homogeneity for the character total protein content in grains and total chlorophyll content. While the effects of the Environment (Linear) interaction were not significant, the G x E interaction partitioning revealed that G x E (L) was highly significant for this trait. Raj 4037, MP 1203, DBW 187, HD 3086, MP 3288, and MP 1203 are suitable for unfavorable environmental conditions, while Raj 3077 is best suited for favorable ones. In breeding programs designed to stabilize yield-contributing traits, the parents stated above can therefore be used.

Key words : *Diallel, bread wheat, stability analysis, quality attributes.*

Introduction

The most valuable and widely farmed food crop in most of the world is wheat (*Triticum aestivum* (L.) em. Thell), which is ranked second to rice in India. Ensuring food security, improving livelihoods, and reducing poverty all depend on this grain, which is regarded as having the highest nutritional value. *Triticum aestivum* L., the second staple crop in the world, supplies 20–40% of the minerals and 20% of the protein needed for human nutrition worldwide (Food and Agriculture Organization of the United Nations [FAO], 2019). It is anticipated that by 2030, India's growing population will require 100 million metric tonnes of wheat. 21.76 million hectares of wheat are planted in India, where it produces 109.52 million tonnes of product at a productivity of 3464 kg/ha (Annual Report of IIW&BR, 2022).

The means used in plant breeding are essential for changing the current circumstances. Plant breeders' first challenge is to select desirable parents with higher genetic potential for superior variety production. To overcome the yield barrier, hybridization is a crucial strategy. A well-thought-out and successful breeding program must begin with the identification of notable parents.

The genotype and its interactions with the environment are the primary factors affecting the final yield. The genotype x environment interaction plays a critical role in the expression of quantitative traits, which are highly influenced by environmental factors. The

primary objective of any breeding program is to increase yield stability and flexibility. The genotype under consideration exhibits stability, as demonstrated by the cultivars' uniform yields across diverse conditions. To create a genotype with the least amount of G x E interaction influence, two methods could be applied. The first step is to create a variety for a specific environmental condition; the second is to devise a way to more accurately deduce the G x E interaction while maintaining stability across a wide range of environmental conditions (Kaya *et al.*, 2006). Breeding researchers and biometricians have developed and proposed several stability analysis techniques for this reason. The most commonly used is the Eberhart and Russell (1966) method, which is based on various parameters with better genotype-resolving power for testing stability. When developing superior kinds, plant breeders consider the choice of attractive parents.

The objective of this research is to use a diallel mating design to estimate the stability analysis to understand the nature and extent of genotype x environment interactions for the total protein content in grains in bread wheat.

Materials and Methods

Two check varieties, Sonalika and HD 2967, as well as ten parents and their forty-five F1 crosses, made up the experimental materials. Half-diallel crossing ten parental genotypes resulted in 45 F1 offspring (without reciprocal). All 57 genotypes (10 parents, 45 crosses, and 2 checks)

Table-1 : Analysis of variance for stability (Eberhart and Russell, 1966) for quality parameters in bread wheat [*Triticum aestivum* (L.) em. Thell].

Character	Genotype	E+ (G x E)	E (L)	G x E (L)	Pool dev.	Pool Err
	[56]	[114]	[1]	[56]	[57]	[336]
Total protein content in grains	0.73**	0.16**	0.00	0.19**	0.13**	0.07

*, ** Significant at 5% and 1% level of significance, respectively.

were grown in Rabi 2020–21 in three different environments: the Rajasthan College of Agriculture, Udaipur (E1), the Instructional Farm, CTAE, Udaipur (E2), and Krishi Vigyan Kendra, Badgaon, Udaipur (E3). Three replications of a randomized complete block design were used. Every genotype was covered in a single-row plot that measured three meters. Plants were spaced 22.5 cm apart from one another, and rows were spaced 10 cm apart. An irrigated environment served as the setting for the experiment. Ten competitive plants were randomly chosen from each genotype in each replication, and observations were made on each plant for fifteen viz., days to 50 % flowering, days to 75 % maturity, plant height, number of effective tillers per plant, spike length, number of spikelets per plant, length of awns, number of grains per spike, flag leaf area, 1000-grains weight, biological yield per plant, grain yield per plant, harvest index, total proteins collected in grain and total chlorophyll collected in each of the three environmental conditions. The model proposed by Eberhart and Russell (1966) was used to estimate the phenotypic stability of genotypes for different characters having homogeneous error variance in different environments and the number of environments more than two. The mean ($\bar{y}$), regression coefficient (b_i), and mean squares due to deviation from linear regression (S^2_{di}) were computed as the three stability parameters. A particular genotype's stability is measured by deviation from regression, while linear regression is thought to be a measure of responsiveness. Based on regression coefficient (b_i), genotypes with non-significant S^2_{di} and higher per se performance were categorized. The genotypes with $b_i < 1$ (significantly less than 1) was identified for adverse environmental conditions, $b_i > 1$ (significantly higher than 1) for favourable environmental conditions and $b_i = 1$ for average or unpredictable environmental conditions. A genotype is considered to be stable in performance if it has high mean performance, unit regression coefficient ($b_i = 1$) and least deviation from regression ($S^2_{di} = 0$).

Results and Discussion

The pooled analysis of variance for stability exhibited that genotypes were found to be highly significant for total protein content in grains (%) character (homogenous according to Bartlett's test). The mean squares due to genotypes, E + (G x E) and G x E (L) were significant for

this trait, indicating that the environments were quite variable for the trait under study and the differential response of genotypes to all the environmental conditions (Table-1). Mohtasham *et al.*, (2014), Ferede (2016), Khuroo *et al.*, (2019), Thakur *et al.*, (2019), Balcha (2020) and Kshatri *et al.*, (2021) reported similar results. The estimates of stability parameters for total protein content in grains are presented in Table 2. For total protein content in grains, all 10 parents 41 crosses and 2 checks depicted non-significant deviation from regression (S^2_{di}) indicating their stability and predictability. Among these parents, one parent Raj 3077 showed a regression coefficient around unity ($b_i = 1$) with a higher mean value than the parental mean (11.26) indicating their suitability and stability of performance under average environments. Three parents viz., HD 3086, MP 3288 and DBW 187 expressed regression coefficient less than unity ($b_i < 1$) with high mean value than parental mean (11.26), indicating their suitability and stability to unfavourable environments. Raj 4037 and MP 1203 showed regression coefficients greater than one ($b_i > 1$) with a higher mean value than the parental mean (11.26), indicating their suitability and stability of performance in favourable environments.

Among the crosses, three crosses viz., HD 3086 x Raj 4079, Raj 4238 x Raj 3077 and Raj 4037 x HI 1544 depicted regression coefficients around unity ($b_i = 1$) with higher mean value than the average mean of crosses (11.40) and were identified as stable to all the environments for this trait. Ten crosses, viz., HD 3086 x MP 1203, Raj 4238 x HI 1544, Raj 4238 x MP 3288, Raj 3077 x Raj 4079, Raj 3077 x DBW 187, MP 1203 x Raj 4079, HI 1544 x Raj 4079, Raj 4079 x MP 3288, Raj 4079 x DBW 187 and MP 3288 x WR 544 showed regression coefficient less than one ($b_i < 1$) with high mean value than the average mean of crosses (11.40) indicating their suitability and stability to unfavourable environments. Seven crosses viz., HD 3086 x Raj 4037, HD 3086 x WR 544, Raj 4238 x MP 1203, Raj 4238 x WR 544, Raj 4238 x DBW 187, Raj 4037 x MP 3288 and MP 1203 x WR 544 showed regression coefficients greater than unity ($b_i > 1$) with low mean value than the average mean of crosses (11.40) indicating, their suitability and stability of performance under favourable environments. Sonalika expressed a regression coefficient greater than unity ($b_i > 1$) with a higher mean value than the mean value of

Table-2 : Stability parameters for total protein content in grains in bread wheat [*Triticum aestivum* (L.) em. Thell].

S. No.	Genotype	Total protein content in grains		
		μ_i	b_i	S^2d_i
1.	HD 3086	11.44	-0.10	0.016
2.	Raj 4238	10.31	-0.89	-0.054
3.	Raj 3077	11.26	1.10	0.026
4.	Raj 4037	11.60	1.18	0.109
5.	MP 1203	11.57	1.46	-0.061
6.	HI 1544	11.06	2.70	0.137
7.	Raj 4079	11.03	0.92	0.057
8.	MP 3288	11.94	0.50	-0.014
9.	WR 544	10.98	-0.09+	-0.066
10.	DBW 187	11.39	-0.23	-0.038
11.	HD 3086 x Raj 4238	11.25	-0.21	-0.050
12.	HD 3086 x Raj 3077	10.74	-0.57	-0.043
13.	HD 3086 x Raj 4037	12.06	3.05	0.019
14.	HD 3086 x MP 1203	11.54	0.79	-0.026
15.	HD 3086 x HI 1544	11.05	0.79	-0.008
16.	HD 3086 x Raj 4079	11.50	1.06*	-0.066
17.	HD 3086 x MP 3288	11.15	0.97	-0.054
18.	HD 3086 x WR 544	11.54	2.02**+	-0.066
19.	HD 3086 x DBW 187	11.26	2.03	0.017
20.	Raj 4238 x Raj 3077	11.46	0.97	-0.054
21.	Raj 4238 x Raj 4037	11.26	0.98	-0.029
22.	Raj 4238 x MP 1203	11.51	2.89	-0.049
23.	Raj 4238 x HI 1544	12.48	-0.02	-0.064
24.	Raj 4238 x Raj 4079	11.10	1.87	0.022
25.	Raj 4238 x MP 3288	11.77	0.76	-0.066
26.	Raj 4238 x WR 544	12.13	1.42*	-0.066
27.	Raj 4238 x DBW 187	11.59	1.95	-0.064
28.	Raj 3077 x Raj 4037	10.80	1.43*	-0.066
29.	Raj 3077 x MP 1203	11.08	1.01	-0.035
30.	Raj 3077 x HI 1544	10.68	0.04	-0.060
31.	Raj 3077 x Raj 4079	11.58	0.58	0.109
32.	Raj 3077 x MP 3288	11.04	0.33	-0.050
33.	Raj 3077 x WR 544	10.97	1.94	0.048
34.	Raj 3077 x DBW 187	11.96	0.52*+	-0.066
35.	Raj 4037 x MP 1203	11.14	3.18	-0.010
36.	Raj 4037 x HI 1544	11.85	0.97	-0.065
37.	Raj 4037 x Raj 4079	11.38	0.82	-0.019
38.	Raj 4037 x MP 3288	12.19	1.16	-0.062
39.	Raj 4037 x WR 544	11.26	-0.23	0.090
40.	Raj 4037 x DBW 187	11.69	0.73	0.744**
41.	MP 1203 x HI 1544	10.74	2.21**+	-0.066
42.	MP 1203 x Raj 4079	11.70	-0.12	-0.031
43.	MP 1203 x MP 3288	11.35	0.55	-0.028
44.	MP 1203 x WR 544	12.14	1.28	-0.057
45.	MP 1203 x DBW 187	10.51	0.54	0.124
46.	HI 1544 x Raj 4079	11.55	0.09+	-0.066
47.	HI 1544 x MP 3288	12.08	1.26	0.411**
48.	HI 1544 x WR 544	10.97	4.56	0.935**
49.	HI 1544 x DBW 187	10.79	-0.80	2.692**
50.	Raj 4079 x MP 3288	11.73	0.69	-0.044
51.	Raj 4079 x WR 544	11.16	0.67	-0.028
52.	Raj 4079 x DBW 187	12.42	0.18	-0.064
53.	MP 3288 x WR 544	11.45	0.18	0.018
54.	MP 3288 x DBW 187	10.55	0.22+	-0.066
55.	WR 544 x DBW 187	11.05	2.66	-0.040
56.	Sonalika	12.27	1.73	0.131
57.	HD2967	11.87	1.32	-0.061

*, ** and +, ++ significantly deviating from 0 and 1 at 5% and 1%, respectively

Table-3 : List of parents and crosses suitable for favourable, unfavourable and average environmental conditions in bread wheat [*Triticum aestivum* (L.) em. Thell] for total protein content in grains.

Characters	Parents			Crosses		
	< (Unfavourable)	~ (Variable)	> (Favourable)	< (Unfavourable)	~(Variable)	> (Favourable)
Total protein content in grains	HD 3086, MP 3288, DBW 187	Raj 3077	Raj 4037, MP 1203	HD 3086 x MP 1203, Raj 4238 x HI 1544, Raj 4238 x MP 3288, Raj 3077 x Raj 4079, Raj 3077 x DBW 187, MP 1203 x Raj 4079, HI 1544 x Raj 4079, Raj 4079 x MP 3288, Raj 4079 x DBW 187, MP 3288 x WR 544	HD 3086 x Raj 4079, Raj 4238 x Raj 3077, Raj 4037 x HI 1544	HD 3086 x Raj 4037, HD 3086 x WR 544, Raj 4238 x MP 1203, Raj 4238 x WR 544, Raj 4238 x DBW 187, Raj 4037 x MP 3288, MP 1203 x WR 544

checks (12.07) indicating, their suitability and stability of performance under favourable conditions.

Analysis of stability parameters of parents for total protein content in grains (%) expressed that among parents, HD 3086, MP 3288 and DBW 187 for total protein content in grains expressed regression coefficients less than one. Thus, all these parents would be suitable for unfavourable environmental conditions. Raj 4037 and MP 1203 for total protein content in grains were suitable for favourable conditions with regression coefficient values more than unity. Raj 3077 for total protein content in grains was observed to have a regression coefficient around unity so it may be utilized in variable environmental conditions (Table 3). Similar result trends were also shown by Siddhi *et al.*, (2018), Thakur *et al.*, (2019), Dhiwar *et al.*, (2020) Malav *et al.*, (2020) and Kshatri *et al.*, (2021).

Conclusions

HD 3086, MP 3288, DBW 187 for unfavourable, Raj 4037 and MP 1203 for favourable and Raj 3077 is suitable for variable environmental conditions. Therefore, above stated parents can be used in the breeding programmes aimed for the stability of yield contributing traits.

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Effect of Scion Age and Kinetin on Growth of Softwood Grafting in Mango Cv. Kesar

Shankar Lal Kumawat¹, K. M. Karetha¹, Chetna Shaktawat² and Salman Khan³

¹Department of Horticulture, College of Agriculture, Junagadh Agricultural University, Gujarat

²Department of Horticulture (Vegetable Science), JNKVV, Jabalpur, M.P.

³Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan

*Corresponding Author Email : kumawatshankarlal516@gmail.com

Abstract

The present investigation entitled “effect of scion age and kinetin on success rate of softwood grafting in mango cv. kesar” was carried out at Hi-Tech Horticulture Park, Department of Horticulture, Junagadh Agricultural University, Junagadh during the year 2020-21. The treatments comprised of eight level of scion age (S) viz., S1 = 90-100 day old scion, S2 = 100-110 day old scion, S3 = 110-120 day old scion, S4 = 120-130 day old scion, S5 = 130-140 day old scion, S6 = 140-150 day old scion, S7 = 150-160 day old scion, S8 = 160-170 day old scion and three level of kinetin (K) viz., K1 = kinetin 200 ppm, K2 = kinetin 250 ppm, K3 = kinetin 300 ppm. The experiment was laid out in Completely Randomized Design (CRD) with Factorial concept comprising twenty four treatment combinations with three replications. The results indication were Maximum number of nodes per graft (2.21 and 2.51) were recorded in S1 at 30 and 60 DAG, respectively and maximum number of nodes per graft (3.27 and 3.68) were recorded at 90 and 120 DAG in S5, respectively. Maximum number of leaves per graft (10.26 and 12.02) were recorded in S1 at 30 and 60 DAG, respectively. But maximum number of leaves per graft (12.94 and 13.62) were noted in S5 at 90 and 120 DAG, respectively. Maximum plant height (60.49, 62.58, 64.41 and 68.81 cm) were noted in S5 at 30, 60, 90 and 120 DAG, respectively. Maximum number of nodes per graft (1.78 and 3.63) was noted in K2 at 30 and 120 DAG, respectively. Maximum number of leaves per graft (9.64, 11.55, 12.58 and 13.13) were noted in K2 at 30, 60, 90 and 120 DAG, respectively. Maximum plant height (56.32, 59.06, 61.65 and 64.06 cm) were recorded in K2 at 30, 60, 90 and 120 DAG, respectively.

Key words : Mango, softwood grafting, scion age and kinetin.

Introduction

Mango (*Mangifera indica* L.) is the most popular fruit crop in the orient particularly in India, where it is considered as the best choice among all indigenous fruits. Mango is the most important commercially grown fruit crop. In India it's tropical and sub-tropical region and ever-green fruit crop which is considered as national fruit. It belongs to the botanical family Anacardiaceae and its origin of Indo-Burma region. Mango is claimed to be the most important tropical fruit and has been thought as ‘king of all fruits’ because of its attractive appearance and owing to its taste, attractive aroma and captivating flavor the very pleasant taste. The fruit is consumed as raw for pickle purpose or ripe fruit as dessert purpose. Good mango cultivars contain 20 per cent of total soluble solids content. It is an important fruit for fresh consumption as well as input for processing industries. Ripe mangoes contain moderate level of vitamin C, are rich in vitamin A, vitamins B₁ and B₂ and many essential minerals (Mukherjee and Litz, 2009). The protein content is generally a little higher than that of other fruits except the avocado. Mangoes are also a fairly good source of thiamine and niacin and contain some calcium and iron (Griesbach, 2003). It's excellent delicious taste and nutritive value.

Mango cultivars are classified into two types:

monoembryonic and polyembryonic. Monoembryony seed is the emergence of one and only one seedling from a seed. The former when propagated from seed do not come true to type, whereas the latter breeds true. Furthermore, the most important cultivars of mango in the world are monoembryonic. Polyembryonic mango varieties, produce two or more plants of nucellar origin from single seed. (Maheshwari and Rangaswamy., 1966). Hence, there is an urgent need to propagate them vegetatively (Majumder, 1988).

The two popular methods of vegetative propagation of mango, namely, budding and grafting are being used for the commercial mango propagation with varying degree of success. The mango propagation by the traditional approach grafting method is cumbersome and time taking. Mango is a commercial propagation by different rapid methods, like, cleft grafting, epicotyls grafting, side grafting, softwood grafting, splice and veneer grafting methods have been investigated by several research (Islam *et al.*, 2004; Pereira *et al.*, 2004; Kumar *et al.*, 2006; Nalage *et al.*, 2010; Sampath *et al.*, 2017; Ullah *et al.*, 2017). The method of soft-wood grafting is one of the simple, quick and inexpensive methods of vegetative propagation. Mango grafting has been investigated, in the recent past, employing the

soft-wood grafting, by a number of investigators (Prajapati *et al.*, 2014)

Plant growth regulators are the most important factors for successful plant regeneration. In tissue culture, cytokinins play a crucial role as promoters of cell division and act in the induction and development of meristematic centers leading to the formation of organs, mainly shoots (Peeters *et al.*, 199), (Kumawat *et al.*, 2021) The success of a graft union is dependent on the formation of a callus bridge between the cut surfaces of the scion and stock, followed by the formation of a working vascular cylinder linking the scion and stock (Mathad *et al.*, 1991). However there has been kinetin application in mango grafts. Thus, the present investigation “Effect of scion age and kinetin on growth of softwood grafting in mango cv. Kesar” was carried out the best scion age and kinetin treatment to increase the growth of softwood grafting in mango.

Materials and Methods

The present investigation was carried out at Hi-Tech Horticulture Park, Department of Horticulture, JAU, Junagadh during the year 2020-21. The treatments comprised of eight level of scion age (S) viz., S₁ = 90-100 day old scion, S₂ = 100-110 day old scion, S₃ = 110-120 day old scion, S₄ = 120-130 day old scion, S₅ = 130-140 day old scion, S₆ = 140-150 day old scion, S₇ = 150-160 day old scion, S₈ = 160 -170 day old scion and three level of kinetin (K) viz., K₁ = kinetin 200 ppm, K₂ = kinetin 250 ppm, K₃ = kinetin 300 ppm. The experiment was laid out in Completely Randomized Design (CRD) with Factorial concept comprising twenty four treatment combinations with three replications. Junagadh is situated in South Saurashtra Agro-climatic region of Gujarat state. Geographically, this place is situated at 21.5⁰C N latitude and 70.5⁰C E longitude with an altitude of 60 meters above the mean sea level and 75- 85kilometers away from Arabian Sea Coast on western side at the foothill of the mount Girnar. The grafting operation was done on 3 month old mango (cv. Rajapuri) rootstock seedlings.

Tagging of Scion on mother tree : We selected new branches on the tree for tagging. Tagging of scion was done on 16th March to 25th march for 160 -170 days old scion, 26th March to 4th April for 150-160 days old scion, 5th April to 14th April for 140-150 days old scion, 15th April to 24th April for 130-0140 days old scion, 25th April to 4th May for 120-130 days old scion, 5th May to 14th May for 110-120 days old scion, 15th May to 24th May for 100-110 days old scion and 25th May to 3th Jun for 90-100 days old scion Non-flowered terminal or lateral shoots with pencil thickness, greenish brown coloured mature and healthy scions were collected from Kesar variety of mango trees at Fruit Research Station, Sakkarbaug. Department of Horticulture. JAU, Junagadh. Defoliation of scion on

mother tree was done at 8-10 days prior to grafting. The petiole stubs dried up and dropped off when touched leaving a healed scar of defoliated scion sticks at this stage indicated that scion was ready for grafting. Unsprouted scion sticks with well-developed buds were detached from the selected mother tree in the morning on the day of grafting.

Method of softwood grafting : Rootstock was headedback at around 40 cm height from ground. A 4- 5 cm vertical cut was given in the centre of headed seedling to insert scion. Slant cut is given in both the sides of lower part of scion stick to make V- wedge shaped end which can fit into the slit made in rootstock. The cut was made before dipping in the kinetin. The scion stick was inserted into the vertical slit. The graft union should be as close as possible to ensure that the cambium layers of stock and scion were in perfect contact with each other. Then the graft union was tied tightly with the plastic wrapping film. The grafted plants were kept open field.

Observations recorded : The observations taken were viz., Number of nodes per graft (No.), number of leaves per graft (No). Plant height (cm) and Graft girth (cm) all parameters were recorded at 30, 60, 90 and 120 DAG. Various characters under study were statistically analyzed by using analysis of variance technique for Completely Randomized Design (CRD) with Factorial concept as described by Panse and Sukhatme (1985).

Results and Discussion

Number of node : There was significant influence of scion age on number of leaves maximum number of nodes per graft (2.21 and 2.51) at 30 and 60 DAG, respectively were noted in S₁ (90-100 day old scion) which was at par with S₅ at 60 DAG, respectively. On the other hand maximum number of nodes per graft (3.27 and 3.68) at 90 and 120 DAG, were noted in S₅ (130-140 day old scion) which was at par with S₁, S₇ and S₈ at 90 and at 120 DAG at par with S₁, S₂, S₃, and S₈. Minimum number of nodes per graft (1.31 and 1.71) at 30 and 60 DAG, respectively were noted in S₆ (140-150 day old scion). However, minimum number of nodes per graft (2.66 and 3.13) at 90 and 120 DAG were noted in S₃ (110-120 day old scion). Higher number of nodes might be due to higher carbohydrate content stored for flowering. Such grafts then produced more number of nodes and leaves. Minimum number of nodes might be due to low flow of cell sap. Similar results were recorded by Singh *et al.* (2018).

For kinetin on number of nodes per graft was observed significant at 30 and 120 DAG. Maximum number of nodes per graft (1.78 and 3.63) at 30 and 120 DAG, respectively were noted in K₂ (Kinetin 250 ppm) which was at par with K₁. Minimum number of nodes per

Table-1 : Effect of scion age and kinetin on number of nodes and number of leaves at 30, 60, 90 and 120 DAG.

Sr. No.	Treatments	Number of nodes				Number of leaves			
		30 DAG	60 DAG	90 DAG	120 DAG	30 DAG	60 DAG	90 DAG	120 DAG
A. Age of scion									
S ₁	90-100 day old scion	2.21	2.51	3.06	3.52	10.26	12.02	12.73	13.38
S ₂	100-110 day old scion	1.81	2.03	2.76	3.51	9.19	11.09	12.24	13.08
S ₃	110-120 day old scion	1.51	2.04	2.66	3.13	8.92	10.32	10.88	11.12
S ₄	120-130 day old scion	1.37	1.51	2.92	3.50	9.13	11.15	11.54	12.34
S ₅	130-140 day old scion	1.74	2.47	3.27	3.68	9.25	11.78	12.94	13.62
S ₆	140-150 day old scion	1.31	1.71	2.76	3.30	8.23	10.21	11.29	13.22
S ₇	150-160 day old scion	1.32	2.25	3.03	3.49	9.12	11.64	12.30	13.58
S ₈	160-170 day old scion	1.54	2.42	3.03	3.51	9.18	11.59	12.49	13.29
S.Em. +		0.08	0.12	0.11	0.10	0.35	0.36	0.33	0.44
C.D. at 5 %		0.23	0.33	0.30	0.28	1.00	1.04	0.93	1.25
B. Kinetin									
K ₁	Kinetin 200 ppm	1.54	2.13	2.87	3.51	9.02	11.36	12.05	13.08
K ₂	Kinetin 250 ppm	1.78	2.18	3.04	3.63	9.64	11.55	12.58	13.13
K ₃	Kinetin 300 ppm	1.50	2.05	2.90	3.23	8.82	10.76	11.53	12.65
S.Em. +		0.05	0.07	0.06	0.06	0.21	0.22	0.20	0.27
C.D. at 5 %		0.14	NS	NS	0.17	0.61	0.64	0.57	0.77

Table-2 : Effect of scion age and kinetin on plant height (cm) and graft girth (cm) at 30, 60, 90 and 120 DAG.

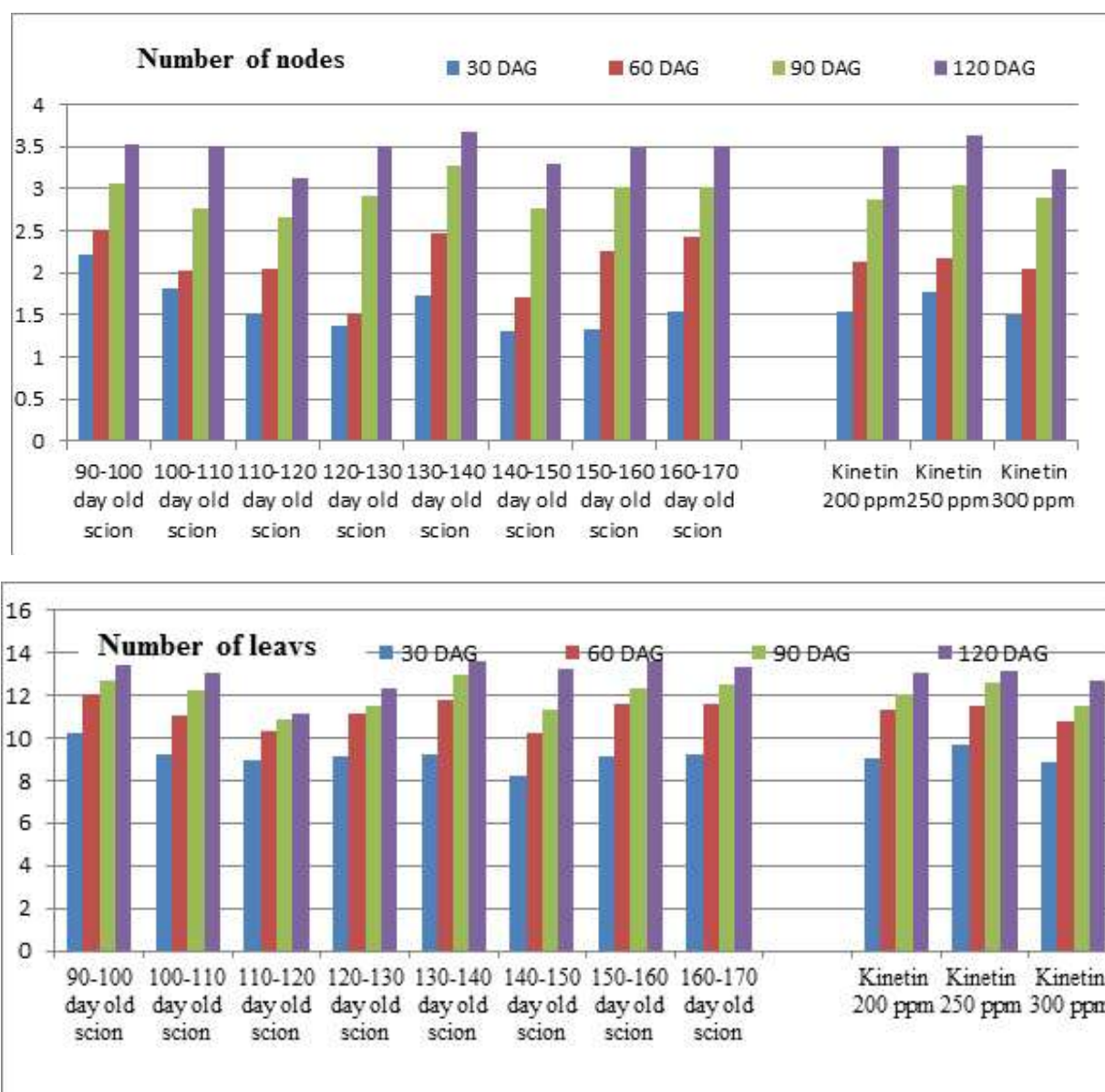
Sr. No.	Treatments		Plant height (cm)				Graft girth			
			30 DAG	60 DAG	90 DAG	120 DAG	30 DAG	60 DAG	90 DAG	120 DAG
A. Age of scion										
S ₁	90-100	day old scion	53.41	56.32	57.34	59.04	0.62	0.64	0.70	0.72
S ₂	100-110	day old scion	50.79	54.11	56.28	58.75	0.63	0.68	0.71	0.73
S ₃	110-120	day old scion	51.75	54.71	57.81	59.25	0.63	0.65	0.69	0.74
S ₄	120-130	day old scion	55.96	57.75	62.69	63.98	0.62	0.64	0.67	0.74
S ₅	130-140	day old scion	60.49	62.58	64.41	68.81	0.67	0.68	0.72	0.78
S ₆	140-150	day old scion	54.46	57.43	60.55	61.82	0.65	0.66	0.72	0.77
S ₇	150-160	day old scion	56.34	59.36	62.22	64.28	0.66	0.68	0.73	0.76
S ₈	160-170	day old scion	55.50	59.35	62.82	65.26	0.68	0.70	0.74	0.77
S.Em. +			0.67	0.52	0.79	0.62	0.01	0.01	0.01	0.01
C.D. at 5 %			1.90	1.47	2.24	1.76	0.03	0.02	0.03	0.03
B. Kinetin										
K ₁	Kinetin	200 ppm	54.95	57.56	60.82	62.61	0.64	0.67	0.71	0.75
K ₂	Kinetin	250 ppm	56.32	59.06	61.65	64.06	0.66	0.67	0.72	0.76
K ₃	Kinetin	300 ppm	53.25	56.48	59.08	61.27	0.64	0.66	0.69	0.74
S.Em. +			0.41	0.32	0.48	0.38	0.01	0.01	0.01	0.01
C.D. at 5 %			1.16	0.90	1.37	1.08	NS	NS	NS	NS

graft (1.50 and 3.23) at 30 and 120 DAG, respectively were noted in K₃ (Kinetin 300 ppm). Higher number of nodes might be due to kinetin play role in the vascular cell growth during growing period. Similar results were recorded by Keny (2005) in mango.

Number of leaves : There was significant influence of scion age maximum number of leaves per graft (10.26 and 12.02) at 30 and 60 DAG, respectively were noted in S₁ (90-100 day old scion) which was at par with S₅, S₇ and S₈ at 60 DAG. Whereas, maximum number of leaves per graft (12.94 and 13.62) at 90 and 120 DAG, were noted in S₅ (130-140 day old scion) which was at par with S₁, S₂, S₇

and S₈ at 90 and 120 DAG, respectively. Minimum number of leaves per graft (8.23 and 10.21) at 30 and 60 DAG, respectively were noted in S₆ (140-150 day old scion) and minimum number of leaves per graft (10.88 and 11.12) at 90 and 120 DAG, respectively were noted in S₃ (110-120 day old scion). It might be due to earlier sprouting, rapid growth of the shoot. On the other hand, quick and strong union formation and better nutrient uptake might have caused which led to the more number of leaves. Similar results were recorded by Karna and Varu (2017) in mango.

Significant influence of the kinetin was also recorded

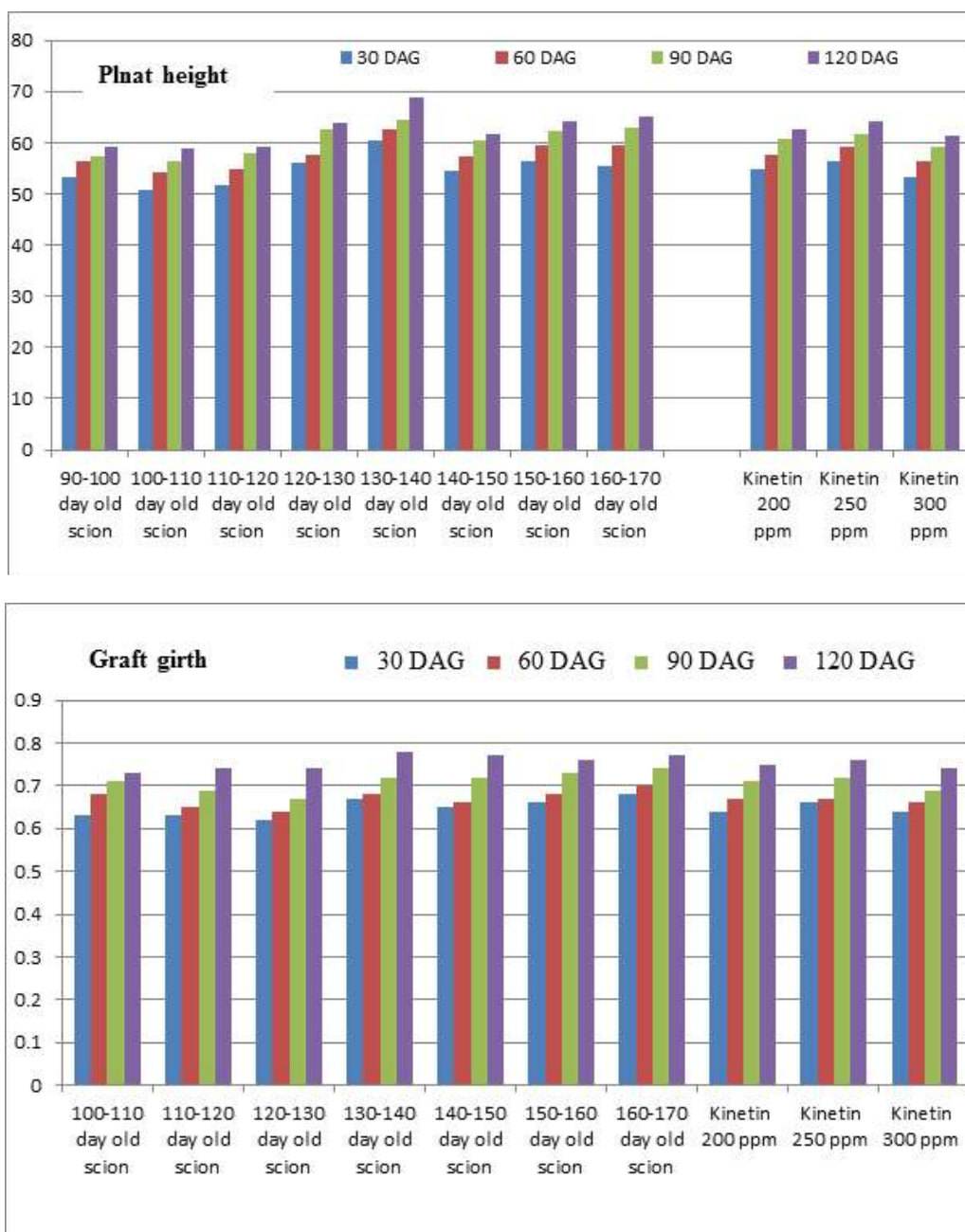


on number of leaves per graft. Significantly that maximum number of leaves per graft (9.64, 11.55, 12.58 and 13.13) at 30, 60, 90 and 120 DAG, respectively were noted in K_2 (Kinetin 250 ppm) which was at par with K_1 at 60, 90 and 120 DAG. Minimum number of leaves per graft (8.8, 10.76, 11.53 and 12.65) at 30, 60, 90 and 120 DAG, respectively were noted in K_3 (Kinetin 300 ppm). These results might be due to the ability of Kinetin (cytokine) to promote shoot growth by enhancing cell division and cell development at suitable concentration. This result is obtained by Siamaket *et al.* (2017) who have reported that kinetin (Cytokine) treatment in grapes grafting enhance the fresh and dry weight of leaves and also the photosynthetic activity and also similar result were recorded by Jenderek and Olney (1999).

Plant height (cm) : The result indicated significant that among scion that maximum plant height (60.49, 62.58,

64.41 and 68.81 cm) at 30, 60, 90 and 120 DAG, respectively were noted in S_5 (130-140 day old scion) which was at par with S_4 , S_7 and S_8 at 90 DAG. Minimum plant height (50.79, 54.11, 56.28 and 58.75 cm) at 30, 60, 90 and 120 DAG, respectively were noted in S_2 (100-110 day old scion). The growth of the plant gets enhanced and there is an increase in plant height growth. This might be due to that plant height positively correlated with number of leaves. The photosynthetic food produced by leaves was in turn utilized to continue the primary growth at a faster rate and resulted as higher plant height. Similar results were recorded by Tanuja and Thippesha (2018) in sapota.

Kinetin had significant effect on plant height maximum plant height (56.32, 59.06, 61.65 and 64.06 cm) at 30, 60, 90 and 120 DAG, respectively were noted in K_2



(Kinetin 250 ppm) which was at par with K_1 at 90 DAG. Minimum plant height (53.25, 56.48, 59.08 and 61.27 cm) at 30, 60, 90 and 120 DAG, respectively were noted in K_3 (Kinetin 300 ppm). When the cytokinin level increases in the plant (Kinetin) it promotes shoot growth. However, there has to be a balance between cytokinin and auxin levels for the proper plant growth. Hence, cytokinin application at optimum concentration can increase plant growth. This result is supported by Siamak *et al.* (2017) in grapes.

Graft girth (cm) : Effect of scion age on graft girth was observed significant at 30, 60, 90 and 120 DAG. The data presented in Table-2 revealed that maximum graft girth

(0.68, 0.70 and 0.74 cm) at 30, 60, and 90 DAG, respectively were noted in S8 (160-170 day old scion) which was at par with S5 and S7. However maximum graft girth (0.78 cm) at 120 DAG was noted in S5 (130-140 day old scion) which was at par with S6, S7 and S8. Minimum graft girth (0.62, 0.64 and 0.67 cm) at 30, 60 and 90 DAG, respectively were noted in S4 (120-130 day old scion). While Minimum graft girth (0.72 cm) at 120 DAG was noted in S1 (90-100 day old scion). This might be due to that more cambium contact between the cut portion of stock and scion that contributed in early callus development leading to quicker repair of broken cells resulting in early union development and thereby, increase in mass of volume diameter at union

(Adjoined). Maintained increased rate of growth in terms of girth of graft. The similar result obtained by Chander *et al.* (2016) in jamun. Effect of kinetin on graft girth was observed non-significant at 30, 60, 90 and 120 DAG.

Conclusions

From the results of present investigation, it can be concluded that use of 130-140 days old scion and dipped it in kinetin 250 ppm solution (S_5K_2), for 2 minutes before soft wood grafting of mango cv. Kesar on Rajapuri root stock observed maximum like number of nodes, number of leaves and plant height and graft girth were observed found effective with respect superior in enhancing parameters.

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Efficacy and Economics Evaluation of Insecticides against Rice Stem Borer (*Scirpophaga incertulas* Walker) in Rewa District of M.P.

J.P. Solanki¹, H.K. Trivedi² and V.K. Jain^{2*}

¹College of Agriculture, Rewa, JNKVV, Jabalpur, M.P.

²Krishi Vigyan Kendra, Ashoknagar, RVSKVV, Gwalior, M.P.

*Corresponding Author Email : jainv71.vk@gmail.com

Abstract

Rice is a monocotyledonous crop, belongs to the Family Poaceae and genus *Oryza* with two cultivated and 22 wild species. *Oryza sativa* and *Oryza glaberrima* are the main cultivated species. It is cultivated in about 161.5 million ha area in the world with a production of about 678.9 million tones and the productivity of 4.2 q/ha. The area and productivity of rice in India, Madhya Pradesh and Rewa is nearly 44.10, 1.76 and 0.236 million ha. and 29.80, 18.07 and 9.96 q/ha, respectively. The trail on the efficacy of insecticides against stem borer of rice had indicated the effectiveness of all insecticides against the pest, but variation in the effectiveness among insecticides was observed. Efficacy of insecticides had indicated that Chlorantraniliprole @ 30 g. a.i /ha was superior over rest of insecticides. It gave 83.21% less infestation of the pest after two spray (i.e. 30 and 50 DAT) of insecticides. In the present study, Quinalphos @ 250 g. a .i/ha was next in order of effectiveness after Chlorantraniliprole, which reduced the pest population by 72.72% and it was followed by Flubendamide (71.33% reduction).

Key words : Rice, insecticides, *Scirpophaga incertulas*

Introduction

Rice is a monocotyledonous crop, belongs to the Family Poaceae and genus *Oryza* with two cultivated & 22 wild species. *Oryza sativa* and *Oryza glaberrima* are the main cultivated species. Rice is one of the most important crop in the world, providing food for nearly half of the global population (FAO, 2004). It is also a key source of employment and income for rural people, who live in developing countries. It is grown under different agro climate and production systems. But, transplanting in puddled condition is the most common practice. China, India and Indonesia are major rice producing countries in the world. It is cultivated in about 161.5 million ha area in the world with a production of about 678.9 million tones and the productivity of 4.2 q/ha. The area and productivity of rice in India, Madhya Pradesh and Rewa is nearly 44.10, 1.76 and 0.236 million ha. and 29.80, 18.07 and 9.96 q/ha, respectively (Anonymous, 2013). The low productivity of the crop in the Rewa district is due to mainly by biotic stresses. Amongst them a larger number of insect pests in especially in tropical region is attacked by them right from the time of sowing till it is harvested. Dozen of them have been recognized as a key or major pest of the crop. Pests of rice have been grouped in various categories, based on their nature of damage like sucking pest which include Brown plant hopper (*Nilaparvata lugens*, Stal), White backed plant hoper (*Sogatella furcifera*, Horvath), Green leaf hoper (*Nephotettix nigropictus*, Stal) and the Gundhi bug (*Leptocorisa varicornis* Thumb.), the defoliator insect like

Grasshopper, Army worm Leaf folder, case worm, Two horned caterpillar & rice hispa etc. Rice stem borers are a key group of insect pest damaging rice crop. There are five species of stem borers distributed throughout India. Among these, yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) is the most wide spread, dominant and destructive.

Among the stem borers, the yellow stem borer, *Scirpophaga incertulas* (Walker), Lepidoptera: Pyralidae, is the most important pest of rice, particularly in lowland and deep-water rice. The pest attack all stages of the crop , tillers during the vegetative stage recognized as 'dead heart' and the panicle stage in the form of 'white ear head' (chaffy, unfilled grains). The pest population has been found influenced by *Chilo polychrysus* crop several environmental factors which determine the relative abundance of stem borer populations. The infestation of this pest on rice has also been reported from Rewa district and need its management to save the crop. Little work on this aspect have been done so far at the regional level but for the effective management of this pest studies related to population dynamics, effects of sowing/planting time, and efficacy of new molecules of insecticides against this pests need to the studied.

Materials and Methods

Rewa is situated under the sub-tropical zone of the north-eastern part of Madhya Pradesh, which is situated at 24° 31' and 88° 15' longitudes in the north and east, respectively, and on an altitude of 306.06 m above the

mean sea level (MSL). The average rain fall in the region varies between 1050 to 1250mm. The prevailing maximum and minimum temperature during Kharif 2015 season ranged between 34 to 38°C and 23 to 24°C respectively.

Experimental details

Design : Randomized Block Design (RBD)
Replication : 03
Treatments : 09

In this experiment 25 days old seeding was transplanted in the main plot spraying of insecticides were done on 30 & 50 days after transplanting of the crop. Number of dead heart/white ear head was counted one day before insecticides spray and there after 7 and 15 day of the treatment. In addition, the number of tillers per hill, Length of panicle, Number of grain per panicle, yield/ plot and Yield q/ha was also recorded and analyzed as per the design of the experiment. The cost benefit ratio was also calculated to find out the economics of the chemical control.

Methods of observation : Pre-treatment observation on number of dead heart or white ear head was recorded 24 hours before the spray of insecticides.

Assessment of stem borer infestation : The infestation of stem borer was assessed by counting the number of dead heart /white ear head and total number of tillers/hill on 10 randomly selected plants. The percentage of infestation was calculated by using the following formula.

Percent Dead heart

$$= \frac{\text{Number of dead hearts / white head}}{\text{Total number of tillers}} \times 100$$

Results and Discussion

The findings of the experiment entitled “Studies on population dynamics and efficacy of insecticides against rice stem borer (*Scirpophaga incertulas*, Walker) under agro ecosystem of Rewa districts” is presented in this chapter. The result deals with the population dynamics of rice stem borer and efficacy of different insecticides against it. The data on weekly population of insects, per cent infestation in different insecticide treatment, effect on number of tillers per hill, Length of panicle, number of grain per panicle, Yield/plot and Yield q/ha were also taken. The economics of different treatments of insecticide to control the stem borer in rice crop was also worked out. The data tabulated in table-1, indicate the efficacy of insecticides against rice stem borer. The pre-treatment population of stem borer was found non-significant in different treatments.

After first spray of insecticides, minimum dead heart was recorded, in all plots treated with insecticide over control after 7th day of the treatment. However, between insecticides Chlorantraniliprole gave minimum infestation (8.33%), but, there was a non-significant difference among Quinalphos, Flubendamide, Monocrotophos, Triazophos and Buprofezin. The highest per cent (17.33%) of the dead heart was noted in untreated control. The following order of efficacy of insecticide was observed in the descending order.

Chlorantraniliprole>Quinalphos>Flubendamide>Monocrotophos>Triazophos>Buprofezin>Dinotefuran>Acephate

Efficacy of insecticides after 15 days had indicated infestation level between 4.67 to 20.33 per cent in various treatments. Minimum per cent infestation (4.67 per cent) was recorded in the plot treated with Chlorantraniliprole which was at par with Quinalphos (5.67 per cent) and Flubendamide (6.0 percent). However Acephate was found less effective against the pest but was found superior over control. The efficacy of insecticides was found in the following descending order

Chlorantraniliprole>Quinalphos>Flubendamide>Monocrotophos>Triazophos>Buprofezin>Dinotefuran>Acephate

Over all insecticides were found effective against stem borer in rice crop but maximum control was recorded in plot treated with Chlorantraniliprole which was at par with Quinalphos and Flubendamide. The order of efficacy of insecticide in descending order was found as given below.

Chlorantraniliprole>Quinalphos>Flubendamide>Monocrotophos>Triazophos>Buprofezin>Dinotefuran>Acephate

Efficacy of insecticides after second spray : The number of dead hearts was same as on 15 days of first spraying as second spraying was done 20 days after first the spraying. So there were no change in number of dead hearts in the observation of before spray.

7 days after treatment : A progressive reduction in dead heart per cent was noted after 7 day of second treatment. The per cent dead heart varied between 5.33 to 12.33 in different treatments of insecticides as compared to control plot the lowest dead heart per cent (5.33 per cent) was noted in the plots whereas in control plot (25 per cent). The lowest dead heart per cent (5.33 per cent) was observed in insecticides, Chlorantraniliprole (T7) followed by Quinalphos. The Chlorantraniliprole and Flubendamide treatment was significantly superior over other insecticide. The efficacy of the insecticides in the descending order is given below :

Table-1 : Efficacy of insecticides against rice stem borer after 1st spray.

S. No.	Treatment	Dose of insecticide g.ai./ha	Formulation quantity (ml/gm./ha)	Per cent Infestation				Per cent reduction
				Before spray	7 days after treatment	15 days after treatment	Average	
T ₁	Quinalphos 25 EC	250	1000	13.00 (21.11)	9.33 (17.63)	5.67 (13.53)	7.50 (15.70)	60.16
T ₂	Flubendamide 39.35% SC (Fame)	48	122	14.33 (21.99)	10.00 (18.38)	6.00 (14.15)	8.00 (16.38)	57.51
T ₃	Triazophos 40 EC	320	800	15.00 (22.59)	11.33 (19.56)	8.33 (16.75)	9.83 (18.21)	47.79
T ₄	Dinotefuran 20 SG (Token)	40	200	13.33 (21.38)	12.67 (20.84)	10.67 (19.03)	11.67 (19.95)	38.02
T ₅	Buprofezin 25 % SC (Apploud)	200	800	14.00 (21.94)	12.33 (20.54)	9.67 (18.09)	11.00 (19.35)	41.58
T ₆	Acephate 75% SP	500	667	14.33 (22.24)	13.00 (21.12)	11.00 (19.36)	12.00 (20.26)	36.27
T ₇	Chlorantraniliprole 18.5 % SC (Coragen)	30	162	14.67 (22.42)	8.33 (16.74)	4.67 (12.28)	6.50 (14.68)	65.48
T ₈	Monocrotophos 36 WSC (Phoskil)	500	1390	12.67 (20.84)	11.00 (19.28)	8.00 (16.35)	9.50 (17.87)	49.54
T ₉	Untreated Control		Water spray	13.00 (21.11)	17.33 (24.53)	20.33 (26.73)	18.83 (25.65)	
	SE (m)±				NS	1.82	1.74	1.73
	CD at 5%				NS	3.86	3.68	3.67

Note : values in parenthesis are angular transformed value.

Table-2 : Efficacy in insecticides against rice stem borer after second spray.

S. No.	Treatment	Dose of insecticide g.ai./ha	Formulation quantity (ml/gm./ha)	Per cent Infestation				Per cent reduction
				Before spray	7 days after treatment	15 days after treatment	Average	
1.	Quinalphos 25 EC	250	1000	5.67 (13.53)	8.33 (16.69)	4.67 (12.36)	6.50 (14.68)	72.72
2.	Flubendamide 39.35% SC (Fame)	48	122	6.00 (14.15)	8.67 (16.96)	5.00 (12.88)	6.83 (15.05)	71.33
3.	Triazophos 40 EC	320	800	8.33 (16.75)	10.00 (18.39)	6.67 (14.78)	8.33 (16.74)	65.04
4.	Dinotefuran 20 SG (Token)	40	200	10.67 (19.03)	10.67 (19.05)	7.33 (15.49)	9.00 (17.42)	62.23
5.	Buprofezin 25 % SC (Apploud)	200	800	9.67 (18.09)	11.67 (19.97)	7.67 (15.95)	9.67 (18.10)	59.42
6.	Acephate 75% SP	500	667	11.00 (19.36)	12.33 (20.56)	9.67 (18.08)	11.00 (19.37)	53.83
7.	Chlorantraniliprole 18.5 % SC (Coragen)	30	162	4.67 (12.28)	5.33 (13.27)	2.67 (9.36)	4.00 (11.50)	83.21
8.	Monocrotophos 36 WSC (Phoskil)	500	1390	8.00 (16.35)	9.33 (17.77)	6.00 (14.05)	7.67 (16.05)	67.81
9.	Untreated Control		Water spray	20.33 (26.73)	22.67 (28.40)	25.00 (29.97)	23.83 (29.19)	-
	SE (m)±			1.74	1.50	1.92	1.33	-
	CD at 5%			3.68	3.17	4.07	2.82	-

Note : values in parenthesis are angular transformed value.

Chlorantraniliprole>Quinalphos>Flubendamide>Monocrotophos>Triazophos>Buprofezin>Dinotefuran>Acephate.

15 days after treatment : A further reduction in the per cent dead heart was recorded after 15 days of 2nd spraying with per cent dead heart 2.67 to 9.67 in various insecticide

treatments as against untreated control. The minimum dead heart infestation (2.67 per cent) was noted in treatment Chlorantraniliprole which was at par with Quinalphos and Flubendamide insecticides.

The order of efficacy in descending order was found as given below :

Chlorantraniliprole>Quinalphos>Flubendamide>Monocrotophos>Triazophos>Buprofezin>Dinotofuran>Acephate.

Though all insecticide were effective against the pest, but minimum infestation was observed in Chlorantraniliprole treated plot (T7) after 15 days of the 2nd spraying.

The trail on the efficacy of insecticides against stem borer of rice had indicated the effectiveness of all insecticides against the pest, but variation in the effectiveness among insecticides was observed. Efficacy of insecticides had indicated that Chlorantraniliprole @ 30 g.a.i/ha was superior over rest of insecticides. It gave 83.21% less infestation of the pest after two spray (i.e. 30 and 50 DAT) of insecticides Sarao and Kaur, 2014 have also reported Chlorantraniliprole @40 and 50 g.a.i/h as an effective insecticide against Rice stem borer. In the present study, Quinalphos @ 250 g.a.i/ha was next in order of effectiveness after Chlorantraniliprole, which reduced the pest population by 72.72% and it was followed by Flubendamide (71.33% reduction). Kalode and Krishnaiah, (1991) also reported the effectiveness of quinalphos as an effective against rice stem borer while effectiveness of Flubendamide against Rice stem borer has been reported by Ramudu and Misra, (2006).

Hence the effectiveness of Quinalphos Flubendamide against the stem borer in the present study is in the conformity of earlier work irrespective of location change. Monocrotophos, Acephate and Buprofezin in the doses of 500g.a.i, 500g.a.i & 200g.a.i/ha, respectively,

although were effective as compared to control; but the extent of control was less than 70%. However, contradictory to present finding Rath *et al*, (2010), have reported Monocrotophos @ 500g.a.i/h and Acephate 500g.a.i/h as a superior insecticide against the rice stem borer. Krishnaiah *et al*, (1996) reported Buprofezin @ 800 g.a.i/h as effective insecticide against the rice stem borer but in the present study only 59.42 per cent reduction in the pest infestation was obtained by two spray of this insecticide, further testing of Buprofezin under Rewa condition is required to ascertain its efficacy against rice stem borer; Perhaps, the prevailing drought condition would have adversely influenced the toxicity of this molecule of insecticide.

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Flock Characteristics of Nainwa Goat and Socio-Economic Analysis of Goat Keepers of Bundi District of Rajasthan

Lokesh Gupta¹, Shankar Lal², Siddhartha Mishra², S.K. Sharma³, Amit Kumar², Vinod Kumar², Mukesh Kumar Panchal² and Goatm Chopra²

¹CDFT, Udaipur, Rajasthan

²Department of Animal Production, RCA, MPUAT, Udaipur, Rajasthan

³Indian Council of Agricultural Research, New Delhi

Abstract

A survey was conducted in three tehsils of Bundi district, 240 goat keepers were interviewed during the survey to study socio economic conditions of the goat keepers. Flock characteristic of the goat flocks which are native of this region was also studied. A total of 5432 animals of different age groups were studied for phenotypic characters, body weight and measurements. Majority (80%) of the goat keepers had nuclear family type and were illiterate (67.92%). The main occupation of majority (81.25%) of the respondents was agriculture and animal husbandry. Majority (66.25%) of respondents were under medium income group, similarly about 75.83% respondents were under medium income group in income from goat. Majority (70.42%) of goat keepers had medium (0.26 to 6.4 bighas) land holding. The goat keepers in the study area had medium sized flock and proportion of doe and kids within flock under small, medium and large categories was higher as compared to buck. The origin of Nainwa goat was found to be in Nainwa, Hindoli and Bundi tehsils of Bundi district where the uniform Nainwa goat population was estimated to be about 170000. The majority (94.43%) colour pattern found in the animals were White with black, brown and tan small patches on face, neck, and ears. The head was slightly convex in majority (98.62%) of animals. Most (91.49%) of the animals were having medium sized cork screw horns pointed upwards. Ears in all the animals surveyed were pendulous and folded. Dewlap was present in majority of male (98.06%) and female (88.12%) animals. There is sizeable uniform Nainwa goat population in the native tract of the Nainwa goat which has unique, distinct and identifiable phenotypic traits.

Key words : Goat, nainwa, family, flocks, size, characterization.

Introduction

India is contributing 10.40% of total livestock in world and about 14.23% of which is contributed by goats. The maximum goat population state in India is Rajasthan followed by West Bengal (20th Livestock Census 2019).

Small ruminant sector is an integral part of Indian rural farming especially in the arid/semi-arid and mountainous areas. On an average, 15% of households in rural areas rear small ruminants across the country and around 70% of goat/sheep are reared by small and marginal farmers and landless labourers, playing an important role in their nutrition, supplementary income and livelihood security (BAHS, 2019). The goat sector alone contributes 8.5% to the India's livestock gross domestic product (GDP) and generates about 4.2% rural employment to the small, marginal farmers and landless labourers (Dixit *et al.*, 2014). Small ruminants play an important role in Indian economy and it provides livelihood to two-third of rural community. Sheep and goats are important species of livestock for India. They contribute greatly to the agrarian economy, especially in areas where crop and dairy farming are not economical, and play an important role in the livelihood of a large

proportion of small and marginal farmers and landless labourers.

Goat is a multi-use animal which is commonly reared for the meat (chevon). In the different parts of the world, goat is raised for the meat, milk, hair and leather. Goat is also called "the poor man's cow". Goats have been considered as poor man's cow because of its immense contribution in rural economy. Goat has been reared since the time immemorial. Goat keeping provides source of regular income to the poor, landless and marginal farmers. Generally, goat farming means rearing goats for the purpose of harvesting milk, meat and fibre. Goat farming has become a profitable business and it requires a very low investment.

The goats found in the south eastern part and it's marked the Aravalli range of Bundi district of Rajasthan are popularly known as Nainwa goat and the native tract is Nainwa, Hindoli and Bundi tehsil of Bundi district, and it is distributed in Tonk, Kota and Jhalawar district of Rajasthan. An exhaustive survey was conducted to study the socio-economic conditions of the goat keepers, morphometric traits of the animals, growth, reproduction and production performance of the animals at farmers field. The findings of the study pertaining to the

socio-economic conditions as well as morphometric traits are discussed in this research article.

Materials and Methods

A survey was conducted to study socio economic conditions of the goat keepers of Bundi district of Rajasthan. Out of six tehsils three tehsils namely Nainwa, Hindoli and Bundi tehsils of Bundi district were surveyed. A total of 240 farm households were surveyed during the survey. The respondents were interviewed with respect to various socio-economic parameters. In addition to socio economic conditions of the farmers, phenotypic traits, growth, production and reproductive traits of Nainwa goat in its native tract were also studied. An interview schedule was designed to include all the physical and production traits and was pre-tested in the field before actually conducting survey. Farmers in about 13 villages of Nainwa, Hindoli, and Bundi tehsil were approached with structured interview schedule to collect information on various aspects of Nainwa goat in the native tract. A total of 240 respondents were contacted and interacted with them on different traits.

Results and Discussion

Socio economic profile of goat keepers

1. Size and type of family : The survey was conducted to know the family type of the goat keepers; the family type was categorized as nuclear or joint family. A total of 240 respondents were interviewed and 192 (80%) respondents had nuclear family type while remaining 48 (20%) goat keepers has joint type family suggesting higher proportion of nuclear family as compared to joint family in the survey area (Table-1). (Bagri *et al.*, 2022)

2. Literacy rate : The literacy rate of the respondents was also studied in the survey area. Majority of respondents were illiterate (163, 67.92%) in the survey area, while 74 respondents (30.83%) were literate and very few farmers were in primary standard 3, (1.25%) in the survey area (Table-1). The goat keeper mainly belonged to Gurjar and Meena community which has lower literacy rate and are mainly engaged in animal husbandry occupation. (Bagri *et al.*, 2022)

3. Type of residence : The type of house was categorized as Kutcha, Pucca and mixed (Kutcha and Pucca) type houses and the information was collected from the respondents on type of houses. The result of survey revealed that as much as 174 respondents (72.50%) had mixed house while the numbers for Kutcha and Pucca type of houses were 26 (10.83%) and 40 (16.67%) respectively. The result indicated that majority of respondents had mixed type houses. (Gurjar *et al.*, 2021).

4. Occupation : The perusal of data revealed that out of

total 240 respondents, 195 respondents (81.25%) belonged to Agriculture + Animal Husbandry occupation while only 45 respondents (18.75%) had animal husbandry alone occupation. Further, within animal husbandry occupation (total 195 respondents) majority (135, 69.23%) reared only goat while remaining 60 respondents were rearing other species of livestock along with goat. (Table-1). (Bagri *et al.*, 2022).

5. Annual income : The annual income of the respondents was categorised as low, medium and high-income groups, the annual income up to Rs. 43277 was considered as low income, between Rs. 43277 to 132710 as medium and more than Rs. 132710 as high-income group. Majority (159, 66.25%) of respondents were under medium income group while 19.17% and 14.58% respondents were in low- and high-income groups respectively (Table-1). (Kumar, V. *et al.* 2019).

6. Income from goat : The income from goat rearing was also categorised as low, medium and high income, an annual income from goat rearing of Rs.28812 was categorised as low, Rs.28812 to 107774 as medium and above Rs.107774 as high annual income from goat. Again majority (182, 75.83%) respondents fell into medium income group in income from goat while 9.58% and 14.58% respondents were in low- and high-income group as far as income from goat rearing is concerned (Table-1). (Gurjar *et al.*, 2021).

7. Land holding : The respondents were categorised as landless, small, medium and large based on land holding. The respondents with no land were kept under landless, up to 0.26 bighas land as small, 0.26 to 6.40 bighas as medium and above 6.40 bighas land as large farmers. In the survey area 70.42% were medium group, 10.83% large, 10.42% landless and 8.33% respondents were small as per land holding (Table-1). (Bagri *et al.* 2022)

Flock characteristics of Nainwa goat : A total of 5425 animals of different age groups were surveyed in the entire area of Nainwa goat for phenotypic, productive and reproductive traits. The data with respect to growth and body conformation traits of 976 adult animals was collected including male and female. The findings of the survey on various aspects are broadly discussed as under in different heads.

I. Flock of Nainwa Goat

1. Flock size : On the basis of the flock size of goats the respondents were categorized into three groups viz: small (up to 12 goats), medium (13 to 40 goats) and large (above 40 goats) maximum number of farmers (147, 61.35%) were having medium flock size followed by small

Table-1 : Family type of respondents.

1. Family Type	F	%
Nuclear	192	80
Joint	48	20
Total	240	100
2. Literacy rate of respondents		
Illiterate	163	67.92
Literate	74	30.83
Primary	03	1.25
Total	240	100
3. Type of House		
Kutcha	26	10.83
Pucca	40	16.67
Mixed (Kutcha and Pucca)	174	72.50
Total	240	100
4. Occupation		
Agriculture alone	0	0.00
Animal Husbandry alone	45	18.75
Agriculture + Animal Husbandry	195	81.25
Among Animal Husbandry	-	-
Rearing Goat alone	135	69.23
Rearing other species of livestock along with goat	60	30.77
5. Annual Income		
Low income group (<43277)	23	09.58
Medium income (43277-132710)	182	75.83
High (> 132710)	35	14.58
Total	240	100
6. Income from goat		
Low income group (<28812)	23	09.58
Medium income (28812-107774)	182	75.83
High (>107774)	35	14.58
Total	240	100
7. Land Holding		
Landless	25	10.42
Small (<0.26)	20	8.33
Medium (0.26-6.40)	169	70.42
Large (>6.40)	26	10.83
Total	240	100

(63, 26.25%) and large (30, 12.50%) flock size (Table-2). (Bagdi, D. K. et al. 2022).

2. Number of animals : a total of 5425 Nainwa goat were characterized which were maintained by 240 goat keepers. Out of the total goats surveyed 3240 (59.72 %) were doe's (adult female), 307 (5.66%) were buck and 1878 (34.62%) were young stock (Table-2). (Bagdi, D. K. et al. 2022).

3. Composition of Young Stock: The young stocks were categorised in five groups based on their age group separately in male and female viz: 0-3 months, 3-6 months, 6-9 months, 9-12 months and above 12 months (Table: 2). Out of 1878 young stock 606 (32.27%) were

Table-2 : Flock characteristics of Nainwa Goat.

Parameter	N	%
1. Flock Size		
Small (up to 12 Goat)	63	26.25
Medium (13 to 40 Goat)	147	61.25
Large (above 40 Goat)	30	12.50
Total	240	100
2. Animal number		
Doe/ adult female	3240	59.72
Buck/ adult male	307	05.66
Young stock	1878	34.62
Total	5425	100
Composition of young stock		
0-3 months-Male	193	10.28
0-3 months-Female	202	10.76
3-6 months-Male	165	08.79
3-6 months-Female	275	14.64
6-9 months-Male	96	05.11
6-9 months-Female	187	09.96
9-12 months-Male	71	03.78
9-12 months-Female	262	13.95
Above 12 months-Males	81	04.31
Above 12 months-Females	346	18.42
Total		100
Composition of Flock		
1. Doe		
Small (< 4)	19	07.92
Medium (4-23)	186	77.50
Large (> 23)	35	14.58
Total	240	100
2. Buck		
Small (<1)	177	73.75
Medium (1-2)	50	20.83
Large (>2)	13	05.42
Total	240	100
3. Kids		
Small (< 3)	41	17.08
Medium (3-12)	173	72.08
Large (> 12)	26	10.83
Total	240	100

male and 1272 (67.73) were female. Proportions of males were low which may be due to sale of male kids up to 12 months of age. (Bagdi, D. K. et al. 2022).

4. Composition of flock: The flock composition in terms of number of doe, buck and kids of the different categories of the flocks were also studied. The percentage of doe's in small, medium and large flocks was 7.92, 77.50 and 14.58% respectively (Table-2). The compositions of bucks were 73.75, 20.83 and 5.42% in small medium and large flocks, respectively (Table-2). The kids in the small

Table-3 : Physical traits.

Particulars	N	%
Colour pattern		
White with black, brown and tan small patches on face, neck, and ears	5123	94.43
Half white and half black and tan	302	05.57
Total	5425	100
Profile of Head		
Straight	0	0.00
Convex	49	1.38
Slightly Convex	3498	98.62
Total	3547	100
Orientation of Horn		
Curved upward	0	0.00
Curved backward	0	0.00
Straight	0	0.00
Medium sized cork screw horns pointed upwards	3245	91.49
backward cork screw horns	302	8.51
Total	3547	100
Size of Horns		
Small (< 15 cm)	534	54.71
Medium (15-25 cm)	442	45.29
Large (> 25 cm)	0	0.00
Total	976	100
Ear Orientation		
Erect	0	0.00
Horizontal	0	0.00
Pendulous and folded	3547	100
Total	3547	100
Wattles		
Adult female		
Present (Nos.)	0	0
Absent (Nos.)	3240	100
Total	3240	100
Adult male		
Present (Nos.)	0	0
Absent (Nos.)	307	100
Total	307	100
Beard		
Adult female		
Present (Nos.)	0	0
absent (Nos.)	3240	100
Adult male		
Present (Nos.)	307	100
Absent (Nos.)	0	0.00
Dewlap		
Adult female		
Present (Nos.)	2855	88.12
Absent (Nos.)	385	11.88
Total	3240	100
Adult male		
Present (Nos.)	301	98.06
Absent (Nos.)	06	01.94
Total	307	100

medium and large flocks were 17.08, 72.08 and 10.83 % respectively (Table-2). (Bagdi, D. K. et al. 2022).

Physical Traits : The survey was conducted in three tehsils of Bundi district which inhabit the uniform Nainwa goat population in the area. A total of 5425 animals of different age groups and uniform phenotypic characteristics were surveyed in the entire area of Nainwa goat. The animals were studied for physical traits such as colour pattern, head profile, horn orientation, ear, wattles and beard. The phenotypic traits of Nainwa goat are discussed as under

1. Colour Pattern: the colour pattern found in the animals were White with black, brown and tan small patches on face, neck, and ears, majority (94.43%) of animals were white while 5.57% animals were half white and half black & tan (Table-3).

2. Profile of Head: The orientation of head was categorised as straight, convex or slightly convex, in majority (3498, 98.62%) of the animals the head profile was slightly convex. The data on profile of head of Nainwa goats revealed that all the goats were having Slightly Convex head which distinguished this breed from others (Table-3).

3. Horn Orientation: In the present survey it was found that maximum number 3245 (91.49%) of Nainwa goats were having Medium sized cork screw horns pointed upwards, whereas only 8.51 % (302) goats were having backward cork screw horns (Table-3). The characteristics of horn in terms of length were categorized into small (<15cm), medium (25 to 25cm) & large (>25cm) (Table-3). The lengths of horns were measured in 976 adult males & females only. Majority (54.71%) of goats were having small size horn and remaining 45.29% were having small sized horns. None of the goats were having large sized horns. The data revealed that Nainwa goats are of small to medium sized horns (Table-3).

4. Orientation of Ear: The characterizations of ears are categorized into erect, horizontal, pendulous with folded. The data on orientation of animals (Table-3) revealed that all the animals (100%) surveyed were having pendulous with folded ears.

5. Presence of Wattles: A total of 3240 adult female and 307 adult males were surveyed for presence of wattles. It was found that wattles were completely absent both in females and males (Table-3).

6. Presence of Beard: A total of 3240 adult female and 307 adult males were surveyed for presence of beard. It was found that wattles were completely absent in females and all males were found presence of beard (Table-3).

7. Presence of Dewlap: The dewlap was present in

88.12% adult females and absent in remaining 11.88 % females. The dewlap was present in majority of adult males 301, 98.06%) animals (Table-3).

The Nainwa goat is characterized by white body coat with black, brown or tan small patches in face, neck and ears, the colour pattern is unique phenotypic trait of the Nainwa goat. There is sizeable population of uniform colour pattern animals in the native tract of the Nainwa goat which is Nainwa, Hindoli and Bunditehsils of Bundi district. The colour pattern, orientation of head, horn character, wattles and beard are the unique features of Nainwa goat and majority of the animals in these three tehsils have uniform phenotypic character as observed in the surveyed area (Table – 3). Total goat population of Bundi district is 306938 (20th livestock census) while total goat population in the Nainwa, Hindoli and Bundi district was 79194, 121943 and 42020 (tehsil wise livestock census, Government of Rajasthan). the estimated population of Nainwa goat having uniform phenotypic characters was found to be about 170000. (Gupta, L. et al. 2023).

Conclusions

The survey was conducted with the aim of comprehensively documenting various attributes of the Nainwa goat breed. The findings of the survey reveal that goat keepers in the study area primarily maintained medium-sized flocks, and a notable prevalence of does and kids within the small, medium, and large categories, while the presence of bucks was comparatively lower. The origin of the Nainwa goat was traced to the Nainwa, Hindoli, and Bundi tehsils of Bundi district, where a relatively consistent Nainwa goat population of approximately 170,000 was estimated. The majority of these goats (94.43%) exhibited a characteristic color pattern characterized by white fur with small black, brown, and tan patches on their faces, necks, and ears. Regarding their physical characteristics, the majority of Nainwa goats displayed a slightly convex head structure (98.62%), and a significant proportion (91.49%) possessed medium-sized corkscrew-shaped horns that pointed upward. Notably, all surveyed animals had pendulous and folded ears. Furthermore, the presence of a dewlap was observed in the majority of male goats (98.06%) and a substantial proportion of female goats (88.12%). These observations collectively indicate the existence of a substantial and homogenous population of

Nainwa goats within their native habitat, which displays unique, distinct, and identifiable phenotypic traits. These distinctive features of the breed have garnered popularity and recognition among people across the country. The data presented in this survey holds significant value for the ongoing efforts aimed at further enhancing the Nainwa goat breed.

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Effect of Foliar Application of Nutrients on Yield, Nutrient Uptake, and Soil Chemical Properties of *Kharif* Onion on Entisol

M.S. Omji Nath*, A.S. Takate, Y.J. Patil, A.B. Rajguru and Sheetal Tatpurkar

Department of Soil Science and Agril. Chemistry, Mahatma Phule Krishi Vidyapeeth, Rahuri-413722, Maharashtra

*Corresponding Author Email : omjinath@gmail.com

Abstract

The present investigation was undertaken to study the effect of foliar-applied nutrients on nutrient uptake and soil available nutrient status after harvest of *Kharif* onion on Entisol during the year 2020-21. The field experiment was conducted at research farm of Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The higher uptake of nutrients and available N status in the soil after harvest of onion were found in the treatment application of GRDF + foliar application of 19:19:19 @ 1%. Interestingly supremacy in soil available phosphorus was found in the soil application GRDF + foliar sprays 0:52:34 @ 1%. The available potassium in the soil after harvest was found in the treatment application of GRDF+ foliar sprays of 0:0:50 @ 1%. The soil available B along with DTPA available Fe and Zn after harvest of onion significantly increased by application of GRDF + Foliar sprays of Micronutrients Grade II @ 1%.

Key words : Available nutrients, foliar application, nutrient uptake, onion.

Introduction

Onion (*Allium cepa* L.) belonging to the family Alliaceae, is one of the most important and popular vegetable as well as spice crop cultivated worldwide. It is a must-have in every kitchen and is used to improve the flavour of a variety of dishes. Hence, it is regarded as the “Queen of Kitchen”. It is high in calcium (180 mg 100 g⁻¹), phosphorus (50 mg 100 g⁻¹), iron (0.7 mg 100 g⁻¹), carbohydrates (11.0 g 100 g⁻¹), protein (1.2 g 100 g⁻¹), dietary fibre (0.6 g 100 g⁻¹), vitamin C (11 mg 100 g⁻¹), and many other minerals (0.4 g 100 g⁻¹). Onion has a strong flavour due to the presence of a sulfur-containing compound in a very small amount (about 0.005%) in the form of volatile oil, allyl propyl disulphide (C₆H₁₂O₂), which is responsible for the onion's distinctive smell and pungency. It also acts as a gastric stimulant and aids digestion¹⁴. In 2018, India ranked first in the area under onion cultivation with 14.31 lakh hectares under onion farming and ranked second in onion production with an output of 261.48 lakh tonnes, trailing only China. However, in comparison to the United States, China, Egypt, and many other nations, India's productivity in onion (18.3 t ha⁻¹) is significantly lower. Maharashtra is the leading producer of onion in India with an area of 2 lakh ha and production of 80.47 lakh tonnes with a productivity of 19.92 MT ha⁻².

Onions have shallow roots and high nutritional demand, as well as a prolonged growing season, hence they are susceptible to nutritional imbalances¹⁸. Nutrient management is one of the most essential aspects governing higher onion production in onion cultivation. A

balanced supply of nutrients is required to fully exploit the onion's higher yield potential. Foliar nutrients usually penetrate the cell through the cuticle (or) the stomata of the leaf. Foliar treatment thus gives an adequate opportunity for more effective nutrient absorption and speedy correction of deficiencies and aiding in the decrease of nutrient loss⁷. Hence, the present investigation was planned to study the effect of foliar-applied nutrients on soil chemical properties and nutrient uptake of *Kharif* onion on Entisol.

Materials and Methods

A field experiment was conducted at research farm of Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India, to study the effect of foliar-applied nutrients on nutrient uptake and soil available nutrient status after harvest of *Kharif* onion on Entisol, during the year 2020-21. The experimental plot is located between 19.34° N latitude, 74.64° E longitude and 569 m above mean sea level.

The experiment was laid out in a randomized block design, with nine treatments and three replications. The nine treatments were, i) Absolute Control, ii) GRDF (100 N : 50 P₂O₅ : 50 K₂O kg ha⁻¹ + FYM @ 20 t ha⁻¹), iii) GRDF + foliar spray of silicic acid @ 0.2% at 45 and 60 DAT. iv) GRDF+ foliar spray of 13:00:45 @ 1% at 45 and 60 DAT v) GRDF + foliar spray of 19:19:19 @ 1% at 45 and 60 DAT vi) GRDF + foliar spray 0:52:34 @ 1% at 45 and 60 DAT vii) GRDF+ foliar spray of 0:0:50 @ 1% at 45 and 60 DAT viii) GRDF+ foliar spray of Potassium schoenite @ 1% at 45 and 60 DAT ix) GRDF + foliar spray of Micronutrient Grade II @ 1% at 30 and 45 DAT. The

experimental soil was shallow, silty clay in texture belonging to the Phaltan soil series, order Entisol (*Typic Ustorthent*). The seedlings of onion cv. *Phule Samarth* were transplanted to the field by following a spacing of 15 cm × 10 cm. Soil and plant samples were processed in the laboratory and analyzed for various parameters by adopting standard analytical methods.

The data on parameters viz., yield, and yield contributing characters, chemical properties of soil, and nutrient uptake by onion were tabulated and analyzed statistically by the method described by Panse and Sukhatme (1985).

Results and Discussion

Yield Contributing Characters : The effect of foliar application of nutrients was significantly affected the average weight of the bulb, polar diameter, equatorial diameter, and neck thickness. (Table-3).

(i) Average Weight of Bulb : The significantly superior average weight of the bulb was recorded in the foliar application of 19:19:19 @ 1% at 45 and 60 DAT along with GRDF, which was 6.56% more than the application of GRDF+ Foliar sprays of 13:00:45 @ 1%. This increment is attributed to enhanced plants' internal balance of nutrient levels, resulting in greater sink assimilations⁶. These findings are in close agreement with those reported by Diwakar⁸ and Shinde *et al.*¹⁶

(ii) Equatorial Diameter : The equatorial diameter was also found to be higher in the application of foliar sprays of 19:19:19 @ 1% along with GRDF, as it recorded a 2.85% higher value than the application of GRDF + Foliar sprays 0:52:34 @ 1%. An increase in equatorial diameter may be attributed to the better utilization of photosynthates and increased allocation of photosynthates towards the storage organ, that is the onion bulb⁴. The results obtained are in close agreement with the observations recorded by Abd El-Samad *et al.*¹ and Deshmukh *et al.*⁶

(iii) Polar Diameter : The mean polar diameter has been reported as improved by the application of foliar sprays of 19:19:19 @ 1% at 45 and 60 DAT along with GRDF, which was 2.50% and 3.15% higher value than with applications of GRDF + Foliar sprays 0:52:34 @ 1% and GRDF + Foliar sprays of 13:00:45 @ 1%, respectively. Such an increment is due to bulbs accumulated with more carbohydrates, resulting in increased diameter (Deshmukh *et al.*, 2019). These results are in close agreement with those of Abd El-Samad *et al.*¹, Diwakar⁸, and Shinde *et al.*¹⁶

(iv) Neck thickness : Maximum neck thickness was recorded in the treatment of foliar sprays of 19:19:19 @ 1% at 45 and 60 DAT along with GRDF, which was a

3.00% higher value than GRDF+ Foliar sprays of 13:00:45 @ 1%. This increase may be due to adequate availability of easily water-soluble nutrients resulting in increased growth and succulency of neck of onion bulbs.

Bulb and straw yield

Application of foliar sprays of 19:19:19 @ 1% at 45 and 60 DAT along with GRDF recorded significantly higher bulb yield (19.8% higher than the application of GRDF alone) and straw yield (18.3% higher than the application of GRDF alone) (Table 2). The availability of nitrogen from foliar spray stimulates photosynthetic activity. Better utilization of photosynthates and greater allocation of photosynthates to economically important parts were associated with higher bulb growth¹². These results of the present investigation were in very close agreement with Bhalekar *et al.*³, Mehta *et al.*¹² and Deshmukh *et al.*⁶

Nutrient uptake

Total nutrient uptake of N, P, K, S and micronutrients viz., Fe, Mn, Zn, Cu, and B also improved significantly by foliar application of 19:19:19 @ 1% at 45 and 60 DAT (Table 3 and 4). This might be because of addition of nutrients through foliar sprays of 19:19:19 @ 1% at 45 and 60 DAT are readily available to the onion which is reflected in higher yields and hence, the higher nitrogen uptake, which further enhanced root growth, anchoring, and deep penetration, which in turn absorbed more nutrients from the rhizosphere and supplied them to the crop, resulting in higher nutrient content in dry matter¹³. Similar observations were also recorded by El- Bassiony⁹, Kumar *et al.*¹¹, and Charbaji *et al.*⁵

Chemical properties of soil

pH, EC, and Organic carbon : The results revealed that the pH, EC, and organic carbon of soil after harvest were found to be non-significant.

Available nitrogen : The data of available N content (Table-5) of the soil was significantly influenced by different foliar applications of nutrients. Available nitrogen was found higher in the application of foliar sprays of 19:19:19 @ 1% at 45 and 60 DAT along with GRDF which was superior over the rest of the treatments, followed by application of GRDF+ Foliar sprays of 13:00:45 @ 1% at 45 and 60 DAT, both of the treatments are at par. The nitrogen supplied through the foliar application during critical stages of growth (45 and 60 DAT) resulted in a slight decrease in N uptake from the soil. These results conform with the earlier findings of Fouda¹⁰, Prajwal Kumar *et al.*¹³, and Prusty *et al.*¹⁵

Available phosphorus : The soil's available phosphorus content at harvest was significantly influenced by the foliar application of nutrients. The maximum soil available

Table-1 : Effect of foliar application of nutrients on yield contributing characters of *Kharif* onion at harvest.

Tr. No.	Treatment	The average weight of the bulb (g)	Polar diameter (cm)	Equatorial diameter (cm)	Neck thickness (mm)
T ₁	Absolute control	49.78	4.03	4.26	10.1
T ₂	GRDF (100:50:50 N:P ₂ O ₅ :K ₂ O kg ha ⁻¹ + 20 t ha ⁻¹ FYM)	52.47	4.86	5.23	11.4
T ₃	GRDF + Foliar sprays of silicic acid @ 0.2%	54.45	4.98	5.61	12.2
T ₄	GRDF+ Foliar sprays of 13:00:45 @1%	61.43	5.21	5.93	13.4
T ₅	GRDF + Foliar sprays of 19:19:19 @ 1%	65.52	5.38	6.13	13.8
T ₆	GRDF + Foliar sprays 0:52:34@ 1%	60.74	5.25	5.96	13.1
T ₇	GRDF+ Foliar sprays of 0:0:50 @ 1%	58.12	5.11	5.69	12.2
T ₈	GRDF+ Foliar sprays of Potassium schoenite @ 1%	57.24	5.19	5.76	12.4
T ₉	GRDF + Foliar sprays of Micronutrients Grade II @1%	55.45	5.07	5.46	12.3
	SE (m) ±	1.25	0.05	0.04	0.09
	CD at 5%	3.8	0.17	0.14	0.3

Table-2 : Effect of foliar application of nutrients on bulb and straw yield of *Kharif* onion on Entisol.

Tr. No.	Treatment	Yield	
		Bulb (t ha ⁻¹)	Straw (q ha ⁻¹)
T ₁	Absolute control	13.76	10.78
T ₂	GRDF (100:50: 50 N: P ₂ O ₅ : K ₂ O kg ha ⁻¹ + 20 t ha ⁻¹ FYM)	19.66	13.33
T ₃	GRDF + Foliar sprays of silicic acid @ 0.2%	19.87	13.54
T ₄	GRDF + Foliar sprays of 13:00:45 @1%	22.06	14.29
T ₅	GRDF + Foliar sprays of 19:19:19 @ 1%	23.57	15.77
T ₆	GRDF + Foliar sprays 0:52:34 @ 1%	22.25	14.45
T ₇	GRDF + Foliar sprays of 0:0:50 @ 1%	20.91	13.84
T ₈	GRDF+ Foliar sprays of Potassium schoenite @ 1%	21.46	14.08
T ₉	GRDF + Foliar sprays of Micronutrients Grade II @1%	20.30	13.71
	SE(m) ±	0.43	0.32
	CD at 5%	1.29	0.94

Table-3 : Effect of foliar application of nutrients on total nutrient uptake of *Kharif* onion at Harvest.

Tr. No.	Treatment	Total nutrient uptake (kg ha ⁻¹)			
		Nitrogen	Phosphorus	Potassium	Sulfur
T ₁	Absolute control	29.24	11.00	33.43	11.70
T ₂	GRDF (100:50:50 N:P ₂ O ₅ :K ₂ O kg ha ⁻¹ + 20 t ha ⁻¹ FYM)	40.43	15.32	46.29	16.71
T ₃	GRDF + Foliar sprays of silicic acid @ 0.2%	40.90	15.49	46.82	16.89
T ₄	GRDF + Foliar sprays of 13:00:45 @1%	44.93	17.05	51.46	18.75
T ₅	GRDF + Foliar sprays of 19:19:19 @ 1%	48.33	18.32	55.34	20.03
T ₆	GRDF + Foliar sprays 0:52:34@ 1%	45.34	17.21	51.92	18.91
T ₇	GRDF + Foliar sprays of 0:0:50 @1%	42.77	16.22	48.98	17.77
T ₈	GRDF+ Foliar sprays of Potassium schoenite @ 1%	43.82	16.62	50.18	18.24
T ₉	GRDF + Foliar sprays of Micronutrients Grade I @1%	41.71	15.80	47.75	17.26
	SE(m) ±	0.75	0.29	0.87	0.36
	CD at 5%	2.26	0.88	2.6	1.09

Table-4 : Effect of foliar application of nutrients on total micronutrient uptake of *Kharif* onion at harvest.

Tr. No.	Treatment	Total micronutrient uptake (g ha ⁻¹)				
		Fe	Mn	Zn	Cu	B
T ₁	Absolute control	936	281	257	94	88
T ₂	GRDF (100:50:50 N:P ₂ O ₅ :K ₂ O kg ha ⁻¹ + 20 t ha ⁻¹ FYM)	1337	401	368	134	125
T ₃	GRDF + Foliar sprays of silicic acid @ 0.2%	1351	405	372	135	127
T ₄	GRDF+ Foliar sprays of 13:00:45 @1%	1500	450	413	150	141
T ₅	GRDF + Foliar sprays of 19:19:19 @ 1%	1603	481	441	160	150
T ₆	GRDF + Foliar sprays 0:52:34@ 1%	1513	454	416	150	141
T ₇	GRDF+ Foliar sprays of 0:0:50 @ 1%	1422	426	391	142	133
T ₈	GRDF+ Foliar sprays of Potassium schoenite @ 1%	1459	438	401	146	137
T ₉	GRDF + Foliar sprays of Micronutrients Grade II @1%	1380	414	380	138	129
	SE(m) ±	29.00	9.00	8.00	8.00	2.73
	CD at 5%	87.00	26.00	26.00	24.00	8.19

Table-5 : Effect of foliar application of nutrients on soil available nitrogen, phosphorus potassium, and sulfur at harvest of *Kharif* onion.

Tr. No.	Treatment	Available nutrients (kg ha ⁻¹)			
		Nitrogen	Phosphorus	Potassium	Sulfur
T ₁	Absolute control	137.3	12.48	316.6	10.67
T ₂	GRDF (100:50: 50 N: P ₂ O ₅ : K ₂ O kg ha ⁻¹ + 20 t ha ⁻¹ FYM)	154.3	15.00	348.6	11.54
T ₃	GRDF + Foliar sprays of silicic acid @ 0.2%	156.7	15.40	349.7	11.73
T ₄	GRDF+ Foliar sprays of 13:00:45 @1%	163.0	15.23	353.1	12.15
T ₅	GRDF + Foliar sprays of 19:19:19 @ 1%	164.6	15.62	356.5	12.26
T ₆	GRDF + Foliar sprays 0:52:34@ 1%	158.9	16.26	355.2	12.31
T ₇	GRDF+ Foliar sprays of 0:0:50 @ 1%	159.7	15.42	361.5	12.31
T ₈	GRDF+ Foliar sprays of potassium schoenite @ 1%	158.4	15.63	351.3	12.35
T ₉	GRDF + Foliar sprays of Micronutrients Grade II @1%	157.2	15.38	347.1	11.82
	SE (m) ±	1.22	0.23	3.92	0.106
	CD at 5%	3.7	0.7	11.52	0.48
	Initial status	161.42	15.46	355.4	13.05

Table-6 : Effect of foliar application of nutrients on DTPA-micronutrient and soil available boron at harvest of *Kharif* onion.

Tr. No.	Treatment	DTPA- micronutrients (mg kg ⁻¹)				Boron (mg kg ⁻¹)
		Fe	Mn	Zn	Cu	
T ₁	Absolute control	3.72	7.99	0.27	0.94	0.19
T ₂	GRDF (100:50: 50 N: P ₂ O ₅ : K ₂ O kg ha ⁻¹ + 20 t ha ⁻¹ FYM)	4.08	10.52	0.51	1.24	0.30
T ₃	GRDF + Foliar sprays of silicic acid @ 0.2%	4.00	10.33	0.49	1.22	0.27
T ₄	GRDF+ Foliar sprays of 13:00:45 @1%	4.01	10.07	0.48	1.09	0.26
T ₅	GRDF + Foliar sprays of 19:19:19 @ 1%	3.99	10.02	0.43	1.04	0.22
T ₆	GRDF + Foliar sprays 0:52:34@ 1%	4.02	10.19	0.45	1.07	0.24
T ₇	GRDF+ Foliar sprays of 0:0:50 @ 1%	4.05	10.25	0.49	1.17	0.30
T ₈	GRDF+ Foliar sprays of Potassium schoenite @ 1%	4.06	9.79	0.50	1.14	0.28
T ₉	GRDF + Foliar sprays of Micronutrients Grade II @ 1%	4.12	10.88	0.57	1.20	0.34
	SE(m) ±	0.013	0.57	0.01	0.07	0.015
	CD at 5%	0.04	NS	0.03	NS	0.04
	Initial value	4.13	10.54	0.54	0.34	0.29

phosphorus was found in the application of GRDF + Foliar sprays 0:52:34 @ 1% at 45 and 60 DAT, which is superior to the rest of the treatments followed by GRDF + Foliar sprays 19:19:19 @ 1% at 45 and 60 DAT both treatments were at par (Table 5). The foliar application of 0:52:34 during critical stages of growth (45 and 60 DAT) resulted in a slight decrease in P uptake from the soil. These results are confirm with the earlier findings of Prajwal Kumar *et al.*¹³ and Prusty *et al.*¹⁵

Available Potassium : The effects of foliar application of nutrients on soil available potassium at harvest of onion were significant. Higher soil available potassium after harvest of onion was found in application of GRDF+ Foliar sprays of 0:0:50 @ 1% at 45 and 60 DAT followed by GRDF + Foliar sprays 0:52:34 @ 1% at 45 and 60 DAT, GRDF + Foliar sprays of 19:19:19 @ 1% at 45 and 60 DAT, GRDF+ Foliar sprays of 13:00:45 @ 1% at 45 and 60 DAT and GRDF+ Foliar sprays of Potassium schoenite @ 1% at 45 and 60 DAT all these treatments are at par (Table 5). The application of potassium-containing foliar fertilizers during critical stages of growth (45 and 60 DAT) resulted in a slight improvement in the soil's available K status after the harvest of onion.

Available Sulphur : Higher soil available sulphur after harvest of onion was found in application of GRDF + Foliar sprays of Potassium schoenite @ 1% at 45 and 60 DAT followed by applications of GRDF + Foliar sprays of 0:0:50 @ 1% at 45 and 60 DAT, GRDF + Foliar sprays 0:52:34 @ 1% at 45 and 60 DAT, GRDF + Foliar sprays of 19:19:19 @ 1% at 45 and 60 DAT and GRDF+ Foliar sprays of 13:00:45 @ 1% at 45 and 60 DAT all these treatments are found to be at par (Table 5). The sulfur supplied through the foliar application of different fertilizer grades during critical stages of growth results in a slight improvement in available S status in soil. This was in line with the earlier findings of Fouda¹⁰ and Prajwal Kumar *et al.*¹³.

DTPA micronutrients and available B : The DTPA available Fe and Zn after harvest of onion (Table 6) significantly increased (4.13 mg kg⁻¹ and 0.55 mg kg⁻¹, respectively) after harvest of onion in the application of GRDF + Foliar sprays of Micronutrients Grade II @ 1% at 30 and 45 DAT. Application of GRDF + Foliar sprays of Micronutrients Grade II @ 1% at 30 and 45 DAT also showed the highest soil available boron (0.34 mg kg⁻¹) after harvest of onion. DTPA available Cu in the soil after harvest of the onion was found to be non-significant. The foliar application of Micronutrients Grade II @ 1% at 30 and 45 DAT slightly increased the available B content of the soil. Foliar spray of Micronutrients Grade II contains different micronutrients that satisfy the need of the plants' critical growth stages (30 and 45 DAT). It leads to slightly less uptake of DTPA micronutrients available of B from the

soil after the harvest of onion. These results are in close conformity with the previous works of Surve¹⁷.

Conclusions

In general, it is concluded that the application of 19:19:19 @ 1% at 45 and 60 DAT along with GRDF (100:50:50 N: P₂O₅: K₂O kg ha⁻¹ + 20 t ha⁻¹ FYM) was found beneficial for an increase in yield and yield contributing characters, uptake of nutrients, maintain the fertility status of soil and higher net monetary returns of *Kharif* onion grown on Entisol.

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Effect of Nutrients and NAA on Phenological and Morphological Traits

N.R. Rangare*, S.K. Pandey and T.R. Sharma

Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur, Madhya Pradesh, India

*Corresponding Author Email : nrrangare@gmail.com

Abstract

The present investigation entitled “Effect of Nutrients and Naphthalene acetic acid on Phenological and morphological Traits” was conducted at Fruit Research Station, Imalia farm, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidhyalaya, Jabalpur (M.P.) during the year 2017-18 and 2018-19. Mango tree of variety Langra and Amrapali were selected. Urea (2%, 4%), Borex (.2%, 0.5%), zinc sulphate(.2%, 0.5%) and NAA (100ppm, 200ppm) were sprayed at first week of October and 50% lowering stage. Result revealed that the in first year first panicle emergence was observed during 19 to 31 January in treatments V2N2D1 and V2N2D2, 50% panicle emergence minimum (6) days were recorded in V1N2D2, maximum (10) days were observed in V1N1D1, V1N1D2, opening of first flower earliest (11th February) V2N2D2, later date of opening of flower V1N1D1 on 25th February. 50% flowering from opening of first flower maximum (15) days in V2N1D1, initial fruit set 18 Feb to 7 March in V2N2D2. At 2nd Year floral bud initiation (16th December) V1N2D2, first panicle (12th January) V1N2D2, 50% panicle emergence minimum of (07) days V2N2D1, opening of first flower (5th February) V1N2D2, 50% flowering from opening of first flower (16) days V2N1D1, initial fruit set (15th February) V1N2D2 and the highest percentage of hermaphrodite flower, lowest percentage of male flower and highest sex ratio (74.14%, 25.86% and 2.873) observed in variety Langra (V1), with respect to nutrients. The maximum fruit set percent at Initial stage (18.00%) was recorded with variety Langra. and Pea, marble and maturity stage (3.83%, 0.72% and 0.51%), respectively noted in variety Amrapali, while the yield of fruit (kg plant⁻¹) and yield of fruit (t/ha) (60.32kg plant⁻¹ and 6.03t/ha) were noted in variety Langra.

Key words : Mango, langra, amrapali, urea, NAA, B, Zn

Introduction

Mango one of the important member of the family Anacardiaceae is originated from Indo-Burma region and favorite fruit of the tropical region after citrus and banana (Merwad *et al.*, 2016, Sahoo *et al.*, 2014). Mango occupies a pre-eminent place amongst the fruit crops grown in India and is acknowledged as the king of the fruit. It is an evergreen tree bearing numerous branches. Inflorescence of mango is panicles which are grown terminally. Mango is andro-monoecious *i.e.* each inflorescence bears both hermaphrodite and staminate flowers (Bose *et al.*, 2000, Yeshitela *et al.*, 2003). The highly mango producing states are Andhra Pradesh, Uttar Pradesh Bihar, and Maharashtra. In M.P, total area under mango cultivation comes around 0.252 mha with a total production of 3.76 MT (Singh *et al.*, 2014). According to horticulturist, only application of primary nutrients could not produce high quality fruit in mango trees, the application of micronutrients is compulsory as well. Foliar application of micronutrients may be 6 to 12 times more effective than soil application. Nutrients are key elements in plants growth, development and play important role in improving pollen germination, fruit set, number of fruit per tree and subsequently yield. Boron, Zn and Urea deficiencies are more probable early in the season because the translocation of elements from the root to the

above ground portion may not be adequate before leaf expansion (Neilsen *et al.*, 2004).

It has been demonstrated that plant nutrition, in particular the amount of N, plays a crucial role in regular orchard management since it influences fruit quality and growth more than any other single plant nutrient (Mandal *et al.*, 2015). The two most crucial nutrients for plant growth and development, pollen germination, and pollen tube elongation are zinc and boron. Growth regulators have proven to be effective when applied as foliar sprays to promote growth, enhance flowering, fruiting, and quality (Lal *et al.*, 2013, Jain *et al.*, 2017, Lal and Das, 2017). They can also be used to synchronize bloom, alter the timing of flowering to avoid unfavorable weather conditions, enhance fruit set, lessen floral malformation, and decrease fruit drop to boost yield. But the greatest amount of fruiting, flowering, and fruit per tree. However, maximum flowering, fruiting, and number of fruits/tree were recorded under combined application of 4 per cent urea and 150 ppm NAA (Baghel and Tiwari 2003).

Materials and Methods

The investigation deals with the “Effect of Nutrients and Naphthalene acetic acid on Phenological and morphological Traits”. For this a field experiment was conducted at Fruit Research Station, Department of Horticulture and the chemical analysis of fruits was done

in the laboratory of the Department of Food Science and Technology, JNKVV, Jabalpur (M.P.) during the year 2017-18 and 2018-19.

Mode of Application

Spraying on trees canopy as a foliar feeding : Using the foot sprayer, the tree canopy was sprayed. Five lit. of solution was thought to be adequate for tree spraying. Therefore, the necessary amounts of growth regulators and micronutrients were dissolved in water to create the five-liter solution of therapy that was needed.

Ten shoots were tagged randomly and date on which floral bud emerged was recorded as date of floral bud initiation. Ten shoots were tagged randomly and date on which first panicle emerged from bud was recorded as date of first panicle emergence. Number of days counted between date of first panicle emergence and 50% emergence of panicle. Ten panicles were tagged randomly and date on which first flower open was recorded as date of first flower. Number of days counted between date of first flower and 50 % of panicle flower. Ten panicles were tagged randomly and date on which fruit set was recorded as date of initial fruit set. Number of male flower was counted and percent mal flower was calculated over the total number of flower. Number hermaphrodite of perfect flower was counted and per cent hermaphrodite flower were calculated over the total number of flower. Ratio of hermaphrodite and staminate flower was calculated with help of formula.

Results and Discussion

The data presented in Table-2 indicates that the first panicle emergence was observed during 19 to 31 January under imposed treatments. The earliest (19th January) panicle emergence was noted in treatments V2N2D1 and V2N2D2, whereas, later date of panicle emergence in treatments V1N1D1 and V1N1D2 were recorded on 31st January.

The 50% panicle emergence period ranged from 6 to 10 days. The minimum (6) days were recorded in treatments V1N2D2, V2N2D1 and V2N2D2 while maximum (10) days were observed in V1N1D1, V1N1D2 and V1N5D1 as shown in Table-2.

Table-3 shows that the opening of first flower was observed during 11 to 25 February in imposed treatments. The earliest (11th February) opening of first flower was noted under V2N2D2 treatment, whereas, later date of opening of flower was recorded in V1N1D1 and V1N1D2 treatments on 25th February.

The 50% flowering from opening of first flower ranged from 12 to 15 days. The maximum (15) days were recorded in treatment V2N1D1, V1N1D2 and V2N5D1

while minimum (12) days were recorded in treatments V2N2D1 and V2N2D2 as shown in Table-3.

The data presented in Table-2 showed that the initial fruit set was observed during 18 Feb to 7 March in imposed treatments. The earliest (18th February) fruit set was noted in treatments V2N2D2. While, treatments V1N1D1 and V1N1D2 was recorded on 7th March.

The data presented in Table-4 showed that the floral bud initiation was observed during 16/12/2018 to 02/01/2019 in imposed the treatments. The earliest (16th December) panicle bud initiation was noted in V1N2D2 treatment whereas; treatments V2N1D1, V2N1D2, V2N5D1 and V2N5D2 were recorded on 2nd January.

The data presented in Table-4 indicates that the first panicle emergence was observed during 12 to 28 January under imposed the treatments. The earliest (12th January) panicle emergence was noted under V1N2D2 treatment. Whereas, treatments V2N1D1, V2N1D2, V2N5D1 and V2N5D2 it was recorded on 28th January.

The 50% panicle emergence period ranged from 7 to 10 days. The minimum of (07) days were recorded in treatment V2N2D1 and V2N2D2 while maximum (10) days were observed in treatments V1N1D1, V1N1D2, V1N3D1, V1N4D1, and V1N5D1 as shown in Table-4.

Table-5 shows that the opening of first flower was observed during 5 to 23 February. The earliest (5th February) opening of flower was noted in treatment V1N2D2, while, later date of first flower opening were recorded under the treatments V1N1D1, V1N1D2, V2N5D1 and V2N5D2 on 23th February.

The 50% flowering from opening of first flower ranged from 12 to 16 days. The maximum (16) days were recorded in treatments V2N1D1, V2N1D2 and V2N5D1 while minimum (12) days were recorded in treatments V2N2D1 and V2N2D2 as shown in Table-5.

The data presented in Table-5 showed that the initial fruit set was observed during 15th Feb to 4th March in the treatments. The earliest (15th February) fruit set was noted in treatment V1N2D2. While, later date of fruit set was noted in treatments V2N1D1, V2N1D2, V2N5D1 and V2N5D2 on 4th March.

Hermaphrodite flower (%), Male flower (%), Hermaphrodite and male flower sex ratio (%) : The percentage of hermaphrodite, male flower and sex ratio (Table-6,7,8) significantly influenced by nutrients and NAA, the highest percentage of hermaphrodite flower, lowest percentage of male flower and highest sex ratio (74.14%,25.86% and 2.873) observed in variety Langra (V1), with respect to nutrients the highest percentage of hermaphrodite flower, lowest percentage of male flower

Table-2 : Effect of nutrients and naphthalene acetic acid on date of floral bud initiation, date of first panicle Emergence and days to 50% panicle emergence (2017-18).

Treatments Symbol	Treatment	Date of floral bud initiation	Date of first panicle Emergence	Days to 50% panicle Emergence
V1N1D1	Tap water	03/01/2018	31/01/2018	10
V1N1D2	Distilled water	03/01/2018	31/01/2018	10
V1N2D1	Urea 2%	31/12/2017	26/01/2018	07
V1N2D2	Urea 4%	31/12/2017	26/01/2018	06
V1N3D1	Borex 0.2%	01/01/2018	28/01/2018	09
V1N3D2	Borex 0.5%	01/01/2018	28/01/2018	08
V1N4D1	Zinc sulphate 0.2%	01/01/2018	28/01/2018	09
V1N4D2	Zinc sulphate 0.5%	01/01/2018	28/01/2018	08
V1N5D1	NAA 100 ppm	02/01/2018	30/01/2018	10
V1N5D2	NAA 200 ppm	02/01/2018	29/01/2018	09
V2N1D1	Tap water	29/12/2017	24/01/2018	09
V2N1D2	Distilled water	29/12/2017	24/01/2018	09
V2N2D1	Urea 2%	26/12/2017	19/01/2018	06
V2N2D2	Urea 4%	26/12/2017	19/01/2018	06
V2N3D1	Borex 0.2%	27/12/2017	21/01/2018	08
V2N3D2	Borex 0.5%	27/12/2017	21/01/2018	07
V2N4D1	Zinc sulphate 0.2%	27/12/2017	21/01/2018	08
V2N4D2	Zinc sulphate 0.5%	27/12/2017	21/01/2018	07
V2N5D1	NAA 100 ppm	29/12/2017	24/01/2018	09
V2N5D2	NAA 200 ppm	28/12/2017	22/01/2018	08

Table-3 : Effect of nutrients and naphthalene acetic acid on date of first flower, days to 50% flowering and date of initial fruit set.

Treatments Symbol	Treatments	Date of first Flower	Days to 50% flowering	Date of initiation of Fruit set
V1N1D1	Tap water	25/02/2018	14	07/03/2018
V1N1D2	Distilled water	25/02/2018	14	07/03/2018
V1N2D1	Urea 2%	18/02/2018	14	27/02/2018
V1N2D2	Urea 4%	18/02/2018	14	27/02/2018
V1N3D1	Borex 0.2%	21/02/2018	14	01/03/2018
V1N3D2	Borex 0.5%	20/02/2018	14	24/02/2018
V1N4D1	Zinc sulphate 0.2%	21/02/2018	14	01/03/2018
V1N4D2	Zinc sulphate 0.5%	20/02/2018	14	24/02/2018
V1N5D1	NAA 100 ppm	24/02/2018	14	06/03/2018
V1N5D2	NAA 200 ppm	22/02/2018	14	02/03/2018
V2N1D1	Tap water	19/02/2018	15	27/02/2018
V2N1D2	Distilled water	19/02/2018	15	27/02/2018
V2N2D1	Urea 2%	12/02/2018	12	20/02/2018
V2N2D2	Urea 4%	11/02/2018	12	18/02/2018
V2N3D1	Borex 0.2%	15/02/2018	13	23/02/2018
V2N3D2	Borex 0.5%	14/02/2018	13	22/02/2018
V2N4D1	Zinc sulphate 0.2%	15/02/2018	14	23/02/2018
V2N4D2	Zinc sulphate 0.5%	14/02/2018	13	22/02/2018
V2N5D1	NAA 100 ppm	19/02/2018	15	27/02/2018
V2N5D2	NAA 200 ppm	16/02/2018	14	24/02/2018

Table-4 : Effect of nutrients and naphthalene acetic acid on date of floral bud initiation, date of first panicle emergence and days to 50% panicle emergence (2018-19).

Treatments Symbol	Treatments	Date of floral bud initiation	Date of first panicle Emergence	Days to 50% panicle Emergence
V1N1D1	Tap water	19/12/2018	16/01/2019	10
V1N1D2	Distilled water	19/12/2018	16/01/2019	10
V1N2D1	Urea 2%	17/12/2018	13/01/2019	09
V1N2D2	Urea 4%	16/12/2018	12/01/2019	08
V1N3D1	Borex 0.2%	18/12/2018	15/01/2019	10
V1N3D2	Borex 0.5%	18/12/2018	14/01/2019	09
V1N4D1	Zinc sulphate 0.2%	18/12/2018	15/01/2019	10
V1N4D2	Zinc sulphate 0.5%	18/12/2018	14/01/2019	09
V1N5D1	NAA 100 ppm	19/12/2018	16/01/2019	10
V1N5D2	NAA 200 ppm	19/12/2018	16/01/2019	10
V2N1D1	Tap water	02/01/2019	28/01/2019	08
V2N1D2	Distilled water	02/01/2019	28/01/2019	08
V2N2D1	Urea 2%	31/12/2018	24/01/2019	07
V2N2D2	Urea 4%	30/12/2018	23/01/2019	07
V2N3D1	Borex 0.2%	01/01/2019	26/01/2019	08
V2N3D2	Borex 0.5%	01/01/2019	26/01/2019	08
V2N4D1	Zinc sulphate 0.2%	01/01/2019	26/01/2019	08
V2N4D2	Zinc sulphate 0.5%	01/01/2019	26/01/2019	08
V2N5D1	NAA 100 ppm	02/01/2019	28/01/2019	08
V2N5D2	NAA 200 ppm	02/01/2019	28/01/2019	08

Table-5 : Effect of nutrients and naphthalene acetic acid on date of first flower, days to 50% flowering and date of initial fruit set.

Treatments Symbol	Treatments	Date of first Flower	Days to 50% flowering	Date of initiation of Fruit set
V1N1D1	Tap water	11/02/2019	15	23/02/2019
V1N1D2	Distilled water	11/02/2019	15	23/02/2019
V1N2D1	Urea 2%	07/02/2019	13	17/02/2019
V1N2D2	Urea 4%	05/02/2019	15	15/02/2019
V1N3D1	Borex 0.2%	10/02/2019	15	21/02/2019
V1N3D2	Borex 0.5%	08/02/2019	15	18/02/2019
V1N4D1	Zinc sulphate 0.2%	10/02/2019	15	21/02/2019
V1N4D2	Zinc sulphate 0.5%	08/02/2019	15	18/02/2019
V1N5D1	NAA 100 ppm	11/02/2019	15	23/02/2019
V1N5D2	NAA 200 ppm	11/02/2019	15	23/02/2019
V2N1D1	Tap water	23/02/2019	16	04/03/2019
V2N1D2	Distilled water	23/02/2019	16	04/03/2019
V2N2D1	Urea 2%	18/02/2019	12	26/02/2019
V2N2D2	Urea 4%	16/02/2019	12	24/02/2019
V2N3D1	Borex 0.2%	20/02/2019	14	28/02/2019
V2N3D2	Borex 0.5%	20/02/2019	14	28/02/2019
V2N4D1	Zinc sulphate 0.2%	21/02/2019	15	02/03/2019
V2N4D2	Zinc sulphate 0.5%	20/02/2019	14	28/02/2019
V2N5D1	NAA 100 ppm	23/02/2019	16	04/03/2019
V2N5D2	NAA 200 ppm	23/02/2019	15	04/03/2019

Table-6 : Effect of nutrients and naphthalene acetic acid on hermaphrodite flower (%).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	73.01	31.44	52.23	52.76	51.70	52.23
Urea (N2)	75.48	38.74	57.11	56.46	57.75	57.11
Borex (N3)	74.07	37.88	55.98	55.61	56.35	55.98
Zinc sulphate (N4)	74.04	36.61	55.33	54.64	56.01	55.33
NAA (N5)	74.10	35.14	54.62	54.36	54.88	54.62
Mean	74.14	35.96		54.77	55.34	
	Varieties					
Doses	V1	V2	Mean			
D1	73.84	35.69	54.77			
D2	74.44	36.23	55.34			
Mean	74.14	35.96				
	SEm±	CD at 5%				
Variety (V)	0.04	0.12				
Nutrients (N)	0.04	0.12				
Doses (D)	0.03	0.09				
(V×N)	0.06	0.17				
(N×D)	0.07	0.20				
(V×D)	0.04	NS				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	73.37	74.79	73.58	73.53	73.94	32.15	38.13	37.63	35.75	34.78
D2	72.65	76.16	74.56	74.56	74.26	30.74	39.34	38.13	37.46	35.49
			SEm±					CD at 5%		
V × N × D			0.10					0.28		

Table-7 : Effect of nutrients and naphthalene acetic acid on male flower (%).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	26.99	68.56	47.77	47.24	48.30	47.77
Urea (N2)	24.52	61.26	42.89	43.54	42.25	42.89
Borex (N3)	25.93	62.12	44.02	44.39	43.65	44.02
Zinc sulphate (N4)	25.96	63.39	44.67	45.36	43.99	44.67
NAA (N5)	25.90	64.86	45.38	45.64	45.12	45.38
Mean	25.86	64.04		45.23	44.66	
	Varieties					
Doses	V1	V2	Mean			
D1	26.16	64.31	45.23			
D2	25.56	63.77	44.66			
Mean	25.86	64.04				
	SEm±	CD at 5%				
Variety (V)	0.03	0.09				
Nutrients (N)	0.03	0.09				
Doses (D)	0.02	0.06				
(V×N)	0.04	0.12				
(N×D)	0.05	0.14				
(V×D)	0.03	NS				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	26.63	25.21	26.42	26.47	26.06	67.85	61.87	62.37	64.25	65.22
D2	27.35	23.84	25.44	25.44	25.74	69.26	60.66	61.87	62.54	64.51
			SEm±					CD at 5%		
V × N × D			0.07					0.20		

Table-8 : Effect of nutrients and naphthalene acetic acid on hermaphrodite and male flower sex ratio.

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	2.707	0.459	1.583	1.615	1.551	1.583
Urea (N2)	3.081	0.632	1.857	1.792	1.922	1.857
Borex (N3)	2.859	0.610	1.734	1.695	1.774	1.734
Zinc sulphate (N4)	2.855	0.578	1.716	1.667	1.765	1.716
NAA (N5)	2.862	0.542	1.702	1.686	1.718	1.702
Mean	2.87	0.56				
	Varieties					
Doses	V1	V2	Mean			
D1	2.825	0.557				
D2	2.920	0.572				
Mean	2.87	0.56				
	SEm±	CD at 5%				
Variety (V)	0.012	0.036				
Nutrients (N)	0.002	0.005				
Doses (D)	0.001	0.003				
(V×N)	0.002	0.007				
(N×D)	0.002	0.005				
(V×D)	0.001	0.003				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	2.756	2.967	2.786	2.778	2.838	0.474	0.616	0.603	0.556	0.533
D2	2.657	3.195	2.932	2.931	2.886	0.444	0.649	0.616	0.599	0.550
			SEm±					CD at 5%		
V × N × D			0.002					0.007		

Table-9 : Effect of nutrients and naphthalene acetic acid on initial fruit set (%).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	17.12	15.19	16.15	16.01	16.30	16.15
Urea (N2)	20.55	19.13	19.84	19.27	20.40	19.84
Borex (N3)	17.27	16.19	16.73	15.33	18.13	16.73
Zinc sulphate (N4)	18.10	15.49	16.80	16.26	17.33	16.80
NAA (N5)	16.97	17.85	17.41	17.44	17.38	17.41
Mean	18.00	16.77		16.86	17.91	
	Varieties					
Doses	V1	V2	Mean			
D1	17.94	15.79	16.86			
D2	18.07	17.75	17.91			
Mean	18.00	16.77				
	SEm±	CD at 5%				
Variety (V)	0.03	0.09				
Nutrients (N)	0.06	0.18				
Doses (D)	0.05	0.16				
(V×N)	0.08	0.25				
(N×D)	0.12	0.35				
(V×D)	0.08	0.22				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	17.27	19.95	16.14	18.82	17.51	14.75	18.59	14.51	13.71	17.38
D2	16.97	21.14	18.40	17.39	16.43	15.64	19.66	17.87	17.27	18.33
			SEm±					CD at 5%		
V × N × D			0.170					0.501		

Table-10 : Effect of nutrients and naphthalene acetic acid on fruit set at pea stage (%).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	0.963	3.947	2.455	2.372	2.539	2.455
Urea (N2)	1.379	3.965	2.672	2.672	2.673	2.672
Borex (N3)	1.118	3.569	2.343	2.226	2.461	2.343
Zinc sulphate (N4)	1.034	3.821	2.428	2.390	2.465	2.428
NAA (N5)	1.007	3.847	2.427	2.408	2.446	2.427
Mean	1.100	3.830		2.414	2.517	
	Varieties					
Doses	V1	V2	Mean			
D1	1.073	3.754	2.414			
D2	1.128	3.906	2.517			
Mean	1.100	3.830				
	SEm±	CD at 5%				
Variety (V)	0.002	0.006				
Nutrients (N)	0.017	0.050				
Doses (D)	0.006	0.018				
(V×N)	0.024	0.071				
(N×D)	0.014	0.040				
(V×D)	0.009	0.025				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	1.011	1.354	1.057	0.974	0.968	3.733	3.942	3.395	3.806	3.848
D2	0.916	1.403	1.178	1.094	1.046	4.162	3.989	3.744	3.836	3.845
			SEm±					CD at 5%		
V × N × D			0.019					0.057		

Table-11 : Effect of nutrients and naphthalene acetic acid on fruit set at marble stage (%).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	0.270	0.727	0.499	0.491	0.506	0.499
Urea (N2)	0.369	0.814	0.592	0.575	0.609	0.592
Borex (N3)	0.333	0.688	0.510	0.476	0.545	0.510
Zinc sulphate (N4)	0.346	0.694	0.520	0.512	0.528	0.520
NAA (N5)	0.302	0.685	0.494	0.464	0.523	0.494
Mean	0.324	0.722		0.504	0.542	
	Varieties					
Doses	V1	V2	Mean			
D1	0.313	0.694	0.504			
D2	0.336	0.749	0.542			
Mean	0.324	0.722				
	SEm±	CD at 5%				
Variety (V)	0.016	0.097				
Nutrients (N)	0.007	0.020				
Doses (D)	0.004	0.011				
(V×N)	0.009	0.028				
(N×D)	0.008	0.024				
(V×D)	0.005	0.015				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	0.297	0.348	0.315	0.334	0.270	0.686	0.801	0.636	0.690	0.659
D2	0.244	0.390	0.351	0.359	0.334	0.768	0.827	0.739	0.697	0.712
			SEm±					CD at 5%		
V × N × D			0.011					0.033		

Table-12 : Effect of nutrients and naphthalene acetic acid on maturity (%).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	0.138	0.394	0.2658	0.277	0.254	0.2658
Urea (N2)	0.227	0.591	0.4091	0.393	0.425	0.4091
Borex (N3)	0.196	0.541	0.3687	0.359	0.378	0.3687
Zinc sulphate (N4)	0.182	0.551	0.3666	0.359	0.374	0.3666
NAA (N5)	0.174	0.451	0.3125	0.281	0.344	0.3125
Mean	0.1834	0.5057		0.3339	0.3552	
	Varieties					
Doses	V1	V2	Mean			
D1	0.180	0.488	0.3339			
D2	0.187	0.523	0.3552			
Mean	0.1834	0.5057				
	SEm±	CD at 5%				
Variety (V)	0.0004	0.0016				
Nutrients (N)	0.0134	0.0401				
Doses (D)	0.0038	0.0112				
(V×N)	0.019	0.057				
(N×D)	0.008	0.025				
(V×D)	0.005	0.016				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	0.153	0.217	0.192	0.168	0.169	0.401	0.570	0.526	0.550	0.392
D2	0.123	0.236	0.200	0.196	0.178	0.386	0.613	0.556	0.552	0.510
			SEm±					CD at 5%		
V × N × D			0.012					0.036		

Table-13 : Effect of nutrients and naphthalene acetic acid on fruit yield (kg/tree).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	53.67	45.01	49.34	50.75	47.93	49.34
Urea (N2)	67.26	66.07	66.66	65.45	67.87	66.66
Borex (N3)	62.68	54.91	58.79	57.31	60.28	58.79
Zinc sulphate (N4)	60.82	54.14	57.48	56.35	58.61	57.48
NAA (N5)	57.17	48.57	52.87	52.05	53.69	52.87
Mean	60.32	53.74		56.38	57.68	
	Varieties					
Doses	V1	V2	Mean			
D1	59.54	53.22	56.38			
D2	61.10	54.25	57.68			
Mean	60.32	53.74				
	SEm±	CD at 5%				
Variety (V)	0.03	0.09				
Nutrients (N)	0.13	0.40				
Doses (D)	0.06	0.17				
(V×N)	0.19	0.57				
(N×D)	0.13	0.39				
(V×D)	0.08	0.24				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	54.73	66.35	60.62	59.52	56.49	46.77	64.56	54.01	53.17	47.62
D2	52.62	68.17	64.74	62.12	57.86	43.24	67.58	55.82	55.11	49.52
			SEm±					CD at 5%		
V × N × D			0.19					0.55		

Table-14 : Effect of nutrients and naphthalene acetic acid on fruit yield (t/ha).

Treatments	Varieties			Doses		
	V1	V2	Mean	D1	D2	Mean
Water (N1)	5.37	4.55	4.96	5.07	4.84	4.96
Urea (N2)	6.73	6.61	6.67	6.55	6.79	6.67
Borex (N3)	6.27	5.49	5.88	5.73	6.03	5.88
Zinc sulphate (N4)	6.08	5.41	5.75	5.63	5.86	5.75
NAA (N5)	5.72	4.86	5.29	5.21	5.37	5.29
Mean	6.03	5.38		5.64	5.29	
	Varieties					
Doses	V1	V2	Mean			
D1	5.95	5.32	5.64			
D2	6.11	5.45	5.29			
Mean	6.03	5.38				
	SEm±	CD at 5%				
Variety (V)	7.07	21.03				
Nutrients (N)	11.67	35.00				
Doses (D)	7.87	23.16				
(V×N)	4.86	16.51				
(N×D)	17.61	51.79				
(V×D)	11.14	32.76				

Treat.	Variety (V1)					Variety (V2)				
	N1	N2	N3	N4	N5	N1	N2	N3	N4	N5
D1	5.47	6.63	6.06	5.95	5.65	4.68	6.46	5.40	5.32	4.76
D2	5.26	6.82	6.47	6.21	5.79	4.42	6.76	5.58	5.51	4.95
		SEm±						CD at 5%		
V × N × D		24.90						73.24		

and higher sex ratio (57.11%, 42.89% and 1.857%) noted under N2, with respect to doses the highest percentage of hermaphrodite flower, lowest percentage of male flower and higher sex ratio (55.34%, 44.66% and 1.75) was observed in higher dose D2.

The interaction of variety and nutrients (V×N) the highest percentage of hermaphrodite flower, lowest percentage of male flower and higher sex ratio (75.48%, 24.52% and 3.081) observed in V1N2, the interaction of nutrients and doses (N×D) the highest percentage of hermaphrodite flower, lowest percentage of male flower and higher sex ratio (57.75%, 42.25% and 1.922) recorded with N2D2 and the interaction of variety, nutrients and dose (V×N×D) the highest percentage of hermaphrodite flower, lowest percentage of male flower and higher sex ratio (76.16%, 23.84% and 3.19) was observed under V1N2D2. Total nitrogen content may be higher in the stem and leaves of trees which were expected to initiate flower buds irrespective of the varieties they belonged to and the nitrogen play an important role-if not the primary role-in flower-bud initiation. Perhaps the accumulation of these compounds may create a favorable condition for the synthesis and action of the substances actually responsible for flower

induction in these plants the above results are in conformity with the findings of Usha Rani (2018). The highest number of flowers per shoot recorded in plants sprayed with different concentrations of urea might be due to significant increase in number of shoots per plant with floral meristems. The increase in number of flowers per shoot in present study was in agreement with the results obtained by kumar et al. (2017). Azam et al (2018) reported the cultivar Langra showed maximum percentage of hermaphrodite flower (73.86%). Banik et al. (1997), Singh and Rajput (1977) reported that spraying mango trees with urea at 2 - 4% during January increased the number of hermaphrodite flowers/panicle. Asif et al (2002) also reported that the three commercial cultivars in Langra were depicted highest number of flower with maximum hermaphrodite flowers and the least male flowers also supported by Baghel and Tiwari (2003).

The fruit yield dependence on the number of fruit set per panicle at initial stage to fruit maturity percentage. However, the highest nutrients concentrations showed the significant difference. The maximum fruit set percent at Initial stage (18.00%) was recorded with variety Langra. and Pea, marble and maturity stage (3.83%, 0.72% and 0.51%,) respectively noted in variety Amrapali, while the

fruit yield (kg plant⁻¹) and fruit yield (t/ha) (60.32kg plant⁻¹ and 6.03t/ha) were noted in variety Langra (Table-9,10,11,12).

In case of individual affect of nutrients, the maximum fruit set percent at Initial, pea, marble, maturity stage, fruit yield (kg plant⁻¹) and fruit yield (t/ha) (19.84%, 2.68%, 0.60%, 0.27%, 66.66 kg plant⁻¹ and 6.67 t/ha) respectively noted with the application of urea.

The doses of nutrients also increased the yield attributes, the maximum fruit set percent at Initial, pea, marble, maturity stage, fruit yield (kg plant⁻¹) and fruit yield (t/ha) (17.91%, 2.52%, 0.54%, 0.35%, 57.68kg plant⁻¹ and 5.29t/ha) was observed with the application of higher dose of urea.

Increasing trends of fruit yield were significantly associated with the combination of variety × nutrients exhibited the maximum fruit set percent at Initial stage (20.55%) recorded with Langra + urea, pea, marble and maturity stage (3.97%, 0.81% and 0.59%) noted in Amrapali + urea, and fruit yield (kg plant⁻¹) and fruit yield (t/ha) (67.26 kg plant⁻¹ and 6.73t/ha) was noted with Langra × urea.

The combination between nutrients × doses enhanced the fruit yield and showed (Table-13,14) that the maximum fruit set percent at Initial, pea, marble, maturity stage, fruit yield (kg plant⁻¹) and fruit yield (t/ha) (20.40%, 2.67%, 0.60%, 0.42%, 67.87 kg plant⁻¹ and 6.79t/ha) were noted with the application of urea 4%.

Similarly interaction between variety × doses also accelerated fruit yield the maximum fruit set percent at initial stage (18.07%) recorded with Langra + higher dose of nutrients whereas, pea, marble and maturity stage (3.91%, 0.74% and 0.52%) noted in Amrapali × higher dose of nutrients. The fruit yield (kg plant⁻¹) and fruit yield (t/ha) (61.10 kg plant⁻¹ and 6.11t/ha) were also noted with Langra + higher dose of nutrients.

The interaction among the variety × nutrients × doses influenced significantly the yield attributes and showed the maximum fruit set percent at initial stage (21.14%) recorded with Langra + urea 4%. The pea, marble and maturity stage (3.99%, 0.83% and 0.61%) were noted in Amrapali + urea 4%. The fruit yield (kg plant⁻¹) and fruit yield (t/ha) (68.17 kg plant⁻¹ and 6.82t/ha) also recorded in Langra + urea 4%. (Anees et al., 2011). Panigrahi et al. (2007) and Sahoo et al (2014) in their study that the foliar application 4% urea was found more effective to control the fruit drop, ultimately fruit retention, fruit weight and yield was increased by 32.79 per cent over control. The urea 4% had the highest number of fruit per panicle at harvest and highest number of fruit per

plant with maximum fruit weight (Kumar et. al., 2008, Sarker and Rahim 2013) revealed that).

Conclusions

It was concluded on the basis of findings that the application of nutrient with higher dose i.e. urea 4% in variety Langra showed the influence on imposed characters like plant height, plant spread, number of leaves, percentage of hermaphrodite, percentage of male flower, sex ratio, initial fruit set percent, pea stage, marble stage and maturity stage of fruit percentage, yield per tree and yield per hectare.

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Effect of Rice Seedling Root Treatment with Zinc and Boron on Growth and Yield and Economics of rice

S.S. Shirsath, Y.J. Patil*, A.S. Takate, M.P. Badgujar and A.G. Durgude

Department of Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri

*Email : yogeshpatil2021@gmail.com

Abstract

The present investigation was undertaken to study the effect of slurry incubated zinc and boron seedling treatments on yield and uptake of lowland paddy. The field experiment was conducted at Zonal Agriculture Research Station, Western Ghat Zone Igatpuri, Dist. Nashik, during Kharif 2019-20. The experimental soil was light and shallow in depth belongs to order Entisol.

The yield and yield contributing characters including number of tillers per plant, height of the plant, and test weight of grain, grain yield and straw yield was significantly influenced by slurry incubated Zinc and Boron seedling treatments in rice. The higher Number of tillers hill^{-1} (17.20), Plant height (98.36), 1000 grain weight (21.21) higher grain and straw yield (44.51 and 53.35 q ha^{-1}) was noticed in the treatment T_{12} seedling treated in zinc sulphate + borax incubated for six days in cow dung slurry, respectively and it was statistically on par with the treatment T_{11} seedling treated in zinc sulphate + borax incubated for four days.

Key words : Slurry, zinc, boron, seedlings.

Introduction

Micronutrient's deficiency such as zinc and boron are widespread in rice growing areas that hamper substantial loss in yield and quality of rice grain with respect to protein and fat contents. Soils deficient in micronutrients are not capable of nourishing crop plant successfully and therefore low yield and quality of crops are obtained (Zia *et al.*, 2004). Generally, rice crop plants show the deficiencies of Zn, Fe, Mn, Cu and B that reflect in low contents of these nutrient minerals in rice grains (Kuaser *et al.*, 2001). Fertilizers particularly zinc and boron is needed to increase uptake and total contents of essential trace nutrients in rice grain.

Zinc deficiency in rice causes a deficiency disorder called *Khaira* disease. Seedling stage of the crop is highly prone to Zn deficiency. Leaves develop brown blotches and streaks, the streaks and blotches may fuse to cover the entire leaf, plants remain stunted and in severe case of deficiency the plant may die. Zinc deficiency decreases the tillering, increases the spikelet sterility and delay the crop maturity (IRRI, 2000). Slaton *et al.* (2001) reported that Zn deficient rice plant show poor root respiration especially in submerged soils.

The deficiency of boron (B) is spreading and it is most common in rice growing soils. Though it is required in small amounts but proved essential for plant growth. Boron is associated with one or more process of calcium utilization, cell division, flowering/fruitlet, disease resistance, water relations and act as catalyst for several reactions (Sprague, 1951). It is also very much essential

for the metabolism of carbohydrate, transport of sugars, synthesis of nucleotide, respiration and pollen viability (Dell and Huang, 1997). Deficiency of B affects the cell wall biosynthesis, phenol metabolism, structure and plasma membrane integrity. It does not affect enzyme activities since it is not an enzyme constituent and it is comparatively immobile in rice plants (Yu and Bell, 1998). The factors contribute to B deficiency in rice are drought, low pH, calcareous nature of the soil, leaching and fixation (Mengel and Kirby, 2001; Niaz *et al.*, 2002; Rashid and Rayan, 2004; Rashid *et al.*, 2005; Niaz *et al.*, 2007 and Rashid *et al.*, 2009). By correcting the deficiency, B has the potential to enhance the rice production.

Lu *et al.* (1982) reported that the dipping of rice seedling roots in fertile soil or compost and water slurry in definite proportion (1:1 to 1:5) enhances rice yield. These past findings though confirmed the usefulness of root dipping methods of nutrient application for higher NUE and the requirement of reduced quantity of applied nutrient. Therefore, this study was undertaken to determine the effect of zinc and boron incubated with slurry on seedling treatment for yield and nutrient uptake of lowland paddy with the following objectives.

To study the effect of slurry incubated Zinc and Boron seedling treatments on growth and yield of lowland paddy.

To study the effect of slurry incubated Zinc and Boron seedling treatments on nutrient uptake and soil properties of lowland paddy.

Material and Methods

A field experiment entitled “Effect of slurry incubated Zinc and Boron seedling treatment on yield and uptake of lowland paddy” was conducted on research farm at Zonal Agricultural Research Station, Igatpuri, Dist. Nashik, during *kharif* 2019. The experimental soil was light and shallow in depth belongs to order Entisol. Textural class was silty loam and neutral in reaction (pH 6.90), low in soluble salts (EC-0.12 dSm⁻¹), low in carbon content (0.34 %), CaCO₃ content (1.82 %), soil available nitrogen (168.6 kg ha⁻¹), soil available potassium (141.2 kg ha⁻¹) and medium in soil available phosphorous (18.01 kg ha⁻¹). The DTPA extractable micronutrient Zn was deficient (0.44 mg kg⁻¹), Fe, Mn and Cu were sufficient (20.14, 19.80 and 0.68 mg kg⁻¹, respectively). The data on parameters viz., yield, and yield contributing characters were tabulated and analyzed statistically by the method described by Panse and Sukhatme (1985).

Treatment details

Tr. No.	Treatments
T ₁	Zinc sulphate with one day incubated cow dung slurry
T ₂	Zinc sulphate with two days incubated cow dung slurry
T ₃	Zinc sulphate with four days incubated cow dung slurry
T ₄	Zinc sulphate with six days incubated cow dung slurry
T ₅	Borax with one day incubated cow dung slurry
T ₆	Borax with two days incubated cow dung slurry
T ₇	Borax with four days incubated cow dung slurry
T ₈	Borax with six days incubated cow dung slurry
T ₉	Zinc sulphate + borax with one day incubated cow dung slurry
T ₁₀	Zinc sulphate + borax with two days incubated cow dung slurry
T ₁₁	Zinc sulphate + borax with four days incubated cow dung slurry
T ₁₂	Zinc sulphate + borax with six days incubated cow dung slurry
T ₁₃	One day incubated cow dung slurry
T ₁₄	Two days incubated cow dung slurry
T ₁₅	Four days incubated cow dung slurry
T ₁₆	Six days incubated cow dung slurry
T ₁₇	Control

Note : 1. The recommended dose of N, P₂O₅ and K₂O was common to all treatments except Control (T17).

2. The paddy seedlings were dipped in incubated cow dung slurry for 12 hours before transplanting.

3. Zinc sulphate @ 2% and boric acid @ 0.5% was added in cow dung slurry as per treatment

The farm yard manure procured and applied as per recommendation @ 10 t ha⁻¹ to all the treatments except absolute control treatment.

Results and Discussion

Grain and straw yield : The grain and straw yield (43.96 and 53.35 q ha⁻¹) of paddy significantly influenced due to

application of GRDF + seedling treated in Zinc sulphate + Borax with six days incubated cow dung slurry respectively and statistically on par with the treatment T₁₁ GRDF + seedlings treated in Zinc sulphate + Borax with four days incubated cow dung slurry (42.72 and 50.96 q ha⁻¹) respectively.

Application of zinc not only relived the chlorosis and produced healthy green plants but also increased the synthesis of chlorophyll, growth promoting substances and mobility of minerals, water photosynthesis and amino acids from source to sink which may have resulted into increase in the paddy grain yield. These results are in conformity with findings of Ramzan, *et al.*, 2020.

Similar findings are also reported by various scientists in case of yield of rice. In rice, seed treatment with boron improved radicle and plumule lengths as boron plays a vital role in cell division, cell elongation and primary events of germination. Boron enhances rice growth in different production systems, more so in aerobic rice B also improves tillering root and leaf scores, and the number of secondary roots (Farooq *et al.* 2011). (Rehman *et al.* 2012).

Number of tillers per hill : The higher number of tillers hill⁻¹ of paddy crop was observed in the treatment GRDF + seedling treatment in Zinc sulphate + Borax with six days incubated cow dung slurry (17.00) and statistically on par with GRDF + seedling treatment in Zinc sulphate + Borax with four days incubated cow dung slurry (16.80).

Plant height (cm) : In case of plant height of paddy crop similar treatment was found in higher plant height of (96.1) and statistically on par with the treatments T₈ to T₁₁. Zinc and Boron plays important role in growth parameters of rice. Application of B enhances the growth attributes due to its favorable influence on metabolic path-ways involved in cell division and elongation (Hatwar *et al.*, 2003).

1000 grain weight : The test weight is also an important yield contributing component. It reflects the magnitude of seed development which ultimately reflects the final yield of a crop. The data pertaining to test weight of lowland paddy revealed that the treatment T₁₂ GRDF + seedling treated in Zinc sulphate + Borax with six days incubated cow dung slurry significantly increased the test weight (21.78) and statistically on par with treatment T₁₁ GRDF + seedling treated in Zinc sulphate + Borax with four days incubated cow dung slurry (21.21).

The economics of paddy influenced by seedling treatment of slurry incubated with Zinc and Boron is presented in Table-2.

Gross monetary returns : The gross monetary returns were influenced by seedling treatment of slurry incubated with Zinc and Boron. Application GRDF + six days

Table-1 : Effect of slurry incubated Zinc and Boron seedling treatments on growth, yield and yield attributing characters of paddy.

	Treatment	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)	1000 grain weight (g)	Plant height (cm)	Number of tillers per hill
T ₁	Zinc sulphate with one day incubated cow dung slurry	37.58	43.22	20.15	86.8	12.00
T ₂	Zinc sulphate with two days incubated cow dung slurry	37.52	44.64	20.17	87.2	12.40
T ₃	Zinc sulphate with four days incubated cow dung slurry	39.87	45.70	20.56	89.7	12.70
T ₄	Zinc sulphate with six days incubated cow dung slurry	39.95	44.56	20.60	90.1	12.99
T ₅	Borax with one day incubated cow dung slurry	39.37	44.46	20.31	87.2	13.20
T ₆	Borax with two days incubated cow dung slurry	39.79	44.83	20.13	88.1	13.10
T ₇	Borax with four days incubated cow dung slurry	39.71	45.43	20.56	89.7	12.95
T ₈	Borax with six days incubated cow dung slurry	39.39	45.81	20.49	91.8	13.00
T ₉	Zinc sulphate + Borax with one day incubated cow dung slurry	39.57	47.39	20.65	92.2	15.15
T ₁₀	Zinc sulphate + Borax with two days incubated cow dung slurry	40.24	48.18	20.97	92.1	15.50
T ₁₁	Zinc sulphate + Borax with four days incubated cow dung slurry	42.72	50.96	21.21	94.5	16.80
T ₁₂	Zinc sulphate + Borax with six days incubated cow dung slurry	43.96	53.35	21.78	96.1	17.00
T ₁₃	One day incubated cow dung slurry	35.86	40.83	19.88	89.2	11.15
T ₁₄	Two days incubated cow dung slurry	36.40	41.52	20.03	87.8	11.17
T ₁₅	Four days incubated cow dung slurry	36.82	41.58	20.05	88.4	11.83
T ₁₆	Six days incubated cow dung slurry	37.06	41.88	20.12	90.6	12.17
T ₁₇	Control	35.58	40.22	20.15	86.8	11.00
	SE ±	1.23	1.71	0.31	1.90	0.54
	CD at 5 %	3.70	4.94	0.94	5.70	1.63
	CV %	7.47	7.69	-	-	-

Table-2 : Effect of slurry incubated Zinc and Boron seedling treatments on economics of paddy.

	Treatment	Gross monetary returns (Rs.)	Cost of cultivation (Rs.)	Net monetary returns (Rs.)	B:C ratio
T ₁	Zinc sulphate with one day incubated cow dung slurry	79908	55214	24694	1.45
T ₂	Zinc sulphate with two days incubated cow dung slurry	79950	55214	24736	1.45
T ₃	Zinc sulphate with four days incubated cow dung slurry	84774	55214	29560	1.53
T ₄	Zinc sulphate with six days incubated cow dung slurry	84808	55214	29594	1.53
T ₅	Borax with one day incubated cow dung slurry	83624	55594	28030	1.50
T ₆	Borax with two days incubated cow dung slurry	84511	55594	28917	1.52
T ₇	Borax with four days incubated cow dung slurry	84424	55594	28830	1.52
T ₈	Borax with six days incubated cow dung slurry	83817	55594	28223	1.51
T ₉	Zinc sulphate + Borax with one day incubated cow dung slurry	84346	55814	28532	1.51
T ₁₀	Zinc sulphate + Borax with two days incubated cow dung slurry	85420	55814	29606	1.54
T ₁₁	Zinc sulphate + Borax with four days incubated cow dung slurry	91046	55814	35232	1.63
T ₁₂	Zinc sulphate + Borax with six days incubated cow dung slurry	94444	55814	38630	1.69
T ₁₃	One day incubated cow dung slurry	76205	54994	21211	1.39
T ₁₄	Two days incubated cow dung slurry	77367	54994	22373	1.41
T ₁₅	Four days incubated cow dung slurry	78214	54994	23220	1.42
T ₁₆	Six days incubated cow dung slurry	78733	54994	23739	1.43
T ₁₇	Control	54641	50454	4187	1.08

Market Rates : -

Urea :	Rs 6 per kg	DAP :	Rs. 25.6 per kg	Paddy grain :	Rs 2000 /q
MOP :	Rs. 12 per kg	ZnSO ₄	Rs. 55 per kg	Paddy straw :	Rs 110 /q
Boric acid	Rs. 600 per kg				

incubated cow dung slurry with Zinc sulphate + Borax seedling treatment recorded higher gross monetary return (Rs. 94,444) followed by the treatment GRDF + Zinc sulphate + Borax with four days incubated cow dung slurry. This might be due to increased grain and straw yield of paddy due to seedling treatment with incubated cow dung slurry with Zinc sulphate + Borax.

Net monetary returns : The net monetary returns were influenced by application GRDF + six days incubated cow dung slurry with Zinc sulphate + Borax seedling treatment recorded higher net monetary return (Rs 38,630), followed by T₁₁ GRDF + Zinc sulphate + Borax with four days incubated cow dung slurry (Rs. 35232)

B : C ratio : In case of B:C ratio of lowland paddy cultivation, the treatment (T₁₂) application GRDF + six days incubated cow dung slurry with Zinc sulphate + Borax seedling treatment recorded higher B:C ratio (1.69) followed the treatment GRDF + Zinc sulphate + Borax with four days incubated cow dung slurry (1.63).

Conclusions

It is concluded that, the rice seedling treatment with cow dung slurry incubated for 4 and 6 days with zinc and boron along with general recommended dose of fertilizer (100:50:50 kg ha⁻¹ N:P₂O₅:K₂O + 10 t ha⁻¹ FYM) to paddy crop was found beneficial for increase in number of tillers per hill, test weight, grain and straw yield, in lowland paddy crop grown on Entisol.

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Impact of Irrigation and PGR on Growth and Yield of Wheat (*Triticum aestivum* L.)

Lekhraj, Vikrant, Sandeep Kumar and Mukesh Kumar

Department of Agronomy, R.M.P. (P.G.) College Gurukul Narsan Haridwar (U.K.) India – 247670

Abstract

A field experiment was conducted during Rabi 2018-2019 at the research farm of R.M.P. (P.G.) College, Gurukul-Narsan (Haridwar), Uttar Pradesh to impact of irrigation and PGR on growth and yield of wheat (*Triticum aestivum* L.). The experiment comprised of 8 treatment combinations and layout in split plot design in main plot 4 irrigation treatments viz., I₀ (No irrigation), I₁ (One irrigation at 45 DAS), I₂ - Two irrigation at 35 DAS + 75 DAS and I₃ - Three irrigation at 21, 45 DAS + 75 DAS and in sub-plots 2 treatments viz., G₀ (No spray) and G₁ (Spray of Lihocin (0.2 %) + Folicur (0.1%) at 45 DAS) and 75 DAS with three replications. The result showed that among the different irrigation levels, irrigation applied at 21, 45 and 75 DAS recorded significantly higher growth and yield attributes and yield compared to no irrigation. Maximum plant height (110.68 cm), higher flag leaf area (1.73 cm²) and higher (15.67 g/plant) dry matter accumulation and highest peduncle length (18.27 cm) were found with irrigation applied at 21, 45 and 75 DAS which was significantly higher than no irrigation. The highest grain yield 35.78 q ha⁻¹ and biomass yield 78.50 q ha⁻¹ were recorded with irrigation applied at 21, 45 and 75 DAS which was 74.62, 23.68 and 12.80% higher yield than the yield of no irrigation, One irrigation at 45 DAS and Two irrigation at 35 DAS + 75 DAS. The application of growth regulators (2% Lihocin + 1% folicur) sprayed at 45 and 75 DAS gave significantly higher growth, yield attributes and yield compare to no growth regulators. Combined application of three irrigation at 21, 45 and 75 DAS stage with foliar application of PGR at 45 and 75 DAS gave significantly higher seed yield of wheat.

Key words : Lihocin, folicur (0.1%), irrigation, flag leaf area, peduncle length, yield attributes, yield, wheat.

Introduction

Wheat (*Triticum aestivum* L.) is the most important among all cereals used as a food grain in the world. It has good nutrition profile with 12.1 percent protein, 1.8 percent lipids, 1.8 percent ash, 2.0 percent reducing sugars, 6.7 percent pentose's, and provides 314 Kcal/100g of food. It ranks first in the world cereal area and production. Globally, wheat covers an area of 220.4 million ha with production of 748.8 million tonnes (Mt). Wheat production in India during the 2018-19 Rabi season is likely to see a dip as the area sown to wheat has declined by 4.2 per cent, amounting to 29.9 million hectares, as compared to 31.7 million hectares in 2017-18. Among wheat cultivated states, Uttar Pradesh rank first with respect to area (9.65 million ha) and production (26.87 Mt) but the productivity is much lower (2786 kg ha⁻¹) than Punjab (4491 kg ha⁻¹) and Haryana (4574 kg ha⁻¹) (Anonymous, 2019). There are many factors responsible for low yield of wheat but insufficient irrigation and poor crop nutrition are the most important. Water is essential at every developmental phase starting from seed germination to plant maturation for harvesting the maximum potential yield of wheat. There is a positive correlation between grain yield and irrigation frequencies (Kumar *et al.*, 2012). Irrigation missing at some critical growth stage sometime drastically reduces grain yield due to lower test weight. It has been well established that dwarf wheat produce their potential yields when it is irrigated at all critical stages of plant

growth viz. crown root initiation, late tillering, late jointing, flowering, milk and dough stages. In most of wheat growing areas of Uttar Pradesh, sufficient and assured irrigation water is not available for irrigation at all critical stages.

Wheat lodging reduces harvestability and quality by disrupting the supply and intake of water to the developing kernels. A good way to improve yield potential is to optimize dry matter partitioning to the developing spike and grain in order to increase spike fertility and harvest index while maintain lodging resistance (Foulkes *et al.*, 2011). At the same time, improving lodging resistance is an essential strategy for increasing the yield. This can be done via either breeding and selection or the use of PGRs. However, in some cases, grain yield could also be decreased if the height is shortened too much (Guoping *et al.*, 2001). The relationship between high yields and lodging resistance depends not only on plant height, but also on stem structure, photosynthetic capacities and vascular bundles (Feng *et al.*, 2014). The basal internodes play an important role in lodging resistance. Cultivation methods need to be improved in order to reduce lodging and increase grain yields further. The reductions of plant height were associated with reducing elongation of the internodes. Plant growth regulators (PGRs) are widely used for lodging control in winter wheat (*Triticum aestivum* L.) grown in irrigation conditions. There are several phases during the growth cycle where PGRs could be applied to modify plant growth and

development. For example, by applying CCC at the beginning of stem elongation and the other PGRs at later stages, prior to heading, cereal straw could be shortened (Rajala and Peltonen-Sainio, 2001). Although the introduction of semi-dwarf wheat cultivars had largely solved the problem of lodging, evidence was already accumulating that a timely application of a growth retardant such as chlormequat (CCC) or ethephon could increase the grain yield of both wheat and barley, independently of any control of lodging

Materials and Methods

A field experiment was conducted during Rabi 2018-2019 at the research farm of R.M.P. (P.G.) College, Gurukul-Narsan (Haridwar), Uttar Pradesh (29°51'N longitude and 77°53'E longitude at an elevation of 274 m above the mean sea level). Soil of experimental field was sandy clay loam in texture, pH 7.6, EC (0.22 dSm⁻¹), low in organic carbon (0.41%), available N (168.72 kg/ha), medium in available P (20.07 kg/ha) and available K (190.4 kg/ha). The experiment comprised of 8 treatment combinations and layout in split plot design in main plot 4 irrigation treatments viz., I₀ (No irrigation), I₁ (One irrigation at 45 DAS), I₂ - Two irrigation at 35 DAS + 75 DAS and I₃ - Three irrigation at 21, 45 DAS + 75 DAS and in sub-plots 2 treatments viz., G₀ (No spray) and G₁ (Spray of Lihocin (0.2 %) + Folicur (0.1%) at 45 DAS and 75 DAS with three replications. Recommended dose of fertilizer as per treatment was applied. The individual nutrients viz. NPK was given in the form of Urea, DAP and MOP in the soil before sowing. The nitrogen was given as basal (50%) as well as in two split doses as topdressing. Plant growth regulator (Lihocin (2 ml/litre) + Folicur (1ml/litre) was applied at first node appearance (45 days) and second spray was applied at flag leaf emerge (75 DAS) with foot spray as per treatments. Wheat variety C-306 was sown @ 100 kg/ha seed rate apart 20 cm row to row spacing during third week of November. The observations were recorded on growth and yield attributes and yield using standard procedures. The data were analyzed statistically among the standard procedure of ANOVA technique and treatments comparisons are made at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Growth attributes : Irrigation exhibited greater influence on the height of the plant, fresh and dry matter production, number of tillers per plant and leaf area index during crop growth (Table 1). Irrigation applied at (21, 45 and 75 DAS stage) recorded longer plants as compared than no irrigation. The maximum fresh and dry weight was produced with three irrigation applied at 21, 45 and 75

DAS, which was significantly higher over two irrigation (35 and 75 DAS) and one irrigation which was applied at 45 DAS only. These growth characters to be increased due to supply of available moisture to growing wheat plants under increased number of irrigation which may also increased the uptake of nutrients to wheat plants. The longest peduncle length 18.34 cm was found under three irrigation, which was significantly superior over the other irrigation levels. Sarma *et al.* (2007) and Kumar *et al.* (2016) reported similar results. The increased dry matter production in plants due to various rates of irrigation application would appear to have resulted due to more number of leaves, plant height and formation of chlorophyll formation and its ultimate effect on photosynthesis.

Foliar application of PGR (Lihocin + folicur) exhibited greater influence on the height of the plant, fresh and dry matter production. PGR at 2% Lihocin + 1% folicur reduced the plant height and this reduction played an important role in the increase of the grain yield in wheat, via the alteration of dry matter partitioning into the spikes. The application of PGR (2% Lihocin + 1% folicur) at 45 DAS and leaf emergence stage (75 DAS) reduced 30.33% height of plant over control. Plant growth regulators (PGRs) are often used to restrain elongation of internodes, improve lodging traits, and protect yield potentials. PGRs are often used as an insurance measure to reduce the incidence of lodging by mimicking or changing the production of hormones, which play an important role in improving stem structure and increasing yields.

Yield attributes : Influence of irrigation levels on yield contributing characters, number of ears per plant, peduncle length, ear length, number of grains/ear, 1000 seed weight, were positively influenced (Table-2). More number of ear per plant was found with three irrigations. Significantly more number of grains/ear and higher test weight were recorded under three irrigation as compared to other irrigation levels. Perhaps this might have been possible due to the fact that irrigations applied appropriate time and the moisture available to the wheat plant and due appropriate moisture availability increased the availability of nutrient to wheat plant. Highest yields of grain and straw were recorded with three irrigations followed by two irrigation and minimum with no irrigation. Similarly, yield per hectare also higher under crop grown under three irrigation applied at 21, 45 and 75 DAS stage of crop. The increase in grains and straw yield may be attributed mainly to the production of grains per spike, which was highly favored under three irrigations. Thakur *et al.* (2000) wheat crop receiving four irrigations gave the maximum grain and straw yields, owing to higher spikes/m², spike length,

Table-1 : Yield attributes of wheat influenced by as influenced fertilizer application and growth regulators.

Treatments	Plant height (cm) at harvest	Leaf area flag leaf (cm ²) at 120 DAS	Fresh weight (g/plant) at harvest	Dry weight (g/plant) at harvest	Padeuncle length (cm)
Irrigation					
No irrigation	90.32	1.45	21.77	9.37	13.87
One irrigation (45 DAS)	99.96	1.58	22.86	11.55	14.88
Two irrigation (35+75 DAS)	106.07	1.61	21.95	14.02	16.84
Three irrigation (21+45+75 DAS)	110.88	1.73	23.47	15.67	18.27
S.Em. $\pm$	0.87	0.011	0.16	0.08	0.17
CD at 5%	3.07	0.038	0.57	0.29	0.61
PGR treatments					
Control	120.01	1.56	18.12	11.71	14.41
PGR spray	83.61	1.62	26.91	13.59	17.52
S.Em. $\pm$	1.70	0.03	0.39	0.22	0.28
CD at 5%	5.64	N/A	1.31	0.74	0.85

Table-2 : Yield attributes of wheat influenced by as influenced fertilizer application and growth regulators.

Treatments	No of ears/plant	Length of ears (cm)	No of grains per ear	Grain weight (g/plant)	1000 seed weight (g)	Grain yield (q/ha)	Total biomass (q/ha)
Irrigation							
No irrigation	3.22	9.14	40.32	4.90	38.72	20.49	49.45
One irrigation (45 DAS)	3.50	9.44	47.95	6.41	41.15	28.93	67.34
Two irrigation (35+75 DAS)	3.78	10.19	50.89	6.83	41.79	31.72	73.45
Three irrigation (21+45+75 DAS)	3.83	10.52	55.50	6.96	42.89	35.78	78.50
S.Em. $\pm$	0.03	0.15	0.97	0.04	0.41	0.30	0.45
CD at 5%	0.09	0.52	3.41	0.14	1.45	1.07	1.58
PGR treatments							
Control	3.30	9.55	46.49	5.74	40.69	27.72	64.06
PGR spray	3.86	10.09	50.83	6.80	41.59	30.73	70.31
S.Em. $\pm$	0.06	0.17	0.72	0.11	0.12	0.52	1.20
CD at 5%	0.21	0.51	2.37	0.37	0.36	1.72	3.97

fertile spikelets/spike, grains/spike, grain and biomass production rate.

Yield contributing characters i.e. number of grain per spike, grain weight per ear and 1000 grain weight. The grain and straw yields were higher with the application of lihocin + Folicur treatment in wheat (Table-2). Application of PGR reduced peduncle length, increase spike length and number of grains per spike. The foliar application of PGR significantly affected total biomass, grain yield and recorded highest 30.73 q ha⁻¹ over control (27.72 q/ha) and highest (78.50 q/ha) biomass yield q ha⁻¹ which was significantly higher than two irrigation (73.75 q/ha) while, minimum biomass (49.45 q/ha) was recorded without irrigated plots. PGR (2% Lihocin + 1% folicur) increase 10.86 and 9.76% seed and biomass yield with double spray of PGR at both 45 and 75 DAS stage. Singh *et al.* 2019 reported the combined spray of CCC+Tebuconazole enhanced the test weight by 7.71%,

2.63 and 2.84% over water spray, CCC and Tebuconazole, respectively. The grain, straw and biomass yields of wheat due to different growth retardant treatments were found statistically at par. Thus for obtaining maximum production and highest profit farmer should applied three irrigation at 21, 45 and 75 DAS stage with foliar application of PGR at 45 and 75 DAS.

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Influence of Fertility Levels and Growth Regulators on Growth and Yield of Wheat (*Triticum aestivum* L.)

Deepak Kumar, Vikrant, Sandeep Kumar and Mukesh Kumar

Department of Agronomy, R.M.P. (PG) College Gurukul Narsan (Haridwar)

Abstract

A field experiment was conducted during Rabi 2018-2019 at the research farm of R.M.P. (P.G.) College, Gurukul-Narsan (Haridwar), Uttar Pradesh to determine the fertility levels and growth regulators on growth and yield attributes and yield of wheat. The experiment comprised of 12 treatment combinations and layout in randomized block design in main plot 4 treatments viz., F0 (No fertilizer), F1 50 % RDF (75 kg N+40 kg P₂O₅+30 kg K₂O₅), F2 100 % RDF (150 kg N+80 kg P₂O₅+60 kg K₂O₅) and F3 150 % RDF (225 kg N+120 kg P₂O₅+90 kg K₂O₅) and in sub-plots 3 treatments viz., G0 (No spray), G1 (Single spray of Lihocin (0.2 %) + Follicur (0.1%) at 45 DAS) and G2 (Double spray at 45 DAS and 75 DAS of Lihocin (0.2 %) + Follicur (0.1%)) with three replications. The result showed that among the different nutrient management levels, application of 150% RDF significantly higher growth and yield attributes and yield compared to control. Maximum plant height (110.67 cm), higher flag leaf area () and more dry matter accumulation were found with 150 kg RDF which was significantly higher than control. The highest grain yield 45.29 q ha⁻¹ and straw yield 52.98 q ha⁻¹ were recorded with 150% RDF which was 132.38, 47.38 and 2.89% % higher yield than the yield of control, 50% RDF and 100%. The application of growth regulators (2% Lihocin + 1% follicur) sprayed at 45 and 75 DAS gave significantly higher growth, yield attributes and yield compare to single spray at 45 DAS and without application of growth regulators. Combined application of 150% RDF + with Lihocin + Follicur at 45 and 75 DAS spray gave significantly higher seed yield of wheat.

Key words: Lihocin, Follicur (0.1%), RDF, yield attributes, yield, wheat.

Introduction

Wheat (*Triticum aestivum* L.) is the important cereal crop for most of the world's population belongs to family Poaceae (*Gramineae*). Globally, wheat is being grown in 124 countries and occupies area of 218.61 million ha with production of nearly 757.92 million tonnes of grain during 2017-18. The area under wheat increased from 13.7 million hectares in 1966-67 to 31.50 million hectares in 2017-18. In this period, production has also increased from 11.4 to 99.78 million tonnes and the productivity increased from 887 to 3146 kg ha⁻¹ (Anonymous, 2019). Lodging, usually characterized by permanent displacement of stems from an upright position due to internal and external factors, is an important constraint limiting wheat yields and quality in both developed and developing countries (Berry *et al.* 2003). The key reasons responsible for wheat lodging are increase in weight of mature ears due to water accumulation, occurrence of high speed winds at grain filling stage, wide use of flat planting and flood irrigation and the lack of acceptable cultivars of wheat that are lodging tolerant at higher nitrogen (N) rates etc. Lodging is a major limiting factor for wheat crop especially under indiscriminate use of fertilizers in irrigated conditions or where rainfall and high winds are common. Lodging severely affects the yield and yield losses vary depending upon the intensity of lodging and stage at which lodging occurs. This yield gap also

exist between researchers managed optimum NPK plots and farmers' fertilizer practices (FFP) indicating a great opportunity for enhancing wheat productivity by proper nutrient enhance grain yields by simply prolonging grain filling period and increasing kernel weights (Bertelsen *et al.*, 2002). The reduction in grain yield caused by lodging ranged from 7 to 35% with greatest effect when lodging occurred within the month after anthesis, is most commonly reported under Indian condition.

Plant growth regulators (PGRs) are widely used for lodging control in winter wheat (*Triticum aestivum* L.) grown at high N rates. Part of such intensive management systems is to increase N fertilizer rates and control lodging with PGRs ultimately to increase grain yields (Tripathi, *et al.*, 2003). Lodging preventers (plant height retardants) are generally antagonistic to gibberellin and act by altering their metabolism (Peake *et al.* 2014) and for aforesaid reason they are frequently called anti-gibberellin. The nature and extent of lodging are closely related to height of the stem, which can be modified by application of growth inhibitors (Peng *et al.* 2014). Application of growth inhibitors, like ethephon (2-chloro ethyl phosphonic acid) or CCC (Chlormequat Chloride), was reported to be useful in decreasing plant height and subsequently reducing lodging (Niu *et al.* 2012, Pitre *et al.* 2007). Spraying PGRs at the right growth stage can improve stem quality, prevent lodging, and increase crop yields (Cailong *et al.*, 2017).

Materials and Methods

A field experiment was conducted during Rabi 2018-2019 at the research farm of R.M.P. (P.G.) College, Gurukul-Narsan (Haridwar), Uttar Pradesh (29°51'N longitude and 77°53'E longitude at an elevation of 274 m above the mean sea level). Soil of experimental field was sandy clay loam in texture, pH 7.4, EC (0.22 dSm⁻¹), low in organic carbon (0.39%), available N (164.72 kg/ha), medium in available P (18.18 kg/ha) and available K (194.3 kg/ha). The experiment comprised of 12 treatment combinations and layout in randomized block design in main plot 4 treatments viz., F0 (No fertilizer), F1 50 % RDF (75 kg N+40 kg P₂O₅+30 kg K₂O₅), F2 - 100 % RDF (150 kg N+80 kg P₂O₅+60 kg K₂O₅) and F3 150 % RDF (225 kg N+120 kg P₂O₅+90 kg K₂O₅) and in sub-plots 3 treatments viz., G0 (No spray), G1 (Single spray of Lihocin (0.2 %) + Follicur (0.1%) at 45 DAS) and G2 (Double spray at 45 DAS and 75 DAS of Lihocin (0.2 %) + Follicur (0.1%)) with three replications. Recommended dose of fertilizer as per treatment was applied. The individual nutrients viz. NPK was given in the form of Urea, DAP and MOP in the soil before sowing. The nitrogen was given as basal (50%) as well as in two split doses as topdressing. Plant growth regulator (Lihocin (2 ml/litre) + Follicur (1ml/litre) was applied at first node appearance (45 days) and second spray was applied at flag leaf emerge (75 DAS) with foot spray as per treatments. Wheat variety HDCSW-18 was sown @ 100 kg/ha seed rate apart 20 cm row to row spacing during third week of November. The observations were recorded on growth and yield attributes and yield using standard procedures. The data were analyzed statistically among the standard procedure of ANOVA technique and treatments comparisons are made at 5% level of significance (Gomez and Gomez, 1984).

Results and Discussion

Growth attributes : Fertilizer application exhibited greater influence on the height of the plant, dry matter production, number of tillers per plant and leaf area index during crop growth (Table 1). The maximum plant height, dry weight and higher number of tillers per plant were recorded with the application of 150%, RDF which was significantly higher over 100% RDF and 50% RDF. The increased growth attributes in plants due to various rates of nitrogen application would appear to have resulted due to more chlorophyll formation and its ultimate effect on photosynthesis and increased the availability of nutrients of plant in root zone and brought an increase in plant height, because of its immense effects on cell enlargement. Kumar et al. (2019) and Singh et al. (2018) revealed that the application of 150% RDF+FYM led to higher plant height and dry matter accumulation of wheat

at all the growth stages where it was maximum with 150% RDF. The foliar application of PGR (Lihocin + follicur) exhibited greater influence on growth parameters i.e. height of the plant, number of tillers per plant and dry matter production. The two time application of PGR (2% Lihocin + 1% follicur) at 45 DAS and leaf emergence stage (75 DAS) reduced 17.48% height of plant while single application of PGR reduced 9.66 % over control. Plant growth regulators (PGRs) are often used to restrain elongation of internodes, improve lodging traits, and protect yield potentials. PGRs are often used as an insurance measure to reduce the incidence of lodging by mimicking or changing the production of hormones, which play an important role in improving stem structure and increasing yields.

Yield attributes : A higher number of grains/spike, more spike length, spike weight and more test weight of grains produced at 150% RDF and 100% RDF as compared to 50% RDF and no fertilizer application. The increase in yield attributing characters under 150% RDF may be due to ever availability of nutrients even during later reproductive and grain filling stage, which resulted in increased rate of photosynthesis, which has direct bearing on yield components and yield. Increase in the ear head length may be due to better assimilation of carbohydrates. The highest grain yield 45.29 q ha⁻¹ and straw yield 52.98 q ha⁻¹ were recorded with 150% RDF which was 132.38, 47.38 and 2.89% higher yield than the yield of control, 50% RDF, 100% in present investigation. Increases in grain and straw yields might be due to increasing in growth and yield attributes of wheat due to increasing recommended dose of chemical fertilizers. Singh et al (2018) and Kumar et al (2019) reported that fertilizer application of 25% more than RDF of NPK fertilizer recorded highest grain (19.65 q ha⁻¹) and straw yield (29.64 q ha⁻¹) over 100% RDF and 25% less than RDF of NPK.

The results on yield attributing parameters viz. number of ears/plant, peduncle length, length of ears (cm) and of grains per ear as significantly increased by PGR application (Table-2). Application of PGR reduced peduncle length, increase spike length and number of grains per spike. The foliar application of PGR significantly affected total biomass, grain yield and recorded significantly highest biomass and yield of wheat was recorded with two time spray at 45 and 75 DAS as compared to single spray at 45 DAS and minimum biomass yield was recorded with no PGR spray. PGR (2% Lihocin + 1% follicur) increase 14.68 and 20.09% seed yield with single and double spray of PGR at both 45 and 75 DAS stage in present investigation. Singh et al. 2019 reported the combined spray of CCC+Tebuconazole enhanced the test weight by 7.71%, 2.63 and 2.84% over

Table-1 : Yield attributes of wheat influenced by as influenced fertilizer application and growth regulators.

Treatments	Plant height (cm) at harvest	Leaf area flag leaf (cm ²) at 120 DAS	Dry weight (g/plant) at harvest	Padeuncle length (cm)
Fertilizer management				
Control	91.71	1.662	8.24	13.96
50 % RDF	101.58	1.739	11.48	15.14
100 % RDF	106.73	1.782	11.91	16.22
150 % RDF	110.67	1.840	12.94	16.62
S.Em. ±	1.104	0.025	0.131	0.189
CD at 5%	3.259	0.075	0.388	0.559
Plant Growth regulator				
No spray	112.86	1.649	8.34	14.75
One spray	102.00	1.789	11.12	15.63
Two spray	93.17	1.830	13.97	16.08
S.Em. ±	0.956	0.022	0.114	0.164
CD at 5%	2.822	1.662	0.336	0.484

Table-2 : Yield attributes of wheat influenced by as influenced fertilizer application and growth regulators.

Treatments	No of ears/plant	Length of ears (cm)	No of grains per ear	Grain weight (g/plant)	1000 seed weight (g)	Grain yield (q/ha)	Straw weight (q/ha)
Fertilizer management							
Control	2.52	9.32	49.51	4.61	38.37	19.49	23.09
50 % RDF	2.95	9.75	53.41	6.51	41.20	30.73	36.97
100 % RDF	3.22	10.66	60.30	7.50	41.98	44.02	44.59
150 % RDF	3.37	10.71	62.78	7.75	42.59	45.29	52.98
S.Em. ±	0.032	0.122	0.762	0.082	0.702	0.486	0.439
CD at 5%	0.094	0.360	2.248	0.241	2.041	1.433	1.295
Plant Growth regulator							
No spray	2.72	9.58	54.02	5.19	39.51	31.02	36.93
One spray	2.99	10.16	55.83	6.83	41.40	35.93	40.38
Two spray	3.33	10.59	59.64	7.77	42.19	37.71	40.91
S.Em. ±	0.028	0.106	0.660	0.071	0.602	0.421	0.380
CD at 5%	0.082	0.312	1.947	0.209	1.756	1.241	1.121

water spray, CCC and Tebuconazole, respectively. The grain, straw and biomass yields of wheat due to different growth retardant treatments were found statistically at par.

Conclusions

The application of recommended dose of fertilizer at 150% was found superior in connection of growth, grain yield, gross income and net return. The PGR applied at two stage at 45 and 75 DAS gave shortest height, highest yield and more income. Thus the getting higher production and highest profit by farmer should applied 150% RDF with combination of PGR applied at 45 and 75 DAS.

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Response of Micronutrients on Yield and Yield Attributes of Blackgram (*Vigna mungo* L.)

Brijesh Kumar Meena*, D.P. Singh, S.C. Meena, K.K. Yadav, Arvind Verma and Hemant Swami

Department of Soil Science and Agricultural Chemistry, Rajasthan College of Agriculture, MPUAT, Udaipur

*Email : mimrote56@gmail.com

Abstract

A field experiment entitled "Response of Micronutrients on yield and Yield attributes of Blackgram (*Vigna mungo* L.)" was carried out at Agronomy Instructional Farm, Rajasthan College of Agriculture, Udaipur, which is located in Zone IVa (Semi-humid Southern Plain and Aravali Hills Zone) during *kharif* 2022. The experiment included nine treatments of micronutrient with RDF, including one common control in blackgram. Three replications of the experiment were set up in a randomised block design. The soil at the experimental site was a clay loam with a slightly alkaline reaction (8.12 pH), medium in available nitrogen (274.43 kg ha⁻¹) and phosphorus (17.50 kg ha⁻¹) and high in potassium (352.17 kg ha⁻¹).

Application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ increased significantly the yield attributes viz., effective nodules at 45 DAS, number of pods plant⁻¹, number of seeds pod⁻¹ and test weight, yields viz., seed, haulm and biological yield. Therefore, for increased yield of seeds and net return ha⁻¹ in Rajasthan's sub-humid Southern Plain and Aravalli Hills, the most profitable dose of micronutrient application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ is advised in this tract for the blackgram variety T-9 followed by application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹.

Key Words : Micro nutrients, yield, yield attributes, ZnSO₄, FeSO₄, Boron

Introduction

India is the largest grower and consumer of pulses in the world. The estimate for 2020-21 indicated that the total pulse production of India is 27.75 m tonnes from 25.58 m ha area productivity (Anonymous, 2022).

In Rajasthan, blackgram occupies 4.25 lakh ha area with a production of 1.56 lakh tones and productivity of 366 kg ha⁻¹ (Directorate of Economics & Statistics, Rajasthan, 2020-21).

One of the oldest and most well-known pulse crops, black gram (*Vigna mungo* L.), is a member of the Fabaceae family and is a key ingredient in Indian cuisine. According to Vavilov (1951), the origin of black gram is India. Chromosome number 2n = 22 is diploid in *Vigna mungo*, often known as urd bean. (Pradhan *et al.*, 2018). It is a self-pollinated, short-lived Leguminosae family crop with 24% protein, 1.4% fat, 59.6% carbohydrate, calcium (154 mg), phosphorus (385 mg), iron (9.1 mg), beta carotene (38 mg), riboflavin (0.37 mg), niacin (2 mg), and thiamine (0.4 mg) per 100 g seeds. (Aggarwal *et al.*, 2019).

Black gram is a tropical crop and it requires hot and humid climate. The ideal temperature for its cultivation ranges between 25°C to 35°C but it can tolerate temperatures up to 42°C. It can be grown in a variety of soils, from sandy loam to heavy clay with the exception of alkaline and saline soils. (Markam *et al.*, 2017).

Micronutrients are necessary elements that plants

utilize in minute amounts to coordinate a variety of physiological processes. Iron is an important micronutrient because it participates in redox reactions, and functions as a cofactor (Benepal, 1967). Iron (Fe) is a key enzyme of the nitrogenase complex in legume plants, and also for the electron carrier, i.e. ferredoxin (Rashid 2005; Imtiaz *et al.* 2010). Iron deficiency in plants is most common in calcareous and alkaline soils (Zhang *et al.*, 1995); (Mengel, 2001).

In India, zinc is considered as the third important yield limiting nutrient after nitrogen and phosphorus (Takkar and Randhawa 1978). According to Stevenson and Cole (1999), a healthy plant contains 27 to 150 mg Zn kg⁻¹ plant biomass. Zinc is also important in plant metabolism and the synthesis of auxins, carbohydrate, phosphate, and nucleic acid (Latef *et al.*, 2017). Zinc is an essential component of enzymes and proteins. It is the only metal found in all six enzyme classes, including oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases (Auld, 2001).

Boron deficiency in plants causes a variety of physiological issues. Sugar transport, cell wall synthesis, cell wall structure, and lipid metabolism are thought to require it. It is critical for the structural integrity of the plasma membrane. Boron increased K⁺ ion uptake and membrane bound ATPase activity, resulting in plasma membrane hyperpolarization. Schon *et al.* (1990) discovered that increased K⁺ ion influx caused by boron in day flowers improved stomatal opening and closing (*Commelina communis*). B is necessary for the

germination of pollen tubes, cell division, elongation, sterility of male flowers, and fruit and seed production in plants, according to Marschner (1995). Keeping in view the above facts, an investigation entitled “Response of Micronutrients on yield and Yield attributes of Blackgram (*Vigna mungo* L.)” was conducted during *kharif*, 2022 to assess effect of RDF, ZnSO₄, FeSO₄ and B on yield and yield attributes of Blackgram (*Vigna mungo* L.)

Materials and Methods

Crop was grown as per standard package of practices recommended by Indian council of agriculture research for Rajasthan. Variety “T-9 of blackgram was used in this experiment. The plots of 4.0 m x 3.0 m size were prepared. Basal dose of RDF, ZnSO₄, FeSO₄ and B were calculated as per treatment and mixed in the soil one week prior to sowing. Seed was drilled at 4-5 cm depth in the opened furrows, keeping row to row distance of 30 cm and plant to plant distance 10 cm. The crop was harvested from a net plot size of 3.7 m x 2.4 m separately, tied in bundles and after tagging these were left on the threshing floor for sun drying. After complete drying, bundles were weighed to record biological yields.

Fully matured and developed pods from randomly selected five plants from each plot were plucked and counted. The average pods plant⁻¹ were worked out. Fully matured and developed seeds from randomly selected five pods from each plot were plucked and counted. The average seed pod⁻¹ were worked out. Seed sample was drawn from threshed produce from each net plot yield. The weight of 100 seeds was recorded in gram. The numbers of effective root nodules were counted at 45 days. Five plants were selected from each plot and uprooted carefully. The soil mass associated with roots was removed carefully with the help of clean water and effective root nodules were counted to record root nodules per plant. After threshing and winnowing, clean seeds obtained from each net plot were weight and converted into kg ha⁻¹. The haulm yield was calculated by subtracting seed yield from the respective biological yield and expressed in terms of kg ha⁻¹. After complete drying, total unthreshed produce from each net plot was weighed to record biological yield and then converted into kg ha⁻¹. Harvest index (%) was worked out by dividing economic yield (seed yield) to the biological yield (seed +haulms yield) was worked out and expressed in percentage. In order to evaluate the most profitable treatment combination, economics of different treatments were worked out in terms of net returns and net returns per rupee investment. First of all, cost of cultivation was calculated then a gross return was estimated on the basis of the total yield (kg) per ha. The data recorded for the evaluation of different parameters was statistical analyzed

using standard procedure for ANOVA of Randomized Block Design in order to test the significance of experimental results. The analysis of variance was done by the method suggested by Fisher (1954) and using analysis as described by Panse and Sukhatme (1995).

Results and Discussion

Response of Micronutrients on yield and Yield attributes of Blackgram (*Vigna mungo* L.)

Effective nodules at 45 DAS : The critical appraisal of data presented in Table-1 revealed that application of 100% RDF with micronutrient significantly improved the number of effective nodules at 45 DAS in blackgram. Highest effective root nodules at 45 DAS recorded under application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹, increased significantly over rest of the treatments. Data further showed that application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹ also significantly increased on effective nodules at 45 DAS as compared to application of 100% RDF + 25 kg ZnSO₄ ha⁻¹, 100% RDF + 25 kg FeSO₄ ha⁻¹, 100% RDF + 5 kg B ha⁻¹, 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄ + 5 kg B ha⁻¹ and application of 100% RDF + 25 kg ZnSO₄ + 5 kg B ha⁻¹.

Application of 100% RDF + 25 kg ZnSO₄ ha⁻¹ also significantly increased the effective nodules at 45 DAS over 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄ ha⁻¹ and application of 100% RDF + 5 kg B ha⁻¹. The effective nodules at 45 DAS was increased by 8.63, 10.83, 31.87, 60.72 per cent with application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ over application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹, 100% RDF + 25 kg ZnSO₄ ha⁻¹, 100% RDF and control, respectively.

Number of pods plant⁻¹ : Data presented in Table-2 revealed that number of pods plants⁻¹ enhanced significantly with application of 100% RDF with Zn, Fe and B micronutrients. Significantly maximum number of pods plants⁻¹ (37.53) found with application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ over rest of the treatments. Application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹ (34.50) also significantly increased on number of pods plants⁻¹ as compared to application of 100% RDF + 25 kg ZnSO₄ ha⁻¹, 100% RDF + 25 kg FeSO₄ ha⁻¹, 100% RDF + 5 kg B ha⁻¹, 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄ + 5 kg B ha⁻¹ and application of 100% RDF + 25 kg ZnSO₄ + 5 kg B ha⁻¹.

Data further showed that application of 100% RDF + 5 kg ZnSO₄ ha⁻¹ (31.50) also significantly increased the number of pods plants⁻¹ over 100% RDF and control, which was remained at par with application of 100% RDF

Table-1 : Effect of micronutrients application on effective root nodules at 45 DAS of blackgram

Treatments	Effective root nodules at 45 DAS
T1: Control	11.66
T2: 100% RDF	14.21
T3: 100% RDF + 25 kg ZnSO ₄ ha ⁻¹	15.75
T4: 100% RDF + 25 kg FeSO ₄ ha ⁻¹	15.71
T5: 100% RDF + 5 kg B ha ⁻¹	15.69
T6: 100% RDF + 25 kg ZnSO ₄ + 25 kg FeSO ₄ ha ⁻¹	17.25
T7: 100% RDF + 25 kg ZnSO ₄ + 5 kg B ha ⁻¹	17.24
T8: 100% RDF + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	17.22
T9: 100% RDF +25 kg ZnSO ₄ + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	18.74
SEm±	0.48
CD (5%)	1.45

Table-2 : Effect of micronutrients application on yield attributes of blackgram.

Treatments	Yield attributes		
	Number of pods plant ⁻¹	Number of seeds pod ⁻¹	Test weight (g)
T1: Control	24.55	3.61	33.70
T2: 100% RDF	27.80	4.03	37.10
T3: 100% RDF + 25 kg ZnSO ₄ ha ⁻¹	31.50	4.47	40.00
T4: 100% RDF + 25 kg FeSO ₄ ha ⁻¹	31.30	4.43	39.80
T5: 100% RDF + 5 kg B ha ⁻¹	30.53	4.41	39.70
T6: 100% RDF + 25 kg ZnSO ₄ + 25 kg FeSO ₄ ha ⁻¹	34.50	4.93	43.00
T7: 100% RDF + 25 kg ZnSO ₄ + 5 kg B ha ⁻¹	34.40	4.92	42.90
T8: 100% RDF + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	34.20	4.90	42.70
T9: 100% RDF +25 kg ZnSO ₄ + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	37.53	5.34	45.70
SEm±	0.90	0.13	0.84
CD (5%)	2.69	0.40	2.51

+ 25 kg FeSO₄ha⁻¹ and application of 100% RDF + 5 kg B ha⁻¹. The number of pods plants⁻¹ was increased by 8.78, 19.14, 35, 52.87 per cent with application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ over application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹, 100% RDF + 25 kg ZnSO₄ha⁻¹, 100% RDF and control, respectively.

Number of seeds pod⁻¹ : An examination of data in Table-2 showed that application of 100% RDF with micronutrient significantly improved the number of seeds pod⁻¹ in blackgram. Highest number of seeds pod⁻¹ (5.34) recorded under application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹, increased significantly over rest of the treatments. Data further showed that application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹ (4.93) also significantly increased on number of seeds pod⁻¹ as compared to application of 100% RDF + 25 kg ZnSO₄ha⁻¹, 100% RDF + 25 kg FeSO₄ ha⁻¹, 100% RDF + 5 kg B ha⁻¹, 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄ + 5 kg B

ha⁻¹ and application of 100% RDF + 25 kg ZnSO₄ + 5 kg B ha⁻¹.

Application of 100% RDF + 25 kg ZnSO₄ ha⁻¹ (4.47) also significantly increased the number of seeds pod⁻¹ over 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄ha⁻¹ and application of 100% RDF + 5 kg B ha⁻¹. The number of seeds pod⁻¹ was increased by 8.31, 10.91, 32.50, 47.92 per cent with application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ over application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹, 100% RDF + 25 kg ZnSO₄ha⁻¹, 100% RDF and control, respectively.

Test weight : The study of data presented in Table-2 indicated that test weight of blackgram enhanced significantly with application of 100% RDF with Zn, Fe and B micronutrients. Significantly highest test weight (45.70g) found with application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ over rest of the treatments. Application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹ (43.0g) also significantly increased on test weight as

Table-3 : Effect of micronutrients application on yield and harvest index of blackgram.

Treatments	Yield (kg ha ⁻¹)			Harvest index (%)
	Seed	Haulm	Biological	
T1: Control	538	1029	1568	34.07
T2: 100% RDF	651	1183	1835	35.64
T3: 100% RDF + 25 kg ZnSO ₄ ha ⁻¹	762	1340	2103	36.24
T4: 100% RDF + 25 kg FeSO ₄ ha ⁻¹	747	1334	2081	35.89
T5: 100% RDF + 5 kg B ha ⁻¹	730	1316	2046	35.68
T6: 100% RDF + 25 kg ZnSO ₄ + 25 kg FeSO ₄ ha ⁻¹	863	1479	2341	36.85
T7: 100% RDF + 25 kg ZnSO ₄ + 5 kg B ha ⁻¹	856	1478	2334	36.69
T8: 100% RDF + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	844	1467	2311	36.51
T9: 100% RDF +25 kg ZnSO ₄ + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	944	1614	2558	36.92
SEm±	26	41	62	0.79
CD (5%)	78	124	185	NS

Table-4 : Effect of micronutrients application on economic.

Treatments	Net returns (₹ ha ⁻¹)	B : C ratio
T1: Control	17790	1.82
T2: 100% RDF	23148	1.95
T3: 100% RDF + 25 kg ZnSO ₄ ha ⁻¹	29612	2.15
T4: 100% RDF + 25 kg FeSO ₄ ha ⁻¹	28652	2.12
T5: 100% RDF + 5 kg B ha ⁻¹	28593	2.17
T6: 100% RDF + 25 kg ZnSO ₄ + 25 kg FeSO ₄ ha ⁻¹	35620	2.31
T7: 100% RDF + 25 kg ZnSO ₄ + 5 kg B ha ⁻¹	36066	2.39
T8: 100% RDF + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	35307	2.36
T9: 100% RDF +25 kg ZnSO ₄ + 25 kg FeSO ₄ + 5 kg B ha ⁻¹	40899	2.50
SEm±	1825	0.08
CD (5%)	5472	0.24

compared to application of 100% RDF + 25 kg ZnSO₄ha⁻¹, 100% RDF + 25 kg FeSO₄ ha⁻¹,100% RDF + 5 kg B ha⁻¹,100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄+ 5 kg B ha⁻¹and application of 100% RDF + 25 kg ZnSO₄+ 5 kg B ha⁻¹.Data further showed that application of 100% RDF + 25 kg ZnSO₄ha⁻¹ (40.00g) also significantly increased the test weight over 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄ha⁻¹and application of 100% RDF + 5 kg B ha⁻¹. The application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹was increased test weight by8.78, 13.30, 23.18, 35.60 per cent over application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹, 100% RDF + 25 kg ZnSO₄ha⁻¹,100% RDF and control, respectively.

Seed yield : An examination of data in Table-3 showed that seed yield of blackgram influenced by the application of micronutrient with 100% RDF. Significantly highest seed yield (944 kg ha⁻¹) recorded under application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ over rest of the treatments. Application of 100% RDF + 25

kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹ (863 kg ha⁻¹) also significantly increased on seed yield by 13.25, 15.52, 18.21, 32.56,75.46 per cent over application of 100% RDF + 25 kg ZnSO₄ha⁻¹, 100% RDF + 25 kg FeSO₄ ha⁻¹,100% RDF + 5 kg B ha⁻¹,100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄+ 5 kg B ha⁻¹and application of 100% RDF + 25 kg ZnSO₄ + 5 kg B ha⁻¹.

Data further showed that application of 100% RDF + 25 kg ZnSO₄ha⁻¹ (762 kg ha⁻¹) also significantly increased the seed yield by 17.05,41.63, 2.0, 4.38 per cent over 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO₄ha⁻¹and application of 100% RDF + 5 kg B ha⁻¹. The magnitude of increase was 9.38,23.88, 45.0, 75.46 per cent in application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹over application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹, 100% RDF + 25 kg ZnSO₄ha⁻¹,100% RDF and control, respectively.

Haulm yield : It is obvious from the data in Table-3 showed that haulm yield of blackgram significantly

affected with application of micronutrient with 100% RDF. Maximum haulm yield (1614 kg ha^{-1}) recorded under application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 + 5 kg B ha^{-1} , increased significantly over rest of the treatments. Data further showed that application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 (1479 kg ha^{-1}) ha^{-1} also significantly increased on haulm yield of blackgram as compared to application of 100% RDF + 25 kg ZnSO_4 ha^{-1} , 100% RDF + 25 kg FeSO_4 ha^{-1} , 100% RDF + 5 kg B ha^{-1} , 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO_4 + 5 kg B ha^{-1} and application of 100% RDF + 25 kg ZnSO_4 + 5 kg B ha^{-1} . Application of 100% RDF + 25 kg ZnSO_4 ha^{-1} (1340 kg ha^{-1}) also significantly increased the haulm yield over 100% RDF and control, which was remained at par with application of 100% RDF + 25 kg FeSO_4 ha^{-1} and application of 100% RDF + 5 kg B ha^{-1} . The haulm yield was increased by 9.12, 20.44, 36.43, 56.85 per cent with application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 + 5 kg B ha^{-1} over application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 ha^{-1} , 100% RDF + 25 kg ZnSO_4 ha^{-1} , 100% RDF and control, respectively.

Biological yield : Data given in Table-3 showed that application of 100% RDF with micronutrient significantly improved the biological yield of blackgram. Highest biological yield (2558 kg ha^{-1}) observed under application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 + 5 kg B ha^{-1} (T_9), increased significantly over rest of the treatments. Data further showed that application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 ha^{-1} (T_6 , 2341 kg ha^{-1}) also significantly increased on biological yield as compared to application of 100% RDF + 25 kg ZnSO_4 ha^{-1} (T_3), 100% RDF + 25 kg FeSO_4 ha^{-1} (T_4), 100% RDF + 5 kg B ha^{-1} (T_5), 100% RDF (T_2) and control (T_1), which was remained at par with application of 100% RDF + 25 kg FeSO_4 + 5 kg B ha^{-1} (T_8) and application of 100% RDF + 25 kg ZnSO_4 + 5 kg B ha^{-1} (T_7). Application of 100% RDF + 25 kg ZnSO_4 ha^{-1} (T_3 , 2103 kg ha^{-1}) also significantly increased the biological yield over 100% RDF (T_2) and control (T_1), which was remained at par with application of 100% RDF + 25 kg FeSO_4 ha^{-1} (T_4) and application of 100% RDF + 5 kg B ha^{-1} (T_5). The magnitude of increase was 9.26, 21.63, 39.40, 63.13 per cent in application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 + 5 kg B ha^{-1} (T_9) over application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 ha^{-1} (T_6), 100% RDF + 25 kg ZnSO_4 ha^{-1} (T_3), 100% RDF (T_2) and control (T_1), respectively.

Harvest index : Data presented in Table-3 revealed that harvest index of blackgram was not affected significantly with application of 100% RDF with Zn, Fe and B micronutrients.

Economics of treatment

Net returns : Data presented in Table-4 revealed that highest net returns (Rs. 40899.00) recorded with application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 + 5 kg B ha^{-1} (T_9), increased significantly over application of 100% RDF + 25 kg FeSO_4 + 5 kg B ha^{-1} (T_8 , Rs. 35307.00), 100% RDF + 5 kg B ha^{-1} (T_5 , Rs. 28593.00), 100% RDF + 25 kg FeSO_4 ha^{-1} (T_4 , Rs. 28652.00), 100% RDF + 25 kg ZnSO_4 ha^{-1} (T_3 , Rs. 29612.00), 100% RDF (T_2 , Rs. 23148.00) and lowest in control (T_1 , Rs. 17790.00), which was remained at par with application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 ha^{-1} (T_6 , Rs. 35620.00) and 100% RDF + 25 kg ZnSO_4 + 5 kg B ha^{-1} (T_7 , Rs. 36066.00).

B C ratio : The present study of data presented in Table-4 indicated that highest B C ratio (2.50) was fetched under application of 100% RDF + 25 kg ZnSO_4 + 25 kg FeSO_4 + 5 kg B ha^{-1} followed by application of 100% RDF + 25 kg ZnSO_4 + 5 kg B ha^{-1} .

The increase in yield attributes viz., effective nodules at 45 DAS, number of pods plant⁻¹, number of seeds pod⁻¹ and test weight of blackgram observed after applying micronutrients to the soil may be attributed to the plant's adequate availability of zinc and iron, which may have improved catalytic or stimulatory effects on the majority of plant physiological and metabolic processes (Zhang *et al.*, 2020). Zinc also increases the cation exchange capacity of roots, which improves the absorption of vital nutrients. Zinc's involvement in the biosynthesis of indole acetic acid (IAA) and, in particular, in the initiation of primordia for reproductive parts and the partitioning of photosynthates towards them (Wear and Hagler, 1968) may have contributed to the increase in yield attributes. This could have led to improved flowering and fruiting.

Sarker *et al.*, (2002) reported that the use of B and Zn had a good influence on haulm yield. The application of B was found to significantly alter haulm output. Micronutrient B is necessary for the integrity of cell walls, cell division and nitrogen fixation. The metabolism of carbohydrates and the movement of sugar inside plants are facilitated by B. Krishnaveni *et al.*, (2004) have found findings that are similar. A balanced intake of these two nutrients may have helped to boost yield metrics such as test weight, total biomass, number of pods plant⁻¹ and seed yield. These results were consistent with those of Rathod *et al.*, (2020). In addition to providing better nutrition over a longer period of time and having a synergistic effect of both nutrients on the yield component (Kobraee *et al.*, 2011), the addition of zinc, iron and B to the soil may have also caused higher activation of micronutrients, primarily due to their beneficial effects in mobilising the native nutrients to increase their

availability. Similar outcomes were also recorded when micronutrients were applied to the soil in the following studies: Choudhary *et al.*, (2014) in greengram, Jha *et al.*, (2015) in blackgram, Todawat *et al.*, (2017) in greengram.

Data further showed that highest yield yields viz., seed, haulm and biological yield of blackgram recorded under application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ followed by application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹, which was remained at par with application of 100% RDF + 25 kg FeSO₄ + 5 kg B ha⁻¹ and application of 100% RDF+ 25 kg ZnSO₄ + 5 kg B ha⁻¹. This might be due applying fertiliser by itself only gave one or two nutrients, but using micronutrient fertilisers in combination has given the plant all the necessary elements in the right amounts for growth and development (Kobraeeet *et al.*, 2011). By applying extra nutrients through fertilisers, the deficiency has been filled up and the blackgram crop has produced greater yield attributes. This could be the result of both the low status of the relevant nutrients in the experimental field and the cumulative influence of all the nutrients. The physiological functions of various nutrients improve yield characteristics, which in turn raises the blackgram biological yield as well as its seed and haulm yield. Results that are comparable were also reported by Chaudhary *et al.*, (2014) in green gram, Jha *et al.*, (2015) in blackgram, Todawat *et al.*, (2017) in greengram, when micronutrients (Fe and Zn) were applied.

Conclusions

Based on the results of a year experiment entitled "Response of Micronutrients on Yield and yield attributes of Blackgram (*Vigna mungo* L.)" was carried out at Agronomy Instructional Farm, Rajasthan College of Agriculture, Udaipur in the *kharif* season of 2022. It was concluded that in the prevailing agro-climatic conditions of Zone IVa (Sub-humid Southern Plain and Aravali Hills) of Rajasthan, blackgram crop fertilised with 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ gave higher productivity and profitability. Consequently, it can be said that application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ + 5 kg B ha⁻¹ is an inexpensive and natural approach to improve soil fertility and boost blackgram productivity. Data also concluded that application of 100% RDF + 25 kg ZnSO₄ + 25 kg FeSO₄ ha⁻¹ gave higher productivity and profitability

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RNA Interference and Plant Virus Suppressors

Josiya Joy* and Radhika N.S.

Department of Plant Pathology, College of Agriculture, Vellayani-695522,
Thiruvananthapuram, Kerala

*Email : josiya1194@gmail.com

Abstract

RNA interference (RNAi) is a potent tool for silencing genes in a broad range of organisms. A form of RNAi involves expression of a double-stranded RNA (dsRNA) or small interfering RNA (siRNAs) that trigger degradation of target mRNA sequences by posttranscriptional gene silencing (PTGS). RNAi-based, host-induced gene silencing (HIGS) is a potentially powerful strategy for disease control in various organisms. Plant siRNAs and miRNAs, collectively termed "small RNAs" exhibit 3', 2-nt overhangs and become stabilized through 3' end methylation by Hsu1. Later one of the two sRNA strands will be loaded onto an argonaute (AGO) protein. The 21 and 22 nt siRNAs are incorporated into argonaute containing RISC for silencing or translational inhibition. To counteract RNA silencing, viruses have evolved an effective strategy to protect themselves by the expression of viral suppressors (VSR) of RNA silencing. Viral suppressors of RNA silencing interfere with host miRNA function, causing developmental defects or disease symptoms in the host plants. Viral suppressors target at viral RNA recognition, dicing, RISC assembly, RNA targeting and amplification steps of RNA silencing.

Introduction

As sessile organisms, plants have to endure a range of adverse conditions imposed by various biotic and abiotic stressors that diversely affect growth, development, and yield of plants. The occurrences and severity of the stress or may vary depending on the locality and natural environment. In particular, biotic stresses caused by the living organisms largely depend on the availability of suitable environments that activate specific organisms to infect their hosts. Among different kinds of biotic stressors that have existed since ancient time, bacteria, fungi, nematodes, and viruses are capable of causing different types of plant diseases. In response to an attacker, plants activate a specific set of defence mechanisms correlated pathways, leading to either increased resistance (limits pathogen multiplication) or enhanced tolerance (reduces the effect of infection) depending on the nature of pathogen and host.

RNA interference (RNAi) or RNA silencing is one of the important defence mechanisms that protect plants from pathogen infection and it controls sequence specific regulation of gene expression (Puyam *et al.*, 2017). The phenomenon of RNAi was first reported in the early 1990s and it was hypothesized that introduced genes potentially co-suppressed the endogenous genes, but soon it was observed that homologous RNA sequences caused the suppression of internal genes. The term RNA silencing was first used in a study on an animal (*Caenorhabditis elegans*) and it was observed that introduction of sense or

antisense RNA caused degradation of the par-1 gene. Later, it was reported that interference of double-stranded RNAs (dsRNA) was more significant in both the injected animals and their progenies. After two years, it was found that dsRNAs could convert to shorter small interfering RNAs (siRNAs) and bind to their homologous target messenger RNAs (mRNAs). These siRNAs also guide and instruct the multicomponent RNA-induced silencing complexes (RISCs) to cleave the specific RNAs. The RNase III family enzymes were found to be involved in the cleavage of dsRNAs and could produce putative guide RNAs (Dubrovina and Kiselev, 2019).

RNA Interference is an ancient mechanism with a promising future. In the age of generating CRISPR/Cas9-mediated gene knockouts, RNAi is still desirable as they create knockdowns, which can be useful for gene functional studies in cases where null alleles might be lethal. Moreover, it may be challenging to knockdown multiple genes of a family simultaneously, using CRISPR, but those can be achieved relatively easily using RNAi. CRISPR-mediated knockouts are permanent, while RNAi can transiently knockdown target genes, apart from creating stable transgenics. In plants, silencing is of two types: transcriptional and post transcriptional gene silencing. In both types, the inactivated genes are in trans position as homologous genes upon interaction reside on opposite chromosomes. TGS and PTGS differ from each other with respect to the underlying mechanism they exhibit. TGS requires sequence homology between promoters as compared to

PTGS which require homology between coding region of the interacting genes.

2. Types of gene silencing

2.1 Transcriptional gene silencing (TGS) : In TGS, an inactive allele residing on one chromosome can render another allele silenced. The mechanism behind transcriptional gene silencing is suggested to be DNA-DNA interaction which is thought to play an important role (Luff *et al.*, 1999). In other studies, it was proposed that RNA molecules interact with DNA and subsequently induce DNA methylation which then leads to gene silencing (Pelissier *et al.*, 1999). However, it is not clear whether methylation of DNA alone is sufficient for silencing or not. It is proposed that DNA methylation in promoter region has a strong negative effect on interaction of certain transcription factors with promoter.

2.2 Post transcriptional gene silencing (PTGS) : 'RNA interference' (RNAi) is a conserved mechanism of post transcriptional gene silencing (PTGS). It has rapidly gained favour as a "reverse genetics" tool to knock down the expression of targeted genes in plants. The term RNAi was coined in 1998 by Fire and Mello to describe a gene-silencing phenomenon based on double-stranded RNA (Kasschau and Carrington (1998)). PTGS mechanism controls processes including development, the maintenance of genome stability and defense against molecular parasites (transposons and viruses). Several reports pointed out that PTGS in plants is strictly linked to RNA virus resistance mechanism.

3. RNA interference- Basic mechanism : RNAi is a natural defence pathway evolved in plants against viruses and potential transposons. It is a cellular pathway in which target sequences are degraded on homology basis at mRNA level by small RNAs, thereby preventing the translation of target RNAs. In plants, two functionally different RNAs; microRNA (miRNA) and small interfering RNA (siRNA), have been characterized. The miRNAs are small 21-26nt long dsRNAs that are genome coded and are endogenous to every cell. Structurally, they comprised of a stem region which is double stranded and a loop region which is single stranded. The miRNAs generated from endogenous hpRNA precursors and are basically. Upon viral attack, long dsRNAs are produced from the replication intermediates of viral RNAs that act as substrate for an endonuclease termed Dicer which is located in the cytosol (Hamilton *et al.*, 2002).

Dicer recognizes these dsRNAs and cleaves them into duplex siRNA (21-25 nt) (Tijsterman and Plasterk, 2004). The siRNA duplex comprised of two strands; strand complementary to target mRNA is guide strand and other is passenger strand. The guide strand of short

siRNA duplex is incorporated into the RNA-induced silencing complex (RISC) and then siRNA programmed RISC degrade viral RNA. As the RISC complex encounters a foreign mRNA which could be of virus origin, it has two consequences. 1) If the homology of guide strand and target mRNA is 100 per cent, then perfect complement form between them resulting in mRNA cleavage and subsequent degradation or 2) in case of imperfect complement, where few mismatches exist between guide strand of RISC and target mRNA, translation of target mRNA is inhibited. Same mechanism operates in microRNA triggered gene silencing. miRNAs processed from stem loop precursors (shRNA and/or hpRNA) and requires Dicer activity (Gregory *et al.*, 2005) followed by RISC is a combination of Dicer (an endonuclease enzyme), some accessory proteins namely argonaute (ago1, 4, 6, 9; catalytic endonucleases) and RNA binding proteins (RBP), and some trans-acting RNA-binding proteins (TRBP) (Schwarz *et al.*, 2003). Stability of RNAi induced silencing is based on enzymatic methylation of siRNA. This reaction is catalyzed by the enzyme methyltransferase (HEN1) which methylates the siRNA at 3' end, hereby preventing it from oligouridylation and subsequent degradation.

3.1 Dicer-Like Proteins (DCLs) : DCLs are the RNase III family of endoribonucleases that contain DExD-box Helicase-C, Piwi- Argonaute- Zwillie (PAZ) domain, the Domain of unknown function 283 (DUF283), RNase III, and dsRNA-binding domains (dsRBDs). These proteins perform the initiation stage of the RNAi mechanism, in which dsRNAs are cleaved into small RNAs 21–24 nt in length. The helicases are enzymes that induce the separation of double-stranded nucleic acids, utilizing the free energy and hydrolyzing a nucleotide triphosphate to displace bound proteins. A functional DExD/H-box helicase domain is also required for the efficient production of DCLs-dependent sRNAs production. PAZ domain has a phosphate-binding pocket composed of arginine components that recognize the 5' monophosphate of pre-miRNAs and are required for cleavage of dsRNAs. DUF283 acts as an annealer that assists hybridization between the complementary strands of nucleic acids (Nicholson, 2014). The function of RNase III domain is to cleave dsRNA, leaving the 2 nt overhang at 3' end of the product. The N- or C-terminal of dsRBDs participate in the regulation of the protein nucleo-cytoplasmic distribution and also have the capacity to bind to dsRNAs. The specific function of each domain varies depending on the Dicer protein (Barraud *et al.*, 2014).

Dicer proteins are conserved across the plant kingdom and up to date, various DCL proteins have been identified in different plant species, which are classified

Table-1 : Viral suppressors of RNA interference.

Action	Suppressor	Virus
ds RNA Binding	P14	Potato leaf roll virus
	P38	Turnip crinkle virus
	NSs	Tomato spotted wilt virus
Blocking DCL4 and DCL3	P1	Rice yellow mottle virus
	P38	Turnip crinkle virus
ds SiRNA Cleavage	Rnase 3	Sweet potato chlorotic stunt virus
Sequestering ds SiRNA	P19	Grapvine leaf roll virus-3
	2b-AV-2	Cucumber mosaic Virus
	HCPPro	Potyvirus
HEN – Binding	HCPPro	Potyvirus
Interaction with AGO 1 of formed RISC	SPMMV P1	Sweet potato mild mottle virus
AGO 1 Degradation	P25	Potex virus
	P0	Potato leaf roll virus
AGO 1 Inactivation	P38	Turnip crinkle virus
	2b	Cucumber mosaic Virus
	SPMMV P1	Sweet potato mild mottle virus
AGO 2 degradation	P25	Potex virus
	P0	Potato leaf roll virus
AGO R inactivation	P38	Turnip crinkle virus
Increase Pre mi R168	P19	Tombusvirus
RDR6 Inhibition	HC Pro	Potyvirus
SGS3 Inactivation	P25	Potexvirus
	VPg	Potato virus A

into four distinct clades. Plant DCLs produce different size of sRNAs: DCL1 produces 21 and 22 nt sRNAs from the short imperfectly hairpins RNAs, while DCL2, DCL3, and DCL4 produce 22 nt, 24 nt and 21 nt, respectively from long perfectly paired RNAs (Banerjee *et al.*, 2014). DCL1 is involved in the generation and processing of miRNAs. Viral ds RNAs processed by DCL2 and DCL3 are required for chromatin modification and also produce heterochromatic siRNAs (hc-siRNAs). DCL3 is also an important element of RNA-directed DNA methylation (RdDM) pathways and it processes RDR2 generated dsRNAs into siRNA. DCL4 processes trans-acting small interfering RNAs (ta-siRNAs) and can be a substitute for DCL1 and DCL2 when these two are missing. The product of DCLs or initiation stage is loaded into the RISCs for further processing (Hohn *et al.*, 2011).

3.2 Argonaute (AGO) Proteins : AGO proteins are highly specialized sRNA-binding modules and are considered to be the essential components of RISCs in silencing pathways. AGO proteins perform the effector phase of silencing and the small RNAs produced in the initiation stage are loaded into AGO proteins to guide sequence-specific regulation of gene expression. Structural analysis shows that AGO proteins contain three

conserved domains, such as PAZ, Middle (MID) and P-element induced wimpy (PIWI) domains (Mallory *et al.*, 2011). The N-terminal domain is composed of the N-terminal region and PAZ domain which facilitate the separation of small RNAs and anchor the 3' end of the bound small RNA, respectively. The C-terminal lobe contains MID, PIWI domains and a binding pocket at the junction of these domains that anchors the 5' end of small RNAs (Parker, 2010). However, the PIWI domain can function similarly to RNase H that cleaves target mRNA. Plant AGO proteins are classified into four groups and each group performs a specific function. These proteins are involved in DNA methylation and epigenetic silencing miRNA-mediated silencing pathways and stage transition of plants from the juvenile to the adult stage of growth. The most important function of AGO proteins is to enhance the defense and immunity of plants through cleavage of the loaded small RNAs (Simon *et al.*, 2011).

3.3 RNA-Dependent RNA polymerase (RDR) proteins : The third phase of RNAi pathways is an amplification of silencing, performed by RDRs, which convert ssRNAs to dsRNAs and these dsRNAs are again processed by DCLs, leading to a new cycle of RNA silencing. In sRNAs,

the phased and repeat-associated siRNAs depend on RDRs for biogenesis, while miRNAs and hairpin-derived sRNAs are RDRs independent RNAs. The activity of RDR was first studied in Chinese cabbage during 1971 and cDNA was isolated from tomato. RDRs are considered as the first identified component of plants small RNAs biogenesis pathways and characterized by a unique RNA-dependent RNA polymerase catalytic domain (RdRp) (Zong *et al.*, 2009).

RdRps belong to the Structural Classification of Proteins (SCOP) and initially, these proteins were identified as an enzyme in the RNA viruses that participated in the replication of the virus genome. RdRps also have a role in the maintenance of genome integrity, RNA-template formation, PTGS, and defense against external RNA or DNA (Venkataraman *et al.*, 2018). RDR proteins of eukaryotic organisms are divided into three main classes, RDR α , RDR β , and RDR γ . RDR α exists in all three kingdoms. Animals comprise the RDR β protein missing the RDR γ , whereas RDR γ is present in plants and fungi contain both RDR β and RDR γ proteins (Bai, 2012).

3.4 The RNA-induced silencing complex (RISC) : In order to guide suppression of homologous targets, the sRNA duplex must become single-stranded which needs a less stable strand with the 5' phosphate end of the helix that is incorporated as a guide RNA into an effector complex containing an AGOs (Schwarz *et al.* 2003). Two types of effector complexes *viz.* cytoplasmic and nuclear complexes have been described for induction of RNAi. Cytoplasmic complex, known as the RNA-induced silencing complex (RISC) can mediate both mRNA cleavage and translational inhibition (Sigova *et al.* 2004). RISC is a multi-subunit, large assembly of 250-500 kDa, associated with the single stranded fragments of the si- or miRNA (Omarov *et al.* 2007).

3.5 siRNA interference pathways : In plants, RNA silencing is triggered by double-stranded RNA (dsRNA) or hairpin RNA (hpRNA) of different sizes and origins. The trigger dsRNA molecules can be synthesized by RNA-templated RNA polymerization or hybridization of complementary transcripts. Small RNAs can be classified as exogenous small interfering RNAs (siRNAs), repeat-associated siRNAs (rasiRNAs), trans-acting siRNAs (ta-siRNAs), natural cis-antisense siRNAs (nat-siRNAs), long siRNAs (lsiRNAs) and microRNAs (miRNAs) on the basis of their origin and function (Diaz-Pendon *et al.*, 2007).

siRNAs are cis-acting, as they are derived from viruses, transgenes and transposons, and degrade source RNA molecules. In contrast, miRNAs and ta-siRNAs do not originate from the genes they regulate,

and miRNAs are derived from endogenous transcripts which contain short complementary inverted repeats and from hairpin-like dsRNA. The principal mode of action of plant miRNAs is similar to siRNAs, primarily targeting the coding region and reducing gene expression via mRNA cleavage (Tiwari, 2013).

Most plant miRNAs regulate transcription factors which are required at various stages of plant development. The importance of miRNAs during development was first realized when developmental abnormalities were observed in miRNA pathway mutants, such as the carpel factory (caf), short integuments 1 (sin1), suspensor (sus1) and embryo defective 76 (emb76) mutants which contain mutations in the DCL1 gene. Likewise, the hyponastic leaves 1 (hyl1) mutant displays impaired hormone response and flower development, and the transition from the juvenile to adult vegetative phase is delayed in the hua enhancer 1 (hen1) mutant. In addition to transcription factors, plant miRNAs have also been shown to target ATP-sulfurylases, superoxide dismutases, laccases and ubiquitin conjugating enzymes (Tiwari, 2013).

4. Viral suppressors of RNA interference : To counteract RNA silencing, viruses have evolved an effective strategy to protect themselves by the expression of viral suppressors of RNA silencing (VSRs) (Csorba *et al.*, 2016) (Table 1).

4.1 Helper Component Protein (HC-Pro) of Potyvirus : The multifunctional potyviral HCPro contains variable regions with some functionally conserved domains, such as the FRNK box. Natural variants occur at the FRNK box, a conserved central domain, known for its role in RNA binding and RNAi suppression activities, although no dominant natural variants for the N182 residue are known to occur. HC-Pro is the first identified suppressor of RNA silencing (Sahana *et al.*, 2014).

De *et al.* (2020) reported that mutations in HCPro partially eliminated HCPro-varicose (VCS) co-localization in cells. HCPro^{WD} (wil type) induced PGs (PVA induced granules), introduced VCS into PGs, and suppressed RNA silencing. Accordingly, PVA carrying HCPro^{WD} (PVA^{WD}-mutated) infected *Nicotiana benthamiana* less efficiently than wild-type PVA (PVA^{WT}) and HCPro^{WD} complemented the lack of HCPro in PVA gene expression only partially.

4.2 P19-Tombusviridae : P19 suppresses silencing by sequestering siRNAs, thereby preventing their incorporation into the RISC complex to serve as guides. Also, Kontra *et al.* (2016) reported that, elimination of p19 resulted in loss of miR168 induction and in parallel enhanced AGO1 accumulation. Their data showed that

the induction of AGO1 mRNA accumulation in virus-infected tissue is a part of a host defense reaction, whereas enhanced accumulation of miR168 is primarily mediated by viral-encoded p19 RNA silencing suppressor.

4.3 P38-Turnip crinkle virus : Turnip crinkle virus (TCV) is a positive single stranded RNA virus belonging to the *Carmovirus* genus of the *Tombusviridae* family. The TCV genome encodes 7 proteins, including two replicase proteins (P28 and P88), two movement proteins (P8 and P9), and the coat protein (CP; P38). P38 is an important VSR present in TCV. Suppressor deficient mutant- TCV CPB was not able to elicit disease symptoms in wild-type host plants (Zheng *et al.*, 2019).

4.4 2b-Cucumber mosaic virus : CMV 2b interferes with miRNA pathways and abrogates RNA silencing by direct interaction with AGO1 and inhibition of its slicer activity. The degree of this inhibition is positively correlated with the protein level. Whether CMV 2b causes any developmental defects depends on the steady level of intact 2b protein *in vivo*. AGO1 is a key factor for VIGS. Direct interference with or usurpation of this core component is an effective strategy for CMV to block VIGS and to evade host defense. This strategy may be used by other suppressors as well (Zhao *et al.*, 2018).

4.5 p25- Potato virus X : In grafting experiments or with movement defective forms of PVX, could not detect systemic silencing unless the 25 kDa viral movement protein (p25) was made non-functional. PVX p25 interacts with the chloroplast protein Ferredoxin 1 (FD1). In an assay conducted by Yang *et al.* (2020), plasmids encoding FD1-Green fluorescent protein (GFP) and p25 were transiently expressed in *N. benthamiana*, with unfused GFP being used as a negative control, and GFP-TRAP-M beads being used to collect GFP-containing proteins and any interacting partners accumulating in the plants. Although expression of all the proteins was confirmed in the plants, p25 was co-precipitated only in the presence of FD1-GFP and not when expressed alone or together with unfused GFP. Also, PVX and p25 reduced the accumulation of FD1 resulting in the RNAi suppression and overexpression of FD1 in *N. benthamiana* reduced accumulation of PVX.

4.6 NSs- Tomato potted wilt virus : Tomato potted wilt virus has a segmented negative-stranded RNA linear genome. These L, M and S segments are 8.8kb, 4.8kb and 3kb respectively and encode for six proteins. Ocampo *et al.* (2016) reported that NSs is a suppressor of antiviral RNA silencing directed against two heterologous viruses: TCV-GFP and TuMV-AS9-GFP. However, NSs was seen to be less suppressive than P19. Inclusion of the 5' UTR did not significantly affect NSs activity. NSs caused a

reduction in the levels of virus derived sRNA with respect to GUS treatment or leaves infiltrated with virus alone.

4.7 P0-Potato leaf roll virus : The P0 protein of the *Polerovirus* (*Polerovirus* is a genus of viruses, in the family *Luteoviridae*) suppresses the plant's RNA silencing machinery. Baron *et al.* (2020) characterized the RNA suppressor activity of P0 protein from the Argentinian isolate of PLRV (P0PL-Ar). Transient expression assays in *N. benthamiana* 16c line demonstrated that P0PL-Ar interferes with local and systemic RNA silencing. LP (L76/P77) and WG (W87/G88) in the F-box-like motif of P0PL-Ar are required for suppression of RNA silencing. P0PL-Ar affects AGO1 accumulation greatly reducing its levels. Furthermore, residues W87/G88 in the F-box motif are essential for this function, while mutations in residues L76/P77 seem not to affect AGO1 stability. Altogether, the residues L76, P77, W87 and G88 present in the F-box like motif are fundamental for P0PL-Ar functionality as an RNA silencing suppressor. In addition, mutations in positions L76/P77 and W87/G88 affect P0PL-Ar at the same step in the silencing pathway, since both mutants are unable to impede siRNA accumulation.

4.8 Gemini virus suppressors of RNA silencing : VSRs showed that the expression of *African cassava mosaic virus* (ACMV) and *Tomato yellow leaf curl virus* (TYLCV) encoded AC2 proteins could reverse the RNA silencing already set in plants. Further, it was observed that the AC2 suppressor activity is consistent with its active nuclear localization signal (NLS) and DNA binding domains. It suggests that geminiviral VSRs influence RNA silencing in a manner different from the RNA viruses as the latter predominantly binds sRNAs to inhibit RNA silencing.

Later, the necessity for NLS and activation domain in silencing suppression was demonstrated for legume *Begomovirus* (*Mungbean yellow mosaic virus*) (MYMV) encoded AC2 protein, which also functions as a transactivator of virus promoters. In addition, AC2 encoded by ACMV did not reveal any sRNA (miRNAs and siRNAs) binding ability differing significantly from VSRs encoded by RNA viruses, for example, *Tomato bushy stunt virus*- P19. However, the silencing suppression is correlated with the transactivation of host transcript(s) by *Mungbean Yellow mosaic India virus* (MYMIV) encoded VSR (AC2) (Shunmugiah *et al.*, 2017).

It is noteworthy that amongst the host transcripts that were up-regulated by AC2, WEL1 (Werner exonuclease-like 1) was shown to suppress RNA silencing in *N. benthamiana*. Prior to this, homologous proteins AL2 and C2 encoded by *Tomato golden mosaic virus* (TGMV) and BCTV, respectively, were shown to interact with and inactivate host serine/threonine kinase (SNF) related kinase (SnRK1) and adenosine kinase

(ADK) that are involved in the host methyl cycle maintenance. ADK is an essential enzyme for maintenance of host methyl cycle and S-adenosyl methionine (SAM) dependent methylation, whereas SnRK1 is a key regulator of the host metabolism. The VSR-kinase interactions occur in the cytoplasm hence, could not account for the transactivation of host genes. These transcription-independent studies also demonstrated that silencing suppression could be achieved by truncated AL2 that lacked the activation domain. Inhibition of ADK by adenosine analogs and or dsRNA-mediated down-regulation also mimicked the effect of *Geminivirus* protein inactivation of ADK (Shunmugiah *et al.*, 2017).

Conclusions

RNA Interference silences the undesirable pathogen actions in plants. It acts against fungal, viral, bacterial pathogens with variations in their interaction mechanisms. Viral suppressors are capable of suppressing the RNA interference.

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Micropropagation of Pomegranate (*Punica granatum* L.) : A Review

K. Uma Maheswari^{1*}, M. Rajasekhar², D.V. Swamy³, P. Sudhakar⁴ and D.R. Salomi Suneetha⁵

¹Citrus Research Station, Petlur, Venkatagiri, Tirupati-524132, Andhra Pradesh, India

²Department of Horticulture, Administrative Office, SKLTSHU, Mulugu, Siddipet-522079, Telangana

³Department of Horticulture, Dr. YSR Horticulture University, Venkataramannagudem-534101, West Godavari, Andhra Pradesh

⁴Department of Biotechnology, Acharya Nagarjuna University, Nagarjuna Nagar, Guntur-522510, Andhra Pradesh

⁵Department of Biochemistry, College of Horticulture, Dr. YSR Horticulture University, Venkataramannagudem-534101, West Godavari, Andhra Pradesh

*Email: umavarma2007@gmail.com

Abstract

Pomegranate (*Punica granatum* L.) is an important and ancient table fruit represents a distinct family 'puniceae'. The fruits have been prized over centuries for its medicinal and dietary properties. The important nutraceutical constituents of pomegranate are ellagic acid, ellagi tannins, punica acid, flavonoids, anthocyanidins, estrogenic flavones, minerals, vitamins and tannins. It is commercially grown in different parts of the country namely Maharashtra, Karnataka, Andhra Pradesh, Gujarat, Tamil Nadu and Rajasthan. Pomegranate commercial cultivation is still expanding in the country mainly due to versatile adaptability to a wide range of climatic conditions, hardy nature, low water requirement and high yield, returns on investment comparative with other crops of dry regions. Conventionally pomegranate is propagated vegetatively by the rooting of hard wood cuttings and air layering which are cumbersome and time consuming. The demand for the good quality planting material has been steadily increasing in recent years. Though, India is the second largest pomegranate producer in the world, but the productivity is lower mainly due to non-availability of healthy and disease-free planting material. Hence, an alternate strategy of sustainable nature is required to check the disease and save the crop. Use of disease free planting materials regenerated through tissue culture is most appropriate measure to manage the disease effectively. In this review described in detail about media and its components, selection of explant, serial sub culturing process, effect of growth regulators, establishment of shoot proliferation and root development media, multiplication, rooting, hardening and acclimatization.

Key words : Establishment, multiplication, nodal explant, pomegranate, micropropagation.

Introduction

The name *Punica granatum* is derived from *pomum* (apple) and *granatum* (grainy) or seeded apple. It is commonly known as 'Anar' and grown in tropical and subtropical regions of the world. Pomegranate (*Punica granatum* L.) is an important and ancient table fruit represents a distinct family 'puniceae' which comprises only one genus (*Punica*) and two species *P. granatum* and *P. protopunica* (Samir, 2010). It is exploited for nutritional value of its fruits, medicinal properties of different parts of the tree and for ornamental purpose as it bears bright red flowers (Naovi *et al.* 1991; Sepulveda *et al.* 2000; Jayesh and Kumar, 2004; Johanningsmeier and Harris, 2011). The double flowered pomegranate plants (which do not bear fruits) are grown in parks and ornamental gardens for their beautiful red flowers (Raj and Kanwar, 2010).

In India, it is found from Kanyakumari to Kashmir but it is commercially cultivated only in Maharashtra, Gujarat, Rajasthan, Karnataka, Tamil Nadu, Andhra Pradesh, Telangana State, Uttar Pradesh, Punjab and Haryana. In India, the Deccan Plateau is having ideal climatic conditions for quality fruit production throughout the year

(Chandra *et al.*, 2006 and 2008; Chandra and Meshram, 2010). Maharashtra is the largest producer occupying 2/3rd of total area in the country followed by Karnataka, Andhra Pradesh, Gujarat and Rajasthan (Jayesh and Kumar, 2004).

The area under pomegranate is increasing worldwide because of its hardy nature, wider adaptability, drought tolerance, higher yield levels, excellent keeping quality and remunerative prices in domestic as well as export markets. It thrives well in dry tropics, sub tropics and comes up very well in soils of low fertility status, adding to that it is salt tolerant too. Because of its ability to grow well in slightly saline soils, it is considered as a saline tolerant plant (Arsey *et al.*, 2002 ; Levin, 2006; Marathe *et al.*, 2009).

The edible portion (arils) is about 45-61 per cent of total fruit weight which includes about 60-85 per cent juice and 15-25 per cent seeds; peel forms 33-40 per cent of the fruit. The fruit juice is a good source of sugars, vitamin C, vitamin B, pantothenic acid, potassium, antioxidant polyphenols and a fair source of iron. Due to its immense potential for health benefits, pomegranate has achieved the title of "super –food". It can be consumed as a raw fruit

or juice. The fruit has a wide consumer preference for its attractive colored, juicy, sweet, acidic refreshing arils. The entire seed is consumed raw though the watery aril is the desired part. The taste differs depending on the subspecies of pomegranate and its ripeness.

India is the second largest pomegranate producer in the world but the productivity is lower mainly due to non-availability of healthy and disease free planting material. Conventionally pomegranate is propagated through air layering, hard wood and semi hard wood cuttings. However, this traditional propagation method does not ensure production of disease-free and healthy plants and it is tedious as it requires about one year to raise the saplings. Advances in biotechnological applications, in particular tissue culture of pomegranate were first reviewed by Omura *et al.*, 1987. Since then, a number of *in vitro* studies have been carried out on pomegranate such as micropropagation through shoot proliferation by means of meristem culture, somatic embryogenesis, synthetic seed production and utilization, plant regeneration via shoot organogenesis either indirectly through callus cultures or directly by adventitious organogenesis in explants. Therefore, micropropagation is the best method to overcome these difficulties. Further rapid regeneration of plants can be achieved by indirect organogenesis involving callus with exogenous application of plant growth regulators. Hence, several studies have been conducted on micropropagation of pomegranate trees over the past several years. Protocols have been developed for regeneration of *P. granatum* L. plantlets *in-vitro* through either organogenesis from callus derived from leaf segments, cotyledon (Murkute *et al.*, 2002; Kanwar *et al.*, 2010, anthers (Soumendra Naik *et al.*, 1999) or through embryogenesis from seedling explants, petals and immature zygotic embryos (Kanwar *et al.*, 2010). Different factors which influence directly or indirectly influence the success of micropropagation of pomegranate will be discussed in this review.

Materials and Methods

Selection of parent material : The explant should be always selected from plant material with proven horticultural trait. This can either be a selected phenotype (a specific tree) or the source of elite seed (Debergh and Read, 1991). Sometimes, the explants from mature trees growing in field are avoided due to problem of endophytic microorganisms in vegetative explants. Instead the propagules (vegetative or sexual) from such trees are grown in more hygienic conditions in the greenhouses are preferred to eliminate the problem of contamination due to endophytic microorganisms.

Selection of explant : The selection of explant is very

important in achieving an eventual success in micropropagation. Murashige (1974) described the different factors that influence the explants, which includes, size and source of explants, season of collection, age of parent *etc.* Use of juvenile material as a source of explant for micropropagation has been reported in many woody plants. Type of explants like leaf, petiole, cotyledonary leaf, hypocotyl, epicotyl, embryo, internode and root explants significantly affect the micropropagation of plants (Alagumunian *et al.*, 2004, Ali and Mirza, 2006 and Kumar *et al.*, 2011). Bharose *et al.* (2014) developed reliable and reproducible *in vitro* regeneration procedure to get healthy and well-formed plants from shoot tip, cotyledonary node, hypocotyls and leaves of pomegranate cv. Bhagwa. Kalalbandi *et al.* (2014) reported in 'Bhagwa' pomegranate, micropropagation undertaken using different explants from fruiting mother plants. Among which shoot tip was found to be the best for culture establishment and less microbial contamination.

Bensaad and Milad (2015) reported that single node explants responded better than shoot tips based on number of growing shoots, number of leaves per explants and shoot length on WPM supplemented with 4.5 μ M BAP.

Season of explant collection : The season for the collection of explant may be influencing the *in-vitro* growth of explants, phenolic exudation and degree of contamination. Amin and Jaiswal (1987) collected nodal explants from field grown guava (cv. Banaras Local) throughout the year to study the effects of season of explant collection on culture establishment and found that, April-June is the most suitable season for culture establishment because the explants collected during April-June months took minimum time for sprouting, shoot bud proliferation and also high frequency of explants showed shoot proliferation. Singh *et al.* (2001) reported that establishment of culture was more successful during April-May (spring season) followed by September-October (autumn season) in guava. The explant collected during the growing season of trees shown better *in-vitro* response in kiwifruit (Shimura *et al.* 1990), jackfruit (Amin and Jaiswal, 1993) and *Robinia pseudoacacia* (Kanwar *et al.*, 1997).

Singh *et al.*, (2001) reported highest culture establishment of nodal explants during April-May (spring season) followed by September-October (Autumn season) when explants reached out lower level of phenol in the media. Guava cultures with minimum contamination were obtained from the explants cultured during April-June (Amin and Jaiswal, 1987).

Surface sterilization of explant : One of the most important factors limiting the use of mature explants for

tissue culture is microbial contamination. Successful surface sterilization of explants is a pre-requisite for *in-vitro* culture and often involves a standard set of treatment which varies with the type of explant and species (Thorpe and Patel, 1984). Contamination is generally can originate from two sources either through carryover of microorganism on the surface of the explant or in the tissue itself (endophytic microorganisms). Although in meristem culture depending on the meristem size most of the microorganisms are eliminated where as in leaf, petiole and stem explants, the infection is carried over to the cultures (Cassles, 1991). Most kind of microorganisms, particularly bacteria and fungi compete adversely for nutrients with plant material growing *in-vitro*. Therefore as far as possible, explants must be free from all microbial contaminants when they are placed on a nutrient medium. To achieve this objective explants are subjected to treat with different sterilants either singly or in combination.

Plant tissues are sterilized by treating with disinfecting solutions (Torres, 1988). Washing the plant material intensively by the clean water before the beginning of sterilization process drastically reduced the infestation (Hughes, 1981). Muralikrishna (1988) reported surface sterilization of explants for 10-15 minutes with saturated chlorine water diluted with double distilled water in 1:1 proportion was found to be the best as compared commercial powder (1% HgCl_2) and (0.1% AgNO_3) in case of pomegranate, guava and grape.

Effective surface sterilization of explant was carried out with 0.05% to 0.5% HgCl_2 for 2-5 minutes after a brief rinse in 70% ethanol (Amin and Jaiswal, 1987), jackfruit (Rahman and Black, 1988 and Roy *et al.*, 1990), mulberry (Yadav *et al.*, 1990), *Zizyphus* sps (Rathore *et al.*, 1992) and apple rootstock (Khan *et al.*, 1998). Meghwal *et al.*, (2001) reported that, the guava shoots when treated with a combination of surface sterilization agents involving Hydrogen peroxide (10%), silver nitrate (0.25%) and mercuric chloride (0.05%) one by one for 3,4 and 6 minutes respectively are found to be aseptic to the maximum extent.

There are some reports of the use of antibiotics and fungicides to inhibit growth of bacteria in plant tissue culture. Torres (1988) reported that, the plant tissues having internal contaminants were disinfected by adding 10 mg/l of benomyl or benlate to the culture media or by treating the tissues with these before disinfecting with commercial bleach.

Suhasini *et al.*, (2017) reported that in pomegranate cv. Bhagwa the culture establishment was good when second nodal segment was sterilized with mercuric

chloride (HgCl_2) at 0.01 percent for 3 minutes followed by incubation on full strength MS medium.

Phenol exudation : One of the most severe problems associated with the establishment of shoot cultures and callus cultures is the extensive release of phenolic compounds, which leads to browning of the medium, necrosis of the explants and eventual death of the explants. Establishment of *in-vitro* culture of several plant species, especially woody plants, generally becomes difficult by the lethal browning of the explant and culture media. The various techniques employed to overcome the harmful effects of browning by either neutralise or avoid the build up toxic substances in the media. These include selecting the juvenile explants or new growth flushes during active growth period (Amin and Jaiswal, 1987 and Bon *et al.*, 1988). The culture should be carried out in darkness (Pieper and Zimmer, 1976 and Wang *et al.*, 1994). The explants are to be transferred to fresh media at short intervals (Lloyd and McCown, 1980).

Antioxidants such as polyvinylpyrrolidine (Foughat *et al.*, 1997) and ascorbic acid may be added to the medium to reduce the effect of phenolics in the explants. The best method to avoid the deleterious effects of phenolics is the transfer explants to fresh medium at regular intervals until phenolics are no longer excluded.

The cultures can also be kept in dark to minimize the release of phenolic compounds. Murkute *et al.*, (2003) conducted studies to overcome the problem of exudation and browning in tissue culture of pomegranate. Several explant sources (leaf segments, cotyledon, nodal segment and shoot tip) were either cultured on medium containing adsorbent (activated charcoal at 1.0, 2.0 and 3.0 g/l) or antioxidant (ascorbic acid at 50,100 and 150 mg/l) or subjected to sub-culturing after 1, 2 or 3 days of inoculation. The browning of the cultures was most effectively controlled by regular sub-culturing of explants (Murkute *et al.*, 2003).

The oxidation of phenolic compounds released from wounded explants occurs upon exposure to air and light. So, initial incubation of explants in darkness and frequent subculturing to fresh medium at 24 hours intervals is the best way to overcome the harmful effects of phenol exudation.

Singh and Patel (2016) conducted an experiment to identify the most suitable types of nodal explants and browning control treatment for *in vitro* regeneration of pomegranate. MS medium containing 1.0 mg/l BAP + 0.5 mg/l NAA was used commonly for all treatments tested. Results revealed that the intensity of browning was increased with increased position and the length of explants. Minimum browning intensity was observed in 1st

nodal explants having 1.5 cm length. However, explants of 3rd node with 2.5 cm length registered higher establishment (68.5 per cent) and growth of explants. Furthermore, the most effective browning control was observed in subculturing of nodal explants twice, at the first day and third day of inoculation, which also found better in establishment of explants followed by activated charcoal 200 mg/l into the medium. Maximum length of shoots (3.9 cm) was recorded in 1st position of node with 25 cm length of explants.

Guranna and Hoolageri (2017) standardized efficient and reproducible protocol for aseptic culture in pomegranate var. "Bhagwa". Among the various explants, maximum aseptic culture (55.00 per cent) establishment was obtained with double nodal explants containing third + fourth nodes. Lesser intensity of browning and higher culture establishment (54 per cent) was observed with 2000 mg/l activated charcoal. The results of the present study clearly demonstrated that surface sterilization of double nodal explants containing 3rd + 4th node with 0.10 per cent HgCl₂ for 3 minute and subsequent incubation of these explants on full strength MS medium containing 1.0 mg/l BAP + 1.0 mg/l AgNO₃ + 2000 mg/l activated charcoal results in better establishment of aseptic culture with minimum contamination.

Media Formulation : The selection or development of the culture medium is vital for success in tissue culture. In general, medium contains inorganic compounds like salts, and organic compounds like plant growth regulators, vitamins, carbohydrates, hexitols and a gelling agent. In addition, the medium can also include amino acids, antibiotics or natural complexes.

Various mineral salt formulations have been used for *in-vitro* cultures. However, full strength minerals salts are not always optimum and different formulations may work better at different stages (Thorpe and Patel, 1984). Modifications with respect to different constituents like phytohormones, sucrose, agar concentrations and other additives like PVP, AC, coconut milk, *etc.*, are usually done in order to ensure a better *In-vitro* response (Thorpe *et al.*, 1991).

Basal Media : Yang and Ludders (1993) tried different media, viz., MS, Gamborg's B5 and WPM for *in vitro* propagation of pistachio (*Pistacia vera* L.) and observed that, MS media resulted in significantly better shoot formation than other media. Normah *et al.*, (1995) reported less shoot proliferation in mangosteen cultures on WPM, as compared to MS media.

Sucrose : The majority of media used for *in vitro* shoot regeneration and rooting invariably contains 2-3% (w/v) sucrose as a source of energy and osmotic agent.

Zimmerman (1983) reported that root induction is inhibited when sucrose is omitted from the media. Adventitious root formation is a high energy requiring process and inhibition of rooting by sucrose omission can be explained by starvations of heterotrophic shoots. Rahman *et al.*, (1992) reported increased rooting with 40g/l of sucrose as compared to 20g/l and 60g/l of sucrose.

Agar : The solidifying agent used in tissue culture is agar, which is the costliest ingredient and often contains impurities which affect the growth of the cultured plant tissue and organ. So many researchers use more purified forms of agar like plytagar, bacto-agar or meragar. Physical and chemical analysis revealed large differences in response of cultures to types of agar used. The optimum concentration of agar is 0.8 to 1% (w/v).

Decrease in rooting performance with increasing agar concentration and 15 g/l of agar inhibits completely. The optimum concentration for root induction was 6 g/l in rose (Rahman *et al.*, 1992).

Plant Growth Regulators : Growth regulators (Phytohormones), are not nutrients but they influence growth and development. Generally growth regulators are produced naturally in plants. But in cultures they are added selectively to culture media as sufficient quantities of growth regulators are not manufactured in cultures. As the phytohormones play a key role in tissue culture studies, efforts are required to determine optimum levels. The formation of adventitious shoots or roots was first determined by Skoog and Miller (1957) through discovery of the regulation of organ formation i.e., shoots and roots by changing the ratio of cytokinin / auxin, when the ratio of cytokinin / auxin is high, it favours the formation of shoot but root formation is inhibited. The reverse favours the root formation, whereas the intermediate ratio induces unorganised growth of callus tissue. Regulation of plant growth and development including plant regulation from isolated cell and tissue is under the control of hormones. Among various hormones, auxins as IAA, IBA, NAA and 2, 4-D, cytokinins as 6- Benzyl amino purine (BAP), Kinetin, Zeatin, 2-iso pentenyl amino purine (2 ip), TDZ, gibberellins and ethylene are important.

Patil *et al.*, (2011) reported that healthy and well-formed plants from nodal explants were developed in pomegranate var. Bhagwa when nodal segments were cultured on two different media at full strength MS medium and WPM. The media was prepared as a basal medium supplemented with 0.2 to 2.0 mg/l BAP, 0.1 to 1.0 mg/l NAA, 0.5 to 2.5 mg/l silver nitrate (AgNO₃) and 10 to 50 mg/l adenine sulphate for establishment. The nodal explants grown on MS medium containing 1.8 mg/l BAP, 0.9 mg/l NAA, 1.0 mg/l silver nitrate and 30 mg/l adenine sulphate shown highest proliferation rate (10 to 15

shoots/explant) in establishment stage. The number of leaves per explant was also maximum (15 to 20 leaves/explant) on proliferation medium containing 0.4 mg/l BAP and 0.3 mg/l NAA. The plantlets grown on MS medium were found to have better survival compared to WPM medium. Rooting response was same in media with 0.5 mg/l NAA and 0.5 mg/l IBA, whereas roots were thicker in the medium containing 0.5 mg/l IBA.

The media supplemented with different concentrations (2.3, 4.7, 9.2 and 18.4 μM) of Kinetin (Kn) along with 0.54 μM NAA in proliferation stage. WPM proved to be more efficient when compared to MS medium. Highest number of nodes, shoot length and leaf number were recorded at 9.2 μM concentration of Kn and half strength WPM supplemented with 5.4 μM NAA was effective for rooting of shoots.

Bensaad and Milad (2015) reported in pomegranate var. 'Khadouri', when cultured on full strength MS medium and WPM supplemented with BAP at 4.5 μM , WPM was superior to MS medium in shoot number and shoot length.

Other Additives : Many other additions to nutrient media serve various purposes. Antioxidants are added if there is excessive browning of the explant and they retard oxidation of the explant. Some of the antioxidants are citric acid, ascorbic acid, pyragallol and phloroglucinol. Sometimes when there is excessive tissue discolouration of the medium and explant, two absorbents, polyvinylpyrrolidone and activated charcoal (0.1-0.3%) are used. PVP has been included in media to avoid explant browning. PVP absorbs phenols through hydrogen bonding by thus preventing oxidation of phenols (Loomis and Battaile, 1996).

Activated charcoal (AC) is also added to media of plant tissue culture because of its beneficial effects on many aspects of *in-vitro* regeneration. Activated charcoal have been attainted to various factors such as, darkening the media removal of inhibitory compounds, adsorption of growth regulations (weatherhead *et al.*, 1978; Johansson, 1982); adsorption of agar impurities (Kohlenbach and Wernicke, 1978); adsorption of phenols produced by the tissues (Johansson, 1983) and gradually releases the adsorbed products (Johansson and Erikson, 1982).

Cultural Environment : Bonga and Durzan (1987) reported that, the factors of culture environment influenced the *in vitro* growth and differentiation of plant tissue cultures. The cultural environment, which is the result of interaction between plant material, cultural media, type of culture vessel and external environment of the culture room, has tremendous influence on a tissue culture system. This may include the physical form of the media, pH, humidity, gaseous atmosphere, light and temperature.

Physical form of Media : The agar solidified media is most successful but, the use of liquid media was increasingly evaluated for the tissue culture purpose (Keathley, 1983). The advantages of liquid media for enhancing shoot multiplication, growth, somatic embryogenesis or rooting have been reported for several species. Through the mechanism involved in this improved performance is not known, may be the absence of gelling agent increasing the availability of water and dissolved substances to the explant (Debergh, 1983) could be the reason.

pH of the Media : The pH of the plant tissue culture media is generally adjusted to P^{H} 5.5 to 6. Below 5.5, the agar will not gel properly and above 6.0, the gel may be too firm (Murashige, 1973). Media pH generally drops by 0.6 to 1.3 units after autoclaving. Cultures of some plant tissues cause a pH drop over time that is attributed to the production of organic acids or nitrogen utilization. The media pH was influenced by inorganic salts, carbohydrate sources, gelling agent, activated charcoal and medium storage method. Media P^{H} can be adjusted by adding 1.0 or 0.1N Hcl or NaOH while stirring the medium. Always P^{H} adjustment should be done before adding the agar.

Light : The quality and intensity of light affects, the shoot growth and morphogenesis in addition to having a role in photosynthesis (Hughes, 1981). Plants cultured *in-vitro* and supplied with carbohydrates as they are heterotrophic. Ziv, (1991) reported that, light regulates the size of leaves and stem as well as morphogenic pathway and therefore, is implicated in pigment formation and vitrification. In some species, the effect of photoperiod may or may not be pronounced. There is no distinct difference in root and plantlet formation between the light 18 hour photoperiod and dark grown cultures of *Prosopis tamaruga* (Jordon, 1987). Tyagi *et al.* (2006) investigated effects of various concentrations of maleic hydrazide (MH) (2.0, 4.0, 6.0 and 8.0 mg/l) and three light treatments (16-h, 24-h, 0-h) on *in vitro* rhizome formation and conservation of ginger (*Zingiber officinale* Rosc. cv. Rio de janerio). *In vitro* rhizome formation occurred in all the above treatments. A significant effect of light treatment was observed on survival of culture but not on rhizome formation. More than 50 per cent culture survived up to 14 months on control of medium less than 16 hours and 24 hours light conditions as compare to 20 per cent culture on same medium incubated under dark.

Singh and Patel (2014) tested various level of light intensity in pomegranate by keeping the constant temperatures $26 \pm 2^{\circ}\text{C}$ and 16/8 hour light/dark period in the incubation room. Maximum number of shoots per explant and highest length of shots was recorded under 3000 lux intensity.

Temperature : The temperature influences the growth and development of explants *in-vitro* just as in the case of *in vivo*. reported that temperature controls the relative humidity in culture vessel, as it is having an indirect effect on vitrification. The temperature of root zone is important to enhance root growth during acclimatization. For increasing the humidity around the cuttings and for good root activity the media should be warmer than the air (Dunstan and Turner, 1984 and McCown, 1986). Wang (1992) observed that rooting percentage and the number of roots increased with increased temperature during darkness between 5 and 25°C in pear. A further increase in dark temperature up to 30°C reduced rooting percentage and root number.

Humidity : The growth, development and photosynthesis of plantlets *in-vitro*, are influenced by humidity in the vessel and osmotic potential of media which influences the water relations of plantlets *in vitro* (Brown *et al.*, 1979 and Zivetal., 1983). In plum, the reduction of relative humidity in *in vitro* culture during proliferation resulted in a progressive reduction in weight of shoot cluster and in number of shoots produced. When the relative humidity was reduced during rooting of the shoots the rooting process was delayed (Sciutti and Morini, 1993).

Micropropagation : In pomegranate Drazeta (1997) reported that usage of apical and axillary vegetative buds as primary explants, the best growth and shoot multiplication were observed on MS media containing relatively low concentrations of NAA (0.1 mg/l) and BAP (0.5 mg/l). Shoots showed rooting on media containing 1BA (0.2 mg/l). The axillary branching of nodal segment and proliferation of shoot tip meristem was the best MS media supplemented with kinetin (0.5 mg/l), BA (10 mg/l) and CH (cycloheximide) (500 mg/l). MS media supplemented with NAA (4.0 mg/l), kinetin (2.0 mg/l) and coconut water 15% is best for rooting, Naik *et al.*, (1999) described an efficient procedure for *in-vitro* clonal propagation by using nodal stem segments of a mature tree. They tried three cytokinins viz. benzyladenine (BA), zeatin riboside (ZR) and thidiazum (TDZ) and found that greatest number of shoots was developed on a media containing zeatin riboside at 2.0 mg/l. Out of all the cytokinins tested TDZ was least effective. For rooting half MS media was supplemented with IBA at 1.0 mg/l was best.

Callus formation : Callus formation is an important aspect of plant multiplication. Callus induction from leaf explants of pomegranate cultured on a modified MS basal media (lacking nicotinic acid, pyridoxine-HCl and glycine), supplemented with 0.8% agar (Omura *et al.*, 1987). In dwarf pomegranate cv. Nana Yang and Ludders (1993) observed callus from leaf and stem explants of *in-vitro*

cultured shoots. Leaf segment and stem explants were initially cultured on modified MS basal media supplemented with BA, zeatin, Kinetin or Zip at 0.1- 1.5 mg/l and IAA, 1BA or NAA at 0.1- 1.0 mg/l plus 0.5 mg/l BAP.

The effect of plant growth regulators BAP and NAA in MS media on *In-vitro* propagation of pomegranate cv. wonderful was investigated by Kantharajan *et al.*, (1998). From leaf and nodal explants of aseptically grown shoots callus cultures were initiated with nodal explants callus initiation and growth was best on MS basal media containing 1mg/l BAP + 0.4 mg/l and with leaf explants 1.0 mg/l BAP was best. Shoot regeneration was observed after 8 weeks of incubation when leaf calluses were initiated on MS and WP media.

Murkute *et al.*, (2002) reported the method for the callus induction and differentiation using leaf segment and cotyledon explants of pomegranate. The MS basal media supplemented with BAP 1.0 mg/l + NAA 0.5 mg/l was highly effective for callus induction resulting in 61.2 and 76.4 per cent success in leaf segment and cotyledon explants respectively. The cotyledon explant responded better when compared to leaf segment explant for callus induction. Because of the absence of phenolic substances in the cotyledons resulted in profuse proliferation of cells. Callus was obtained successfully in ber when leaf pieces were cultured on MS basal media supplemented with 0.25 mg/l 1BA and 2.5 mg/l BA (Fougat *et al.*, 1997). But when the callus obtained from leaf explant was transferred to shoot regeneration media after 40 days, there was no shoot differentiation observed.

Organogenesis and shoot proliferation : The process of organ differentiation from dedifferentiated tissue *i.e.*, callus is organogenesis. The main objective of plant tissue culture is to regenerate complete plantlets after successful induction and growth of callus from various tissue sources and to achieve this various interaction of different plant hormones and nutrient constituents are required. In pomegranate, leaf segment explant initially cultured as a modified MS basal media supplemented with a range of 0.5-10 µM BA and 0.5 µM NAA. Shoot elongation was stimulated most efficiently when the initial calluses were transferred from the shoot induction media to half-strength MS supplemented 2µM BA. Elongated shoots rooted easily on half MS media + 0.1µM NAA (Omura *et al.*, 1987).

Yang and Ludders (1993) reported that, adventitious shoot elongation in pomegranate was stimulated most effectively when the initial calluses were transferred from the shooting media to MS basal media supplemented with 0.5 mg/l BA and 0.1 mg/l IBA. Nataraja and Neelambika (1996) reported that, the petal explants of pomegranate

cultured on MS basal media supplemented with 5.0mg IAA and 5.0mg/l BAP differentiated numerous embryoids, but they developed multi-lobed or fused cotyledons. However, callus induced on MS media with 1.0 mg IAA or 1.0 mg/l IBA with half-strength MS salts and sucrose (4%) produced both roots and shoots resulted in plantlets.

Kantharajan *et al.*, (1998) observed high frequency shoot organogenesis in pomegranate with nodal cutting explant on MS basal media supplemented with 1.0 mg/l BAP. The best adventitious bud formation was observed on ½ MS medium supplemented with 0.5 mg/l + 0.1 mg/l NAA. This medium is also effective for shoot proliferation. NAA was effective than BAP in root elongation and the maximum shoot length per explant was observed on media containing 0.1 mg/l NAA. Root induction observed after twelve days on appropriate rooting medium with NAA. Murkute *et al.*, (2003) observed the shoot proliferation from pomegranate var. Ganesh was obtained on MS basal medium supplemented with BAP 1.0 mg/l + NAA 0.5 mg/l, the elongated shoots were separated and sub-cultured for rooting individually on ½ MS basal medium with 0.5 mg/l NAA or IAA. The plantlets were transferred to vermicompost + Soil mixture (1:1 V/V) and where hardened in mist chamber with 50 per cent survival.

In-vitro rooting : The proliferated shoots should be transferred to a rooting medium supplemented with high concentration of auxin, which stimulates the formation of roots. The commonly used auxins for rooting are indole acetic acid (IAA), indole butyric acid (IBA) and naphthalene acetic acid (NAA) among these IBA is the most commonly used auxin. *In vitro* rooting can be more synchronous because shoots are uniformly in contact with the media (Mohammad and Vidavel, 1988). However, the roots produced by this method are usually thickened and are generally devoid of root hairs. Sometimes, callus may also form at the base of shoots and if roots originate from this callus cells, vascular connection between root and shoot may be interrupted (Thorpet *et al.*, 1991). In some woody legumes, a combination of auxins and low level of cytokinin has also been used for *in-vitro* rooting (Harris *et al.*, 1989; Puri *et al.*, 1992 and Raghavaswamy *et al.*, 1992). IBA has been reported to have favoured root induction in several tree species including *Artocarpus heterophyllus* (Rahman and Blake, 1988) and *Morus nigra* (Yadav *et al.*, 1990).

Naik *et al.*, (1999) reported that, half strength MS media containing IBA 1.0 mg/l induced rooting (80%) of *in-vitro* derived pomegranate shoots in 8-10 days and from each shoots 3-4 roots were developed. Addition of auxin to the media was essential to induce rooting in case of *in-vitro* regenerated shoots of pomegranate. Root

initiation occurred within 10-15 days in half strength MS media supplemented with 0.054 to 5.4 µM NAA. However, highest percentage of shoots were rooted (10.3 roots/shoot) in media containing 0.54 µM NAA (Naik *et al.*, 2000).

Singh *et al.*, (2003) studied *in-vitro* grown micro-shoots of khasi mandarin (*Citrus reticulata*) and sweet lime sour mutant (*Citrus limettoidis*) which were cultured on Murashige and Skoogs (MS) medium supplemented with NAA (0.1 or 0.2 mg/l), paclobutrazol (PCB) (1.00 or 2.5 mg/l) and IBA (5.0 mg/l).

Hardening and acclimatization : In climatic adaptation of an organism especially a plant, that has been moved to a new environment is known as acclimatization. At an early stage of acclimatization, the main effort of environmental control to be done is to maintain high relative humidity, which can be achieved by covering the plantlets with plastic film under shade and with frequent misting. Strong solar light may directly damage the plantlets and the fluctuating solar light intensity with time leads to the fluctuation of temperature and relative humidity which causes excess water loss from the plantlets. So shading is necessary to protect the plantlets from the loss of excess water.

aik *et al.* (1999) reported 68 per cent survival of the plantlets of pomegranate var. Ganesh transferred to vermicompost that lead 80 per cent survival of plants on transferring to soil, plantlets with well-developed roots were successfully acclimatized and eventually established in soil. Plantlets with well-developed roots were successfully acclimatized and eventually established to soil (Naik *et al.*, 2000). Shah *et al.*, (1999) reported that the influence of different potting mixtures *i.e.*, soil + sand (2:1 v/v), soil + sand + FYM (1:1:1 v/v), soil + sand + sphagnum mass (1:1:1 v/v), soilrite mix on survival and growth of acid lime plantlets. Among these potting mixture soil + sand + FYM (1:1:1 v/v) was found to be the best potting mixture in which the survival percentage was 100 per cent and plant height and number of leaves per plantlet were also better than remaining.

Bhagat V.V. (2002) experimented that to the *in-vitro* produced acid lime plantlets were acclimatized to natural environment; uniformly rooted plantlets were taken out from the culture vessels with the help of forceps. The roots were washed thoroughly in distilled water. The plantlets were then transplanted in pots containing agro pit. After one month these were transplanted to pots containing different mixtures and found that the best mixture was soil + sand + FYM (1:1v/v) effected on percentage of survival, height of plantlet, more number of leaves in seedless lemon and in variety Pramalini.

Bonyanpour and Khui (2013) cultured leaf explants of a local cultivar of dwarf pomegranate on MS medium supplemented with various concentrations of BAP and NAA for callus induction. Highest callus proliferation observed on a medium containing 1.0 mg/l BAP and 1.0 mg/l NAA. The highest number of shoots (97 shoots per explant) was obtained by transferring the calli to the media containing 5.0 mg/l BAP with 0.1 mg/l NAA. Maximum shoot proliferation was observed when shoots were cultured on WPM supplemented with 5.0 mg/l Kn and reported root induction on *in vitro* developed shoots on WPM medium containing IBA with 100 per cent roots on cultured shoots. Rooted plantlets were shifted in a soil mixture containing vermiculite (60 per cent), perlite (30 per cent) and coco peat (10 per cent) v/v. After 2 months, 80 per cent of plants survived and transferred to the greenhouse.

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Effect of FYM and Foliar Application of Nutrients on Growth and Yield of Cowpea (*Vigna unguiculata* L.)

Manna Lal Raiger^{1*}, P.K. Sharma¹, Vinit Kumar Meena¹ and Bhawani Singh Meena²

¹Department of Agriculture, Vivekananda Global University, Jagatpura, Jaipur, Rajasthan-303012

⁴Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan-303328

*Email : manla.lal@vgu.ac.in

Abstract

A field experiment was conducted at was carried out at research farm, Vivekanand Global University, Jaipur during *rabi* seasons 2022-23 on loamy sand soil, which considered four treatments of fertility levels (control, 2.5 t/ha and 5.0 t/ha) and three treatments of foliar application of nutrient spray (KCL 1%, Urea @ 2% and DAP @2% spray at branching and flowering) thereby making nine treatment combinations were tested in (RBD) Randomized Block Design with three replications. Recommended dose of FYM for cowpea was 2.5 t/ha and 5.0 t/ha. Results indicated that application of F₂- 5.0 t/ha significantly increased the plant height, dry matter accumulation per metre row length at 50 DAS and at harvest, total chlorophyll content, number of pods per plant, seeds per pod, seed, and biological yield, potassium content in seed, total uptake of protein content, protein yield, nitrogen, phosphorus and potassium and net returns over preceding levels. Whereas, straw yield, protein content in seed, nitrogen and phosphorus content in seed and straw and potassium content in straw increased significantly upto F₂-2.5 t/ha and remained at par with F₁-5.0 t/ha fertilizers. However, in respect of dry matter accumulation per metre row length at 25 DAS, test weight and harvest index, the treatments 2.5 t/ha to 5.0 t/ha fertilizer remained almost same.

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp] commonly known in India as *lobia* is one of the important *kharif* pulse crop grown for grain, forage and green manuring. The crop gives such a heavy vegetative growth and covers the ground so well that it checks the soil erosion in problem areas and can later be ploughed down for green manure. It has considerable promise as an alternative pulse crop in dry land farming. Being rich in protein and containing many other nutrients, it is known as vegetable meat. On dry weight basis, cowpea grains contain 23.4 per cent protein, 1.8 per cent fat and 60.3 per cent carbohydrates. It is also rich source of calcium and iron. Cowpea is consumed as whole grain as well as *dal* or to make flour in variety of ways for table purposes. Green tender pods are used as a vegetable.

Cowpea belongs to family Papilionaceae and sub family Fabaceae with a chromosome number of 2n=2x=22. Its primary center of origin is in Africa. It is a warm season, annual and herbaceous legume. Cowpea is consumed as whole grain as well as *dal* or to make flour in variety of ways for table purposes. Green tender seeds are used as vegetable. Cowpea green pods are good source of protein, fiber, minerals, calcium and vitamins particularly vitamin A and C. It contains 60.03 g Carbohydrates, 23.52 g proteins and 1.26 g fat, 10.6 g fiber per 100 g of edible portion. Green tender fruits contain 100 mg calcium, 424 mg phosphorus and 8.27 mg iron per 100 g fresh pods (Anonymous, 2019). The

common names are 'Black-eye-pea', 'Southern pea', 'China pea' and 'Marble pea'. In Gujarati languages, the famous names are 'chola' or 'chorap'.

Materials and Methods

Growth attributes

Plant stand : Plant stand per metre row length was counted at 20 DAS and at harvest from 5 randomly selected spots (1m length) in each plot and the average was worked out. Since foliar spray treatments were not given upto 25 DAS, hence the treatment effect on this aspect was not evaluated.

Plant height : Five plants were selected randomly from each plot, tagged permanently and used for measurement of plant height. Height of each tagged plant was measured periodically at 20, 40 DAS and at harvest from base of the plant to the tip of the main shoot by metre scale and average of five plants was computed as mean plant height.

Dry matter accumulation per metre row length : Dry matter production was recorded at 20 DAS, 40 DAS and at harvest. For this, plants from one metre row length were uprooted randomly from sample rows of each plot. After removal of root portion, the samples were first air dried for some days and finally dried in an electric oven at 70 °C till constant weight. The weight was recorded and expressed as average dry matter per metre row length.

Chlorophyll content : The chlorophyll content of cowpea at 40 DAS was estimated by the method advocated by

Arnon (1949). The leaf sample was ground in 80% acetone, centrifuged to 10 minutes at 2000 rpm and made final volume to 10 ml. The resultant absorbance of clear supernatant was measured by spectronic 20 at 652 nm and presented in terms of mg/g fresh weight of leaves.

$$\text{Total chlorophyll} = \frac{A_{(652)} \times \text{Total volume (ml)} \times (\text{mg / g})}{1000 \times \text{Weight of sample (gm)}}$$

Where, d is the path length = 1 Cm

Number of root nodules per plant : Five plants were selected randomly at 40 DAS in sample rows of each plot and uprooted carefully in wet soil with the help of khurpi. The soil mass embodying the roots of the plants was washed off with water and effective and total root nodules were counted to record average number of nodules (effective and total) per plant.

Fresh and dry weight of nodules per plant : The total root nodules so obtained from the five plants from each plot were weighed for fresh weight and then subjected to oven dry at 70°C till a constant weight. The weight was recorded and expressed as average dry weight of nodules in mg per plant.

Yield attributes and yield

Number of pods per plant : The randomly selected plants used for recording the height and branches were used for counting the number of pods per plant at harvest and their average was worked out to record pods per plant.

Number of seeds per pod : At the time of threshing, 10 pods were randomly selected from five tagged plants in each plot and their total seeds were counted to record the average number of seeds per pod.

Test weight : One thousand seeds were counted from the sample drawn randomly from the finally winnowed and cleaned produce of each plot and their weight was recorded as test weight (g).

Biological yield : The weight of the thoroughly sun dried harvested produce of each plot was recorded separately before threshing and expressed as biological yield in kg/ha.

Seed yield : After threshing, winnowing and cleaning, the produce of each plot was weighed separately in kg per plot and then converted to seed yield kg/ha.

Straw yield : Straw yield (kg/ha) was obtained by subtracting the seed yield (kg/ha) from biological yield (kg/ha).

Harvest index : Harvest index was computed by using the formula outlined by Singh and Stoskopf (1971).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield (kg / ha)}}{\text{Biological yield (kg / ha)}} \times 100$$

Result and Discussion

Effect of fertility levels

Growth : The results revealed that application of F₂-5.0 t/ha recommended dose of fertilizers (20 kg N and 40 kg P₂O₅/ha) have favourable effect on growth and biomass production. All the growth parameters viz., plant height, dry matter accumulation per metre row length, total chlorophyll content, increased linearly with the corresponding increase in levels of recommended dose of N and P. This increment was, by and large, statistically significant over control, F₁-2.5 t/ha and F₂-5.0 t/ha (Table 4.2). The increase in these components seems to have been brought about by increase in amount of growth substances and naturally occurring phytohormones with increased nitrogen supply. Probably the increase in auxin supply with higher levels of nitrogen brought about increase in the dry matter. The observed improvement might be due to an early and plentiful availability of nitrogen leading to better nutritional environment in the root zone for growth and development. As nitrogen is one of the major essential plant nutrients required for growth. Therefore, increased availability of nitrogen on otherwise poor soil (Table 3.3) might have increased cell number and cell size leading to better growth in terms of height. Nitrogen is a constituent of chlorophyll, it harnesses solar energy and fixes atmospheric CO₂ as carbohydrates and amino acids (Anonymous, 2020). Thus, nitrogen application increased dry matter production. Similarly, increased supply of available phosphorus has long been considered as an essential constituent of all living organisms and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells including biological energy transformations. In terms of significance, phosphorus is more indispensable mineral nutrient for pulse crops as it helps in better root growth and development and thereby making them more efficient in biological nitrogen fixation (BNF). Increased availability of phosphorus owing to its application in the soil low in phosphorus content (Table 3.3) might have improved the availability of nutrients, resulting in to more uptake. The energy obtained from photosynthesis and metabolism of carbohydrates is stored in storage compounds (ATP and ADP) for subsequent use in growth which in turn resulted in vigorous growth of plants.

Thus, application of recommended dose of fertilizers (N and P) at optimum level increased the plant height, dry matter accumulation, chlorophyll content in leaves and number and weight of root nodules in the present investigation over their lower doses. The observed improvement in overall vegetative growth of the crop with the application of N and P in the investigation is in conformity with those of Malav *et al.* (2018) in cowpea,

Table-1 : Effect of FYM and foliar spray on plant stand per metre row length

Treatments	Plant stand	
	40 DAS	At harvest
FYM Levels		
F ₀ -Control	11.83	10.70
F ₁ -2.5 t/ha	11.93	10.91
F ₂ -5 t/ha	11.95	11.06
SEM±	0.23	0.24
CD (P=0.05)	NS	NS
Foliar Application of Nutrients		
N ₁ -KCL @ 1%	11.80	10.85
N ₂ -Urea @ 2%	11.95	10.90
N ₃ -DAP @ 2%	11.96	10.92
CD (P=0.05)	NS	NS
CV (%)	5.75	6.54

Table-2 : Effect of FYM and foliar spray on plant height per metre row length

Treatments	Plant height (cm)		
	20 DAS	40 DAS	At harvest
FYM Levels			
F ₀ -Control	11.25	33.51	45.82
F ₁ -2.5 t/ha	11.35	38.80	50.60
F ₂ -5 t/ha	11.55	41.49	57.98
CD (P=0.05)	1.96	5.86	8.24
Foliar Application of Nutrients			
N ₁ -KCL @ 1%	11.30	37.70	51.10
N ₂ -Urea @ 2%	11.40	39.00	53.00
N ₃ -DAP @ 2%	11.45	37.10	50.30
CD (P=0.05)	1.96	5.86	8.24
CV (%)	7.90	6.05	6.63

Yadav *et al.* (2019) in cowpea, Shivran *et al.* (2017) in chickpea, Kulkarni *et al.* (2018) in cowpea and Tiwari and Kumar (2009) in mungbean, who supported increased plant height, dry matter accumulation, number of branches per plant and number of nodules per plant.

Yield attributes and yield : Application of successive fertility levels upto F₂- 5.0 t/ha significantly increased the yield attributes viz., number of pods per plant, seeds per pod and test weight of cowpea. The over all improvement in vigour and crop growth as explained in preceding paragraph due to adequate supply of nitrogen early in the life of a plant is considered important in promoting rapid vegetative growth and branching. Thus, N fertilization stimulated seed setting and increased yield attributes of cowpea.

As already discussed in preceding paragraph that phosphorus plays an important role in nitrogen-fixation in legumes, where it acts as a source of energy. It plays a

pivotal role in early formation of roots, their proliferation, increased microbial activity in nodules and symbiotic biological N-fixation process. This also led to efficient and greater partitioning of metabolites and adequate translocation of photosynthates and nutrients to develop reproductive structures (Kulkarni *et al.* (2018). During leaf senescence also, carbohydrates, nitrogenous compounds, phosphorus and other mobile nutrients are remobilized and translocated to current plant sinks i.e. seeds which are very close to the source resulting into higher test weight due to bold seed formation.

Application of increasing levels of fertilizers upto F₂- 5.0 t/ha significantly increased seed and straw yields (Table 4.6). The increase in seed and straw yields might be due to better nutritional status of the crop in the soil, which was low in N and P and medium in K (Table 3.3) as evidenced by their uptake in the plant (Table 5 and 6). The increased supply of NPK and their higher uptake by plants might have stimulated the rate of various physiological processes in plant and led to increased growth and yield parameters and resulted in increased seed and straw yields. It was observed that a unit increase in yield attributes viz., pods per plant, seeds per pod and test weight, increased seed yield by 159, 201 and F₂-5.0 t/ha, respectively.

The biological yield is a function of seed and straw yields. Thus significant increase in biological yield with the application of N and P could be ascribed due to increased seed and straw yield. The results of present investigation are in line with those of Patil and Udmale (2016) in cowpea, Malav *et al.* (2018) in mothbean, Yadav *et al.* (2019) in cowpea, Sutar *et al.* (2019) in cowpea and Gowda *et al.* (2018) in cowpea, who obtained increased yield attributes, seed, straw and biological yields with the combined application of fertilizers (N and P).

Effect of foliar application of nutrient spray

Growth parameters : Significant increase in plant height, dry matter accumulation per metre row length and total chlorophyll content in leaves was observed with foliar application of nutrient spray of fertilizers at branching and flowering (N₃-DAP @ 2%, N₂- urea 2% and N₁-KCl @ 1%) as compared to water spray. Among foliar application of nutrient spray treatments N₃-DAP @ 2% spray recorded the highest value of growth parameters (Table 2 to 6). The favorable effect of foliar application of fertilizers might be due to on account of improved photosynthetic efficiency. The overall growth of plant increased in terms of plant height and which contributed for higher dry matter production (Hadiyal *et al.* (2017)). Foliar application of nutrient spray of N₂-Urea @ 2% retarded the loss of chlorophyll content with increased photosynthesis ability resulting in enhanced supply of carbohydrates to plant

Table-3 : Effect of FYM and foliar spray on dry matter accumulation per metre row length of cowpea.

Treatments	Dry matter accumulation per metre row length (g)		
	20 DAS	40 DAS	At harvest
FYM Levels			
F ₀ -Control	11.65	76.45	95.42
F ₁ -2.5 t/ha	14.52	93.42	116.63
F ₂ -5 t/ha	15.03	99.83	124.55
CD (P=0.05)	2.55	5.81	15.58
Foliar Application of Nutrients			
N ₁ -KCL @ 1%	13.50	89.10	112.30
N ₂ -Urea @2%	13.90	92.90	114.90
N ₃ -DAP @ 2%	13.80	87.70	109.40
CD (P=0.05)	2.55	5.81	15.58
CV (%)	6.90	6.72	6.43

Table-4 : Effect of FYM and foliar spray on total chlorophyll content of cowpea

Treatments	Total chlorophyll content
FYM Levels	
F ₀ -Control	2.07
F ₁ -2.5 t/ha	2.26
F ₂ -5 t/ha	2.43
CD (P=0.05)	0.40
Foliar Application of Nutrients	
N ₁ -KCL @ 1%	2.25
N ₂ -Urea @2%	2.29
N ₃ -DAP @ 2%	2.22
CD (P=0.05)	0.40
CV (%)	6.55

(Malav *et al.* (2018)). Application of fertilizers as foliar spray provide plant nutrients as well as water to plant through leaves at critical juncture of its life, which results in better growth and development of plant. Similar results were also obtained by Kulkarni *et al.* (2018) in cowpea, Hadiyal *et al.* (2017) in chickpea, Choudhary *et al.* (2017) in chickpea, Bag *et al.* (2015) in greengram and Gowtham chand *et al.* (2019) in blackgram.

Yield attributes and yield : Number of pods per plant, seeds per pod and seed and straw yields (Table 4.4 and 4.5) increased significantly with foliar spray of fertilizers (N₃-DAP @ 2% and N₂-Urea @ 2% over N₁-KCL @ 1%). However, no significant effect was observed on test weight (Table 6). As stated earlier that foliar application of nutrient spray of fertilizers plays vital role in growth and development of plants because of its stimulatory effect on chlorophyll content and photosynthetic ability of plants. The increase in seed yield of cowpea with foliar application of nutrients could be attributed to reduced flower drop percentage by preventing abscission layer formation compared to water sprayed control, hence it

increased the sink capacity for maximum yield potential. Generally crops requires a favourable nutrient balance at reproductive stage for favourable development of pods and seeds, whereas the soil applied nutrient does not meet the demand of crop for optimum nutrition. So foliar application of nutrient is a good way for supplying optimum nutrition for crop to complete its reproductive phases for obtaining higher productivity from crop plants. These results are in close conformity with those of Choudhary *et al.* (2017) in cowpea, Gowda *et al.* (2018) in greengram, Sutar *et al.* (2019) in pigeonpea, Kulkarni *et al.* (2018) in greengram and Hadiyal *et al.* (2017) in blackgram.

Conclusions

Based on results of experimentation, it may be concluded that the combined application of F₂- 5.0 t/ha and N₃-DAP @ 2% as foliar application of nutrient spray proved to be the most superior treatment with regard to seed yield (1443 kg/ha) of cowpea. However, independent application of F₂- 5.0 t/ha and N₃-DAP @ 2% as foliar application of nutrient spray fetched significantly higher net returns (Rs 86145 and 71387/ha, respectively) as compared to N₁-KCL @ 1%. These results are only indicative and require further experimentation to arrive at some more consistent and final conclusion.

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Foliar Application of Nutrients on Growth of Pearl Millet (*Pennisetum glaucum* L.)

Paras Ram Meena^{1*}, P.K. Sharma¹, Kamini Sharma¹, Garima Khaspuria¹, Vinit Kumar Meena¹ and Bhawani Singh Meena²

¹Department of Agriculture, Vivekananda Global University, Jagatpura, Jaipur, Rajasthan-303012

²Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan-303328

*Email : parsrammeena168@gmail.com

Abstract

An experiment was conducted at carried out during *kharif* season of the year 2022 at research farm, Vivekananda Global University, Jaipur. The objectives were to study the effect of foliar application of nutrients on growth of pearl millet. The experiment consisted of 9 treatment combinations comprising of nutrients (control, water spray, 100% RDF (60:30:30 NPK/ha), 100% RDF + one spray of 1% NPK (19:19:19) at 30 DAS, 100% RDF + two spray of 1% NPK (19:19:19) at 30 and 45 DAS, 100% RDF + one spray of 0.5% ZnSO₄ at 30 DAS, 100% RDF + two spray of 0.5% ZnSO₄ at 30 and 45 DAS, 100% RDF + one spray of 1% NPK (19:19:19) + 0.5% ZnSO₄ at 30 DAS and 100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO₄ at 30 and 45 DAS). The experiment was laid out in randomized block design and replicated thrice. Among treatments levels of foliar nutrients significantly influenced highest plant height (cm) of plant height (83.46, 165.25 and 196.25 cm) at 20,40 and 60 DAS and chlorophyll content in leaf (3.35 mg/g) at 60 DAS with the foliar application of T₉ (100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO₄ at 30 and 45 DAS).

Introduction

Pearl millet (*Pennisetum glaucum* L.) is one of the most important drought tolerant crop. It is considered as the principal food grain and fodder crop among millets. It is widely distributed across the arid and semi-arid tropics of Africa and Asia because of its tolerance to difficult growing conditions such as drought, low soil fertility and high temperature. Pearl millet is grown mostly as rainfed crop on marginal and sub-marginal land, poor in organic matter, low in available nitrogen, phosphorus and zinc, which results in low yield. It is the fourth most important food crop after rice, wheat, and sorghum. In India, it occupies an area of 7.4 million ha with production of 9.13 million tons and productivity of 1237 kg/ha (Directorate of millet development-2019). The major Pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which account for more than 90% of pearl millet acreage in country. Among the states, Rajasthan has biggest share of 4.18 million ha with production and productivity of 3.81 million tonnes (60.30% to all India) and of 911 kg/ ha (44.22% to all India) respectively (Directorate of Economics & Statistics, DAC&FW, 2018-19).

Pearl millet is a dual purpose crop as its grain is used for human consumption and its fodder as cattle feed. The nutrient content of pearl millet grains is very well comparable with other cereals and millets. It has high protein content with slightly superior amino acid profile. It contains about 12.4 %moisture, 11.6% protein, 5% fat, 67% carbohydrates, 2.7% mineral matter and gives 361

kilo calories per 100 gm with high amount of vitamin A and B. It imparts substantial energy to the body with easy digestibility. Pearl millet is rich in B vitamins, potassium, phosphorus, magnesium, iron, zinc, copper and manganese. It is gluten free grain and is the only grain that retains its alkaline properties after being cooked which is ideal for people with wheat allergy (Chauhan *et al.* 2015).

Material and methods

Growth parameters

Plant stand : The plant stand was counted at 20 DAS and at harvest from five randomly selected rows in each plot and the average in /ha was worked. Similarly, final plant stand was also recorded from each plot at harvest.

Plant height : Five plants were selected randomly from each plot and tagged. Height of individual plant was measured at 20, 40, 60 DAS and at harvest from base of the plant to top of the main shoot by scale and expressed as average plant height in cm.

Chlorophyll content : Total chlorophyll content of leaves at 40 and 55 DAS was determined using the method advocated by Arnon (1949) by taking 50 mg fresh leaf material. Samples were homogenized in 80% acetone and centrifuged for 10 minutes at 2000 rpm and volume of supernatant was made to 10 ml. The resultant absorbance of clear supernatant was measured by spectrophotometer at 652 nm.

Treatment details :**Table-1 : Treatments and their symbols**

S. No.	Treatments	Symbols
Foliar nutrients		
1.	Control	T ₀
2.	Water spray	T ₁
3.	100% RDF (60:30:30 NPK/ha)	T ₂
4.	100% RDF + one spray of 1% NPK (19:19:19) at 30 DAS	T ₃
5.	100% RDF + two spray of 1% NPK (19:19:19) at 30 and 45 DAS	T ₄
6.	100% RDF + one spray of 0.5% ZnSO ₄ at 30 DAS	T ₅
7.	100% RDF + two spray of 0.5% ZnSO ₄ at 30 and 45 DAS	T ₆
8.	100% RDF + one spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 DAS	T ₇
9.	100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 and 45 DAS	T ₈

Experimental details

(i) Season and year	Kharif Season, 2022
(ii) Crop name	Pearlmillet
(iv) Experimental design	Randomized Block Design
(v) Replications	03
(vi) Treatments	9
(vii) Total treatment combinations	27
(vii) Seed rate 4 kg/ha	
(viii) Total number of plots	27
(ix) Spacing	45 cm x 10 cm
(x) Plot size 2.0 x 3.2 = 6.4 m ²	
(xi) Expected duration of work	Six months

$$\text{Total chlorophyll (mg/ g)} = \frac{A (652) \quad 29 \quad \text{Total volume (ml)}}{@ \quad 100 \quad \text{Weight of sample (g)}}$$

Where, @ = is the path length = 1 cm

Design and layout of experiment : The experiment was laid out in Randomized Block Design and replicated three times. The treatments were randomly allocated to different plots, using random number table of Fisher and Yates (1963).

Result and Discussion**Growth attributes**

Plant height, Dry matter accumulation and chlorophyll content : Results revealed (Table 2) that different foliar applications of nutrients did not show significant influence on plant stand recorded at 20 DAS and at harvest. Results further showed that foliar application of various levels of nutrients significantly increased the growth attributes of

pearl millet viz. plant height, dry matter accumulation and chlorophyll content at different growth stages (Table 2 to 4). The maximum values of plant height (83.46, 165.25 and 196.25 cm) at 40, 60 DAS and at harvest, chlorophyll content (3.35 mg/g) at 60 DAS were observed with foliar application of T₈ (100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO₄ at 30 and 45 DAS). However, the foliar application of T₇ (100% RDF + two spray of 0.5% ZnSO₄ at 30 and 45 DAS) and T₅ (100% RDF + two spray of 1% NPK (19:19:19) at 30 and 45 DAS) remained at par with it in respect to plant height, dry matter accumulation, chlorophyll content.

An increase in growth parameters may be due to foliar application of nutrients which helped in encouragement of growth during early stages of crop development and it is regarded to be a vitally important plant nutrient. In addition, it improved chlorophyll content in leaves (Table 4) which is primary absorber of light energy needed for photosynthesis. Further, an adequate supply of nitrogen helped in overall development of plants

Table-2 : Foliar application of nutrients on plant height at different stages of pearl millet.

Treatments	Plant height (cm)			
	20 DAS	40 DAS	60 DAS	At harvest
T ₁ -Control	19.10	60.12	130.24	159.95
T ₂ -Water spray	19.22	61.33	130.29	160.99
T ₃ -100% RDF (60:30:30 NPK/ha)	20.11	72.14	145.82	177.42
T ₄ -100% RDF + one spray of 1% NPK (19:19:19) at 30 DAS	20.15	72.39	146.13	177.69
T ₅ -100% RDF + two spray of 1% NPK (19:19:19) at 30 and 45 DAS	20.42	82.64	163.64	194.99
T ₆ -100% RDF + one spray of 0.5% ZnSO ₄ at 30 DAS	20.29	72.78	146.82	178.11
T ₇ -100% RDF + two spray of 0.5% ZnSO ₄ at 30 and 45 DAS	20.44	82.99	163.92	195.35
T ₈ -100% RDF + one spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 DAS	20.35	72.93	147.19	178.65
T ₉ -100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 and 45 DAS	20.59	83.46	165.25	196.25
CD (P=0.05)	NS	9.13	15.50	16.25
CV (%)	7.89	7.18	6.02	5.22

Table-3 : Foliar application of nutrients on on plant height at different stages of pearl millet.

Treatments	Plant height (cm)			
	20 DAS	40 DAS	60 DAS	At harvest
T ₁ -Control	19.10	60.12	130.24	159.95
T ₂ -Water spray	19.22	61.33	130.29	160.99
T ₃ -100% RDF (60:30:30 NPK/ha)	20.11	72.14	145.82	177.42
T ₄ -100% RDF + one spray of 1% NPK (19:19:19) at 30 DAS	20.15	72.39	146.13	177.69
T ₅ -100% RDF + two spray of 1% NPK (19:19:19) at 30 and 45 DAS	20.42	82.64	163.64	194.99
T ₆ -100% RDF + one spray of 0.5% ZnSO ₄ at 30 DAS	20.29	72.78	146.82	178.11
T ₇ -100% RDF + two spray of 0.5% ZnSO ₄ at 30 and 45 DAS	20.44	82.99	163.92	195.35
T ₈ -100% RDF + one spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 DAS	20.35	72.93	147.19	178.65
T ₉ -100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 and 45 DAS	20.59	83.46	165.25	196.25
CD (P=0.05)	NS	9.13	15.50	16.25
CV (%)	7.89	7.18	6.02	5.22

as well as early vegetative growth as nitrogen is considered to be the most important nutrient for growth and development of plant as it is the basis of structural constituents of all living matter in plants and also has an important role in plant metabolism by being a constituent of many essential compounds like amino acids, proteins, nucleic acids, enzymes, coenzymes, alkaloids and a number of hormones. The highest plant height recorded might be due to the better nutrition, which played a vital role in cell division and growth of the plant. The significant improvement in nutrient content and uptake by plant parts might have resulted in increased synthesis of amino acids, proteins and other growth promoting substances which implies to have increased the meristematic activity and increased cell division and their elongation resulted in higher plant height (Table-2).

The highest plant height recorded might be due to the better nutrition, which plays a vital role in cell division and growth of the plant. The above trend of results are in

agreement with the findings of Kumar *et al.* (2012) who reported in sorghum where 2% urea spray was superior over other foliar treatments. These results are in conformity with Pandey and Gupta (2012) and Patil *et al.* (2013) in pearl millet.

As reported by Chouhan *et al.* (2018) higher dose of potassium and foliar supplied nutrients might be the reason that improved the pollen germination due to enhancing nutrient supply to flower parts which helped in high spikelet fertility and thus produced high number of fertile filled grains in ear head than control.

Nitrogen is the most important nutrient in all the mineral nutrients required for growth and development of plant as it is the basis of structural constituents of all living matter and also plays an important role in plant metabolism by virtue of being a constituent of many essential compounds like amino acids, proteins, nucleic acids, enzymes, coenzymes, alkaloids and a number of

Table-4 : Foliar application of nutrients on chlorophyll content at 60 DAS of pearl millet.

Treatments	Chlorophyll content at 60 DAS (mg/g)
T ₁ -Control	2.81
T ₂ -Water spray	2.83
T ₃ -100% RDF (60:30:30 NPK/ha)	3.01
T ₄ -100% RDF + one spray of 1% NPK (19:19:19) at 30 DAS	3.04
T ₅ -100% RDF + two spray of 1% NPK (19:19:19) at 30 and 45 DAS	3.29
T ₆ -100% RDF + one spray of 0.5% ZnSO ₄ at 30 DAS	3.09
T ₇ -100% RDF + two spray of 0.5% ZnSO ₄ at 30 and 45 DAS	3.31
T ₈ -100% RDF + one spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 DAS	3.10
T ₉ -100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO ₄ at 30 and 45 DAS	3.35
CD (P=0.05)	0.16
CV (%)	3.04

hormones. The results of the present study also corroborate the findings of Narayan and Joshi (2000) and Chaudhari *et al.* (2002) in pearl millet and Reddy *et al.* (2018) in finger millet, Kumar *et al.* (2021) and Gurjar *et al.* (2022) in pearl millet.

The results of present study are confirmed with the findings of Das and Jana (2015) who had reported highest seed yield of chick pea with application of 2% urea spray over different concentrations of 19:19:19 foliar spray and also reported highest seed and straw yield for wheat with 2% urea spray.

Application of micronutrient (Fe, Zn and B) might have increased the availability and steady supply of micro nutrients for plant metabolism and photosynthetic activity resulting into optimum growth and development of the crop. In addition, zinc is important in the synthesis of tryptophan, a component of some proteins and a compound needed for production of growth hormones (auxins) like IAA. Such improvement under increased availability of zinc in rhizosphere might have resulted in greater uptake by the plant consequently leading to a favourable stimulatory effect on physiological and metabolic processes of pearl millet plant. These favourable influences of nutrients resulted into greater meristematic activities and apical growth, thereby improving plant height, tillers per meter row length and higher value of leaf area ultimately resulting in improved LAI, chlorophyll content. The results obtained in present investigation are in line with the findings of Naveenaa *et al.* (2018) and Kishor *et al.* (2017) who reported that the foliar applied nutrients enhance the mobilization of photosynthates from source to sink and improved the sink accumulation capacity which resulted in increased grain weight.

Conclusions

The result revealed that levels of foliar nutrients significantly influenced highest plant height (cm), chlorophyll content in leaf at 60 DAS, effect tillers per plant with the foliar application of T₉ (100% RDF + two spray of 1% NPK (19:19:19) + 0.5% ZnSO₄ at 30 and 45 DAS).

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Importance of Biofortification in Millets–A Review

S.S Dighe^{1*} and V.R. Najan

¹Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra-413722

²Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra-413722

*Email : sumatidighe19@gmail.com

Abstract

The viable, affordable and sustainable method of adding micronutrients is biofortification.. It mainly affects those whose main source of sustenance has been major food crops, which are regrettably inadequate sources of micronutrients. Over 20 million farming families in underdeveloped nations are currently cultivating and consuming biofortified foods. Here, we discussed the importance of millets and biofortification, its three distinct agronomic approaches, as well as techniques. The major benefits of biofortified crops is that biofortification provide a promising future for the fight against hunger. Biofortification in millets have great promise for addressing the issue of malnutrition. Agronomic biofortification typically produces a win-win scenario for developing countries.

Key words : Biofortification, Millets, Nutrition, malnutrition.

Introduction

Our agricultural system is mainly concerned with raising crop productivity and grain yield. It was not intended to advance human health. This strategy has caused a sharp increase in food grain yield which has raised consumers micronutrient malnutrition and vitamin deficiencies. Developing bio-fortified crops eliminates the need to purchase fortificants and add them to food during processing, Biofortification is a one-time investment that provides a long-term, sustainable and cost-effective strategy to combat hidden hunger. Physically applying nutrients to crops, agronomic biofortification techniques can temporarily improve their nutritional and health condition. Consuming these crops can also improve human nutritional status. Agronomic treatments are used to manage plants and soil. Farmers that apply micronutrient fertilizers to fortify cultivars must have commercial support in order to strengthen the bio fortification programme. Beyond these obstacles, Bio-fortified millets have great promise for addressing the issue of malnutrition. (Kadapa *et al.*, 2023).

Malnutrition mostly impacts mothers and young children in developing countries by variety of ways. Biofortification of various kinds of crops is an important technique for reducing the prevalence of malnutrition worldwide. It provides a long-term, sustainable option for providing people with crops rich in micronutrients. Biofortification and biological fortification are terms used to describe nutrient-enhanced food crops that are created and developed using agronomic practices, conventional plant breeding methods and modern biotechnology methodologies. Traditional agricultural and food trade

practices use biofortified crops with higher bio-available concentrations of essential micronutrients to reach consumers. This presents a practical means of reaching families in low-income and undernourished groups who have limited access to diversified diets, supplements and fortified foods. Additionally, these crops are more bioavailable to people. (Tulchinsky, 2010).

Importance of millets : The staple food in many Asian and African nations are millets, which are high in phytic content and minerals. Amongst all the grains, millet has the lowest cost of agricultural production (Hasan *et al.* 2021).

Previous studies on millets for medicinal purposes have demonstrated their nutritional value in terms of antioxidant activity. Bioactive compounds found in millets may reduce the risk of a number of diseases, such as diabetes, high blood pressure, cancer, and cardiovascular diseases (Sharma *et al.*, 2021).

Millets have many nutritional advantages, They also include antioxidants such phenols, tannins, and flavonoids (Liang and Liang, 2019). Through the enzymatic breakdown of carbohydrate complexes, millets have the potential to lower levels of pancreatic amylase and -glucosidase, hence reducing postprandial hyper glycemia. Millets are essential in maintaining nutritional security for people all over the globe by offering calories and protein (Serna-Saldivar *et al.*, 2016).

Millets are distinguished from cereals by their high calcium levels, dietary fibre, polyphenols, and protein (Amadou *et al.*, 2013). Millets are a nutrient-dense food that contains 60-70 percent dietary carbs, 6-19 percent protein, 1.5-5 percent fat, 12-20 percent dietary fibres, 2-4

percent minerals, and various additional phytochemicals (Haldimani *et al.* 1995).

They are high in vitamin B, magnesium, and antioxidants (Sarita and Singh, 2016). Millets have a great deal of promise for use as health foods because they are gluten-free and high in micronutrients (Sood *et al.*, 2015).

Significance of biofortification in millets : Our bodies need trace amounts of minerals, vitamins, and other micronutrients. They also play a big role and their deficits cause serious health issues such as chronic illnesses, stunting, compromised immune and reproductive systems and deterioration in our mental and physical capacities (WHO). More than 2 billion people are impacted by micronutrient deficiencies, which claim the lives of more than 20 million people annually [Kennedy *et al.*, 2007]. Another name for it is “hidden hunger.” This is primarily brought by eating a repetitious pattern, not getting enough protein, or not having access to nutritious meals high in micronutrients like iodine, iron, and zinc. Thus, biofortification was introduced as a new phase. It is the process of introducing nutrients into food crops through breeding, and it is an affordable, long-term way to improve micronutrient delivery. This strategy not only reduces the number of severely malnourished individuals who need additional care, but it also helps those individuals maintain their improved nutritional status. Furthermore, biofortification is a feasible option for impoverished rural residents who might not have access to commercially available fortified foods and supplements. The soils in this region are depleted of zinc (50%) and iron (30%) and iodine, and much of the soil is harmed by alkalinity and salt issues. They also favour cereal-based diets, which are poorer in protein and vitamins [Fuge and Johnson, 2017].

Millets are recommended for the health of nursing moms, older adults, recovering patients, and babies. Because the grains release sugar into the bloodstream gradually, they are considered to be “gluten-free”. Because of their high fibre and protein content, millets are recommended as dietary products for those with diabetes and cardiovascular problems [Muthamilarasan, 2016].

Agronomic biofortification in millets : The application of mineral fertiliser containing micronutrients to the soil or plant leaves (foliar) with the goal of increasing micronutrient concentrations is known as agronomic biofortification. of the food crops’ edible portion. Applying micronutrients to soil, foliar, soil in combination with foliar, seed treatment, organic matter, and soil amendments, it raises the concentration of micronutrients. The application of mineral fertilisers and improving the solubility and mobilization of mineral elements in the soil are the usual agronomic ways to increase the content of mineral nutrients in edible sections. (White and Broadley, 2009).

Agronomic Biofortification in sorghum : In comparison to the control, recommended fertiliser dose, and recommended package of practices in sorghum, Kumar *et al.* (2017) found that soil application of RDF + Enriched FYM (i.e., 50 kg FYM ha⁻¹ + 3.75 kg ZnSO₄ ha⁻¹ and FeSO₄ ha⁻¹) recorded significantly higher grain yield (4287 kg ha⁻¹), fodder yield (7.51 t ha⁻¹), and test weight (37.77 g).

Ek Nath (2018) found that various treatments under evaluation had a considerable impact on the Fe and Zn content of sorghum grain and stover. Although there was a numerical difference in the Mn and Cu contents in the stover and grain, the difference was not statistically significant. Notably, under Enriched vermicompost, increased Fe and Zn content in grain was observed, and it was comparable to Enriched FYM. Regarding sorghum stover had a major impact on the Fe and Zn concentration. Arbuscular mycorrhizal (AM) fungi are a type of soil microorganism that are known to help plants for absorption of all available nutrients and to promote healthier plant growth (Douds *et al.*, 2005).

According to research by Cavender *et al.* (2003), vermicompost boosted mycorrhizal colonization in sorghum roots, in soil-scarce locations with low soil quality. Because of the varied activities of soil micronutrients with respect to uptake of native soil micronutrient content, a numerical difference in concentration was observed.

Techniques of biofortification in millets :

Agricultural Practices : Fertilisers are needed to increase the amount of micronutrients in plants grown in soils deficient in those nutrients.

Conventional Plant breeding: This involves using traditional breeding methods to produce adequate genetic diversity in agricultural plants so that they, for example have a high vitamin content. It takes several generations for carrying multiple kinds to get nutrient-rich plants and other desirable traits. This is the sole technique utilized in India to produce bio-enriched plants.

Genetic Engineering.: The process of adding DNA to an organism’s genome to create new or altered characteristics, such attributes or disease resistance, is known as genetic engineering.

Advantages of biofortification :

1. It is used on cultivars of crops that farmers presently use and whose harvests are well-liked by customers.

2. It is possible to acquire improved micronutrient

concentration in grain and other crop components in the same year.

3. Very little micronutrient is needed when the foliar treatment is applied.

4. Investment is not necessary for new seed.

Agronomic biofortification typically produces a win-win scenario for developing countries.

Conclusions

Agronomic methods are the most significant long-term sustainable biofortification strategies.

In spite from these difficulties, biofortified crops have a very promising future since they can help billions of underprivileged people, particularly in emerging nations, become micronutrient malnourished.

Biofortification has long been recognised as a viable and economical agricultural approach to enhance the nutritional condition of undernourished people worldwide. Enough amounts of these and other similar micronutrients, which are typically deficient in the diets of the developing and developed nations, are being provided via the development of biofortified food crops with enhanced nutrient contents, such as increases in iron, zinc, selenium, and provitamin.

Plant breeders, nutritionists, genetic engineers, and molecular biologists must work together to accomplish the goal. From these difficulties, biofortified crops have a very promising future since they can help billions of underprivileged people, particularly in emerging nations, become micronutrient malnourished. Instead of focusing on just one element of the food chain, the idea of involving biofortification should be seen as effective tool for soil, plants, animals and humans.

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Residual Effect of Organic Manures, Phosphorus and Sulphur on Growth, Yield Attributes and Yield of Greengram and Soil Nutrient Status under Summer Groundnut-Greengram Cropping System

D.M. Solanki^{1*}, J.R. Jat¹, Omprakash Meena², Priyanka Pannu¹ and K.A. Solanki³

¹Department of Soil Science and Agricultural Chemistry, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat

²ICAR-Central Arid Zone Research Institute, Jodhpur, Rajasthan

³Department Agronomy, C.P. College of Agriculture, S.D. Agricultural University, Sardarkrushinagar, Gujarat

Abstract

A field experiment was conducted at Agronomy Instructional Farm, Department of Agronomy, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar to study the effect of organic manures, phosphorus and sulphur on summer groundnut and their residual effect on succeeding greengram in loamy sand was carried out during summer-kharif, 2020 and 2021. There were eighteen treatment combinations made of three organic manures (i.e., M₁: 5 t FYM/ha, M₂: 0.75 t castor cake/ha and M₃: 2.5 t vermicompost/ha) as well as three levels of phosphorus (i.e., P₁: 25 kg P₂O₅/ha, P₂: 50 kg P₂O₅/ha and P₃: 75 kg P₂O₅/ha) and two levels of sulphur (i.e., S₁: 20 kg S/ha and S₂: 40 kg S/ha) were tested in a split-split plot design with four replications. The results revealed that among the different organic manures tested, residual effect of 5 t FYM/ha and among the different levels of phosphorus, residual effect of 75 kg P₂O₅/ha resulted in significantly higher growth, yield attributes, and yield parameters, such as plant height, root nodules per plant, number of pods per plant, test weight, seed yield, and stover yield of greengram. In terms of soil nutrient status, the residual effect of 75 kg P₂O₅/ha recorded significantly higher soil available phosphorus after harvest of greengram.

Key words : Organic manures, phosphorus, sulphur, greengram, yield, soil nutrients.

Introduction

Modern agricultural systems are progressively shifting towards sustainable practices, necessitating a nuanced understanding of the residual effects of key inputs on both soil and crop dynamics. The residual effect of organic manures applied to the soil refers to the carryover effect of the application on the subsequent crop (Silva *et al.*, 2006). Decomposition of organic manure and the release of nutrients are more gradual and stored for a longer period in the soil, thus ensuring longer residual effect and improved crop yields (Paul and Beauchamp, 1994). Similarly, incorporation of organic manures in agricultural soils is primarily a means to maintain soil organic matter which results in enhanced biological activity, physical properties and nutrient availability (Antil and Narwal, 2007). The most immediate effect of organic manures application is on the availability of nutrients to the succeeding crop as a result of mineralization-immobilization processes.

Phosphorus, a vital macronutrient for plant growth, influences crop yield and quality. Investigating the residual interactions of phosphorus within the soil-plant system is essential for understanding the intricate dynamics that impact greengram cultivation in a groundnut-greengram cropping sequence. Meanwhile, sulphur, often underestimated in comparison to other

macronutrients, plays a crucial role in plant metabolism and stress tolerance. Unravelling the residual effects of sulphur, both individually and in combination with organic manures and phosphorus, is pivotal for comprehending its contribution to overall nutrient availability in the soil and its subsequent influence on crop growth and yield.

Greengram commonly known as mung bean or moong, is a staple pulse crop in India, gaining significance for its high protein content (18-24%), nutritional value and adaptability to diverse agro-climatic conditions. India is the major producer of greengram in the world and grown in almost all the States. In 2022, greengram was cultivated in India over 5.5 million hectares, resulting in a total production of 3.17 million tonnes at a productivity rate of 570 kg/ha. The cultivation of greengram in the Gujarat region covered an area of 0.80 lakh ha (ICAR-IIPR, 2023). It plays a crucial role in providing a protein-rich dietary source, particularly for vegetarians, while also contributing to sustainable agriculture through nitrogen fixation and short-duration crop cycles.

The chosen summer groundnut-greengram cropping system serves as a one of the important model for semi-arid region of north Gujarat regions. The study aims to shed light on the long-term implications of organic manures, phosphorus, and sulphur within this cropping system, providing insights into sustainable nutrient

management strategies. As agriculture adapts to more environmentally friendly practices, deciphering the intricate dynamics of residual effects becomes paramount.

Materials and Methods

A field experiment was conducted at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar to study the effect of organic manures, phosphorus and sulphur on summer groundnut and their residual effect on succeeding greengram in loamy sand carried out during summer-kharif, 2020 and 2021. The soil of the experimental plot was loamy sand in texture, low in organic carbon, available N and DTPA-extractable Fe and Zn, medium in available P_2O_5 , K_2O and S whereas high in DTPA-extractable Mn and Cu content. There were eighteen treatment combinations made of three organic manures (*i.e.*, M_1 : 5 t FYM/ha, M_2 : 0.75 t castor cake/ha and M_3 : 2.5 t vermicompost/ha) as well as three levels of phosphorus (*i.e.*, P_1 : 25 kg P_2O_5 /ha, P_2 : 50 kg P_2O_5 /ha and P_3 : 75 kg P_2O_5 /ha) and two levels of sulphur (*i.e.*, S_1 : 20 kg S/ha and S_2 : 40 kg S/ha) were tested in a split-split plot design with four replications.

The greengram cultivar GM 4 were selected for the investigation of residual effect. As per treatments, the preceding summer groundnut crop was fertilized with phosphorus in the form of DAP and sulphur in the form of elemental sulphur with organic manures *i.e.*, farm yard manure, castor cake and vermicompost in respective treatments. There was no application of fertilizer and manure was applied to greengram because this crop was selected as the succeeding crop to test the residual effect of fertilizer and manures applied in the previous crop. All agronomical practices and plant protection measure was followed for better and successful crop production. The observation on growth yield attributes and yield were recorded by randomly selected five plants from net plot area and tagged all plants for further observations. The data of various parameters were statistically analysed using analysis of variance (ANOVA) technique and the treatments were compared at 5% levels of significance (Cochran and Cox, 1967).

Results and Discussion

Residual effect of organic manures : The pooled data of 2020 and 2021 presented in Table-1 revealed that the residual effect of the treatment of 5 t FYM/ha significantly increased the plant height, root nodules per plant, number of pods per plant, test weight, seed yield, and stover yield of greengram over 0.75 t castor cake/ha and 2.5 t vermicompost/ha. This might be due to the fact that FYM

improved the organic carbon content and the microbial population in the soil and also improve the physical properties of soil *i.e.*, bulk density and water holding capacity of soil up to certain extent compared to castor cake and vermicompost. Another reason might be most of the nutrients present in castor cake and vermicompost are comparatively readily available to plants and most of the part was utilised by the first crop but in case of FYM it provides only 1/3 part of plant nutrients to the first crop and remaining amount provided to the next crop. That's why FYM provides more nutrients to subsequent crops compared to castor cake and vermicompost. Similar results were obtained by Mahata *et al.* (2018), Yasodha and Chinnusamy (2019) and Lakum *et al.* (2022).

A perusal of pooled data of 2020 and 2021 given in Table-2 revealed that soil organic carbon, available phosphorus, potassium and sulphur had not significantly influenced due to residual effect of organic manures. However, numerically higher values of soil organic carbon, available phosphorus, potassium and sulphur was found under the treatment of 5 t FYM/ha (M_1) compared to 0.75 t castor cake/ha and 2.5 t vermicompost/ha.

Effect of phosphorus : The pooled data of 2020 and 2021 given in Table-1 showed that residual effect of 75 kg P_2O_5 /ha (P_3) significantly increased plant height, root nodules per plant, number of pods per plant, test weight, seed yield and stover yield of greengram over 25 and 50 kg P_2O_5 /ha. Whereas Plant height at harvest of greengram being at par with 50 kg P_2O_5 /ha (P_2). This might be due to higher application rates might have sustained phosphorus availability in the soil over a longer period, providing continuous support to the growing plants throughout their life cycle helps in root growth of plants which provides a sheet for formation of root nodules, due to improvement in nodulation more nitrogen fixation occurs. Ultimately it improves the availability of nitrogen as well as other nutrients through the extensive root growth developed through the phosphorus. Similar results were obtained by Nimje and Seth (1988) in maize, Munda *et al.* (2015) in potato, Gaspar *et al.* (2018) in chickpea and Kumawat *et al.* (2020) in chickpea.

The pooled data of 2020 and 2021 given in Table 2 indicated that significantly the higher content of available P_2O_5 in soil was noted under treatment of 75 kg P_2O_5 /ha over 20 and 50 kg P_2O_5 /ha. This might be attributed to the greater initial phosphorus application to first crop. This higher dosage likely increased phosphorus accumulation in the soil, leading to sustained release.

Effect of sulphur : The pooled data of 2020 and 2021 given in Table-1 and 2 indicated that residual effect of different levels of sulphur had no significant effect on plant

Table-1 : Residual effect of organic manures, phosphorus and sulphur on plant height, root nodules per plant, number of pods per plant, test weight, seed yield and stover yield of greengram (Pooled data, 2020 and 2021)

Treatments	Plant height (cm) at harvest	Root nodules per plant (at flowering)	Number of pods per plant	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)
Organic manures (M)						
M ₁ : 5 t FYM/ha	50.4	66.1	20.8	35.1	843	1360
M ₂ : 0.75 t castor cake/ha	47.7	64.0	18.9	34.5	730	1090
M ₃ : 2.5 t vermicompost/ha	48.8	65.1	20.0	34.9	796	1221
S.Em.±	0.42	0.24	0.15	0.14	13.4	32.9
C.D. at 5 %	1.47	0.83	0.52	NS	46	114
Phosphorus levels (P)						
P ₁ : 25 kg P ₂ O ₅ /ha	48.0	64.0	18.6	33.4	733	1162
P ₂ : 50 kg P ₂ O ₅ /ha	48.7	65.3	19.8	34.8	796	1197
P ₃ : 75 kg P ₂ O ₅ /ha	50.1	66.3	21.3	36.1	840	1312
S.Em.±	0.51	0.21	0.10	0.16	13.8	31.5
C.D. at 5 %	1.53	0.63	0.30	0.48	41	94
Sulphur levels (S)						
S ₁ : 20 kg S/ha	48.7	65.1	19.8	34.7	786	1213
S ₂ : 40 kg S/ha	49.1	65.3	20.0	35.1	792	1233
S.Em.±	0.46	0.24	0.11	0.11	10.9	32.0
C.D. at 5 %	NS	NS	NS	NS	NS	NS
CV%	10.1	9.20	9.12	9.24	10.4	10.1
Interactions	-	-	-	-	-	-

Table-2 : Residual effect of organic manures, phosphorus and sulphur on soil organic carbon, available phosphorus, available potassium and available sulphur after harvest of greengram (Pooled data, 2020 and 2021.)

Treatments	Organic carbon (%)	Available P ₂ O ₅ (kg/ha)	Available K ₂ O (kg/ha)	Available S (mg/kg)
Organic manures (M)				
M ₁ : 5 t FYM/ha	0.331	42.8	242	12.7
M ₂ : 0.75 t castor cake/ha	0.317	42.1	239	12.0
M ₃ : 2.5 t vermicompost/ha	0.321	42.3	241	12.3
S.Em.±	0.004	0.14	1.89	0.13
C.D. at 5 %	NS	NS	NS	NS
Phosphorus levels (P)				
P ₁ : 25 kg P ₂ O ₅ /ha	0.319	41.3	242	12.5
P ₂ : 50 kg P ₂ O ₅ /ha	0.323	42.5	241	12.4
P ₃ : 75 kg P ₂ O ₅ /ha	0.325	43.4	240	12.1
S.Em.±	0.002	0.13	1.48	0.08
C.D. at 5 %	NS	0.38	NS	NS
Sulphur levels (S)				
S ₁ : 20 kg S/ha	0.322	42.3	241	11.6
S ₂ : 40 kg S/ha	0.324	42.5	240	13.1
S.Em.±	0.002	0.11	0.91	0.09
C.D. at 5 %	NS	NS	NS	NS
CV%	4.18	3.06	3.23	3.74
Interactions	-	-	-	-

height, root nodules per plant, number of pods per plant, test weight, seed yield and stover yield of greengram. Also, it had not influenced soil organic carbon, available phosphorus, available potassium and available sulphur after harvest of greengram. This could be attributed to the relatively short-term retention of sulfur in loamy sand soil. This soils typically have low clay content and limited ability to retain nutrients, including sulphur. Sulphur is prone to leaching in soils with low retention capacity, and it may not persist for an extended period. As a result, even if sulphur was applied to first crop, its availability to succeeding greengram plants might have been transient, and any short-term benefits might not have translated into a sustained improvement in greengram over the entire growth period.

Conclusions

Based on the experimental investigation, it is established that the residual effect of 5 t FYM/ha has a significant effect on growth, yield attributes and yield of greengram over 0.75 t castor cake/ha and 2.5 t vermicompost/ha. Whereas, among the different levels of phosphorus, the residual effect of 75 kg P_2O_5 /ha resulted in significant effect growth, yield attributes and yield of greengram as well as soil available phosphorus compared to 25 kg P_2O_5 /ha and 50 kg P_2O_5 /ha.

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Importance of Millets – A Review

V.R. Najan^{1*} and S.S Dighe²

¹Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra-413722

²Department of Horticulture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra-413722

*Email : vishakhanajan@gmail.com

Abstract

In recent years, millets have gained prominence in the hunt for wholesome and sustainable food sources, especially in India. A class of ancient cereal grains known as millets are a valuable addition to diets all around the world because they are nutrient-dense powerhouses with a range of health advantages. These resilient plants flourish in a range of agro climatic circumstances, needing less inputs and water than other major cereal crops. Because of its high fibre content and low glycemic index, millet is beneficial for heart health since it lowers LDL cholesterol and raises good cholesterol. Recently, millets have gained international interest due to their potential to improve environmental sustainability and alleviate dietary issues. The Indian government made a UN General Assembly proposal to declare 2023 the International Year of Millets, which received approval from 71 nations.

Key words : Millet, Nutrition, Health, fibre content, International year

Introduction

Millets are the widely diversified collection of small-seeded grasses. These are small-grained cereals from the Poaceae family, or millets. (Hrideek and Nampoothiri, 2017). They are cultivated as grains or cereal crops for human use and fodder. Archaeological documents indicate that millet has been cultivated in India for thousands of years (Weber and Fuller, 2008). Due to their numerous millets advantages, environmental sustainability, and adaptability in the kitchen, these ancient grain which are also very nutritious have become more and more popular. Pearl millet (bajra), sorghum (jowar), finger millet (madua), foxtail millet (kangni), small millet (kutki), barnyard millet (jhangora), kodo millet (kodra), and proso millet (barri) are among the various types of millets. Each has distinct qualities and uses in cooking. Millets are a great complement to a balanced diet because they are free of gluten and high in dietary fibre, vitamins, minerals and antioxidants. India is home to several significant types of millet, including pearl millet, barnyard millet, foxtail millet finger millet and sorghum (Rathore *et al.*, 2016). Most of these millets are grown in dryland environments, like the semi-arid and desert parts of Maharashtra, Rajasthan, Gujarat, Karnataka, Andhra Pradesh, and Tamil Nadu. A crop with high quantities of vitamins and minerals, millets are incredibly nutrient-dense. They are also known as “super-foods,” and their production can help with concerns about farmer livelihood and nutrition security. (Singh, 1996).

One of the earliest foods are millets, which are small-seeded cereal grasses that grow in arid or rain-fed

environments with poor fertility and mountains as a growing region. In addition to being a fantastic source of energy, millets also include dietary fibre, slowly digesting starch, and resistant starch, which releases glucose gradually and promotes satiety. Millets are a very nutrient-dense, acid-free, and non-glutinous food. Because of this, they have a high lecithin content, are calming and highly palatable, and help to stimulate the nervous system. (Michaelraj and Shanmugam, 2013). Because millets have a brief growth season, growers can harvest several crops each year. Farmers in areas with scarce water supplies and erratic weather patterns can depend on them since they are resistant to diseases, pests, and drought. But because to improvements in farming methods, millet yields are now increased by farmers using methods like contour bunding, moisture conservation, and integrated pest management. Because millets are naturally pest-resistant and require fewer chemical inputs, the adoption of organic and sustainable agricultural practices has also gained support. (Shahidi and Chandrasekara, 2013).

Apart from their nutritional worth, millets are essential for conservation of biodiversity and sustainable agriculture. When compared to other staple crops, they require less chemical inputs. We can improve soil health, preserve water resources, and lessen the negative effects of agriculture on the environment by encouraging the production and consumption of millets. The production and consumption of millet have received international prominence, and many programmes are in progress to encourage their use. The International Year of Millets will be observed in 2023 by the UN in recognition of the

significance of millets in accomplishing sustainable development objectives. (Theuri and Burkhart, 2023).

Nutritional importance of Millets : When it comes to nutrition, millets are on par with or even better than a number of the most significant cereal grains. Millets have a high antioxidant content, high fibre content, low glycemic index, and gluten-free protein. They are also packed with physiologically active compounds. These small-seeded crops have an excellent nutritional profile, making them a fantastic source of minerals, protein, and energy. Niacin (B3), thiamine, riboflavin, and folic acid are among the vitamins that are abundant in millet grains. About 70% of grains are thought to be made up of carbohydrates, the majority of which are soluble carbs and dietary fibre. 70–80% of the polysaccharides in millets are made up of amylopectin and amylose. Not only do they have higher dietary fibre content, but they also have higher polyphenol content (0.2–0.5%).

Finger millet has roughly 5-8% protein, 65-75% carbs, 15-20% dietary fibre, and 2.5–3.5% minerals. The bare finger millet caryopsis, which has a brick-red seed coat, is typically utilised as a complete meal in traditional dishes like roti, muddle, and ambali (thin porridge). (Chethan and Malleshi, 2007a). Epidemiological studies have demonstrated that regular eating of whole grain cereals and their products can reduce the incidence of diabetes mellitus, gastrointestinal disorders, and cardiovascular disease (McKeown, 2002). The utilisation of millets as a whole grain concentrates vital nutrients, including vitamins, minerals, phenolics, and dietary fibre, in the grain's outer covering or seed coat, which contributes to the food's nutritional and health benefits. (Antony, *et al.*, 1996).

Health Benefits

1. Cardiovascular disease : Millets, which are high in magnesium, lower blood pressure and the risk of heart attacks, particularly in cases of atherosclerosis. Additionally, the potassium in millets lowers the risk of cardiovascular disease and acts as a vasodilator to assist blood pressure stay low. Furthermore, the plant lignans found in millets can change into animal lignans in the presence of microbiota in the digestive tract and offer protection against heart disease and several types of cancer. Millets' high fibre content is essential for reducing cholesterol, removing LDL from the body, and enhancing the benefits of HDL. When compared to rice and other minor foods, rats fed a diet of treated starch from barnyard millet had lower blood glucose, serum cholesterol, and triglycerides. (Kumari and Thayumanavan, 1997). Increased plasma concentrations of adiponectin and high-density lipoprotein (HDL) cholesterol for nutrition and health in genetically obese type-2 diabetic mice in high-fat

environments were noted when Proso millet was fed. (Park *et al.*, 2008). Additionally, it has been demonstrated that rats fed finger millets and proso millets had much lower serum triglyceride concentrations than rats fed white rice and sorghum. In hyperlipidemic rats, finger millet and proso millet lower plasma triglycerides, which may prevent cardiovascular disease. (Lee *et al.*, 2010).

2. Diabetes : Diabetes mellitus is a long-term metabolic disease marked by changes in the metabolism of fat, protein, and carbohydrates as well as hyperglycemia. Known as the most prevalent endocrine condition, it causes either insufficient production of insulin (type 1) or a combination of resistance to the effect of insulin and the insulin-secretory response (type 2). (Saleh *et al.*, 2013). Millets contain a substantial amount of magnesium, which increases the body's efficiency of insulin and glucose receptors and helps avoid diabetes. Diets based on finger millet have demonstrated a decreased glycemic response because of their high fibre content and alpha amylase inhibitory characteristics, which are known to decrease the absorption and digestion of starch. (Kumari and Sumathi, 2002).

Under high fat feeding conditions, proso millet has been demonstrated to enhance insulin and glycemic responses in genetically obese type 2 diabetic mice. (Park *et al.*, 2008). As a result, millet grains may be helpful in the management and prevention of diabetes.

3. Disorders of the Digestive System : Controlling the digestive process can improve nutritional retention and lower the risk of developing more severe gastrointestinal disorders like colon cancer or gastric ulcers. Millets' high fibre content aids in the elimination of conditions like cramping, bloating, constipation, and excessive gas. Celiac disease is an immune-mediated enteropathic illness that typically develops in susceptible people after consuming gluten. (Catassi and Fasano, 2008) People following a gluten-free diet may find it easier to substitute dishes derived from gluten-free grains such as rice, corn, sorghum, millet, amaranth, buck wheat, quinoa, and wild rice for cereals like wheat, barley, and rye. (Thompson, 2009) Because millets don't contain gluten, they offer a lot of potential in food and drink recipes. They can also satisfy the growing demand for gluten-free foods and be a good option for people with celiac disease. (Taylor *et al.*, 2006)

4. Cancer : According to values found in the literature, millet grains are known to be high in phytate, tannins, and phenolic acids (Thompson, 1993). These nutrients lower an animal's risk of developing breast and colon cancer. (Graf and Eaton, 1990). Compared to people who eat wheat or maize, those who consume sorghum and millet have been linked to a lower incidence of oesophageal cancer due to the fibre and phenolic compounds included

Table-1 : Nutritional profile of various millets.

Millet type	Fibre (%)	Protein (%)	Minerals	Vitamins
Barnyard millet	11-14	6-12	Magnesium, Phosphorous, Iron, Zinc	Niacin(B3), Thiamine(B1), Folate(B9)
Kodo millet	8-9	8-10	Magnesium, Phosphorous, Iron, Zinc	Niacin(B3), Thiamine(B1), Folate(B9)
Little millet	6-8	7-12	Magnesium, Phosphorous, Iron, Zinc	Niacin(B3), Folate(B9)
Proso millet	1.2-12	10-15	Potassium, Phosphorous, Zinc	Niacin(B3), Pyridoxine(B6), Folate(B9)
Foxtail millet	5-8	8-12	Magnesium, Phosphorous, Iron, Zinc	Niacin(B3), Thiamine(B1), Folate(B9)
Finger millet	3.6-5.8	7.5-12	Calcium, Iron	Niacin(B3), Thiamine(B1), Folate(B9), Riboflavin (B2)
Pearl millet	2-3	8-17	Magnesium, Phosphorous, Iron, Zinc	Niacin(B3), Thiamine(B1)

(Source : Tripathi et al., 2023)

in these grains (Van Rensburg, 1981). According to recent studies, consuming fibre is one of the best and simplest strategies for women to delay the start of breast cancer. Eating more than thirty grams of fibre per day can lower their risk of breast cancer by more than fifty percent.

Conclusions

Millets are the nutritional goldmine for our diets because of its many health and nutritional advantages. Their high fibre content, vital minerals, and advantageous phytochemicals support improved management of ailments as well as general health and the avoidance of illness. It helps for treating diabetes, gluten-free diets, and sustainable agriculture, millets are incredibly helpful. Millions of Indians rely heavily on millets to meet their nutritional needs. By appreciating the advantages of millet, we may embrace and promote a healthier lifestyle and a future free from hunger. India can boost its agricultural resilience, preserve its traditional food history for future generations, and improve the nutritional quality of its people by encouraging the production and use of millet.

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Single Nucleotide Polymorphisms Analyses of Key Gene Sucrose Synthase Involved in Starch Metabolism in *Musa*

Muhilan Mahendhiran^{1,2*} and Hoshiyar Singh²

¹Unidad de Biotecnología, Centro de Investigación Científica de Yucatán (CICY), A.C., Calle 43, # 130, Col. Chuburna de Hidalgo, CP. 97200, Mérida, Yucatán, México.

²Faculty of Agriculture, Vivekananda Global University (VGU), Sector 36, NRI Colony Rd, VIT Campus, Jagatpura, Jaipur - 303012, Rajasthan, India

*Corresponding Author Email : m.muhilan@vgu.ac.in

Abstract

Starch is a very important energy source for the human diet. In higher plants, the starch metabolism is under the control of a regulatory pathway. In this study, Sucrose synthase (SUCS) enzyme was studied, and this enzyme plays a major role in starch metabolism. We investigated the Single Nucleotide Polymorphisms (SNPs) and the variations in the partial sequences of starch metabolism gene SUCS. The genomic DNA was isolated from 10 *Musa* accessions including the representatives of wild ancestors, desserts, plantains and cooking bananas. Amplicons of the length of 400 bp of Sucrose synthase were obtained, cloned and then sequenced. A total of 123 cloned sequences for SUCS enzyme were obtained and analyzed. The bioinformatics analyses revealed that SNPs/Indels could be identified in both coding and non-coding regions of the gene fragments. Two SUCS isoforms were generated by the bioinformatics analyses from the analyzed sequences. The SUCS gene showed vast differences in their intron regions, though the coding regions were almost similar, and contig 2 was only found in the B genome. A total of 35 SNPs giving 31 haplotypes and were found in two SUCS variants, 25 were from exons and 10 from introns. The phylogenetic analysis showed that the relationships between the haplotypes and the externals of monocots and dicot species. These results concluded that, there is more than one member in SUCS gene families. This study is the first of SNPs based variants of SUCS gene fragments in starch metabolism in *Musa*.

Key words : Starch metabolism, Sucrose synthase, Variants, Bananas and Plantains, SNP, *Musa*

Introduction

Starch is one of the most important sources of energy from food in the world. Banana starch is one of the most accessible sources of starch in tropical and subtropical regions all year-round. This is one of the most important staple food crops in the globe and ranks fourth after rice, wheat and maize (Martin *et al.* 2013; Pillay and Tenkouano, 2011; Jainand Swennen, 2004). Population increases day by day but there is a scarcity for feeding this much people. In 2050 the human population will increase from 7 billion to ~10 billion and the staple crop harvest should increase with the same or less cultivated land area (Pillay *et al.* 2012). Starch is a major energy source for living organisms including humans. This is used as food, feed and an essential raw material in many industries (BeMiller and Whistler, 2009).

The majority of dessert and cooking bananas are descended from the common ancestors *Musa acuminata* and *Musa balbisiana*; over 1000 varieties are recognized worldwide (Hippolyte *et al.* 2012; Youssef *et al.* 2011; Crouch *et al.* 1998). Depending on the starch and sugar content in their fruits they are divided into desserts, plantains, cooking and beer bananas. According to the

region, people use their own varieties for food purposes (Simmonds and Shepherd, 1955).

For basic as well as applied science, it is essential to understand the differences in the starch content and taste differences. There are more than 20 enzymes involved in the starch metabolic pathway (Whitt *et al.*, 2002). Some of these are key metabolic enzymes such as ADP-glucose pyrophosphorylase (AGPase), Starch synthase (SS) and Sucrose synthase (SUCS). Variations in the enzymes are reflected in phenotypic variation, so it is important to correlate them with their phenotype in the germplasm bank. These enzymes work both in allosteric and catalytic regulations and the sub-units of each enzyme can vary. In order to increase the starch content and alter its composition (amylase amylopectin ratio) in the banana fruit we need to study these enzymes at the molecular level. Single Nucleotide Polymorphisms (SNPs) of DNA molecules alter the coding sequences and subsequently might cause changes at the protein sequence level. These changes may be shown in phenotypic variations in different banana accessions.

There are more than 20 genes involved in starch metabolism in higher plants; in maize 30 genes have been identified and 27 genes in rice (Yan *et al.*, 2009), however

in banana it is unknown. In *Musa*, sucrose synthase (locus *sh1*) plays an important role in starch metabolism.

Importance of new molecular markers for agronomic traits

(1) Molecular markers allow breeders to track genetic loci without phenotyping thereby reducing time and space involved in field testing.

(2) Can be used to identify genes for transgenic approaches for plant improvement such as up / down gene regulation and gene transfer

(3) To be used in breeding, markers should be polymorphic so that alleles associated with traits of interest can be identified.

Starch metabolism in plants : Starch synthesis is a complex biological process which requires multiple enzymes not only for synthesis but also for degradation (Davis *et al.*, 2003). The involvement of various sequences of the enzymes involved in starch metabolism are highly conserved (Tetlow *et al.* 2004; Smith *et al.* 1997). Starch is degraded to sucrose when the banana fruit ripens (Liet *et al.* 2011; Gelencsér *et al.* 2008; Huber *et al.* 1990).

Sucrose synthase : Sucrose synthase (SUCS, UDP-glucose: D-fructose-glucosyl-transferase; EC 2.4.1.13) has a major role in starch metabolism, since it is the primary enzyme responsible for sucrose cleavage (Baroja-Fernández *et al.* 2009; Wang *et al.* 1993). SUCS converts sucrose into fructose and UDP-glucose in tomato fruit and other higher plants. Sucrose synthase plays a major role in sucrose-starch inter-conversions which is found in many species such as potato, maize, wheat and banana (Li *et al.* 2011; Kubo *et al.* 1999). In sink organs SUCS converts the imported sucrose into UDP-glucose (UDPG) and fructose. UDPG is then transformed to hexose-phosphates and ADPG necessary for starch biosynthesis. SUCS also involves the direct conversion of sucrose into ADPG linked to starch biosynthesis in both autotrophic and heterotrophic cells. It involves the degradation of sucrose and the synthesis of UDP-Glucose (Klotz *et al.* 2008; Amor *et al.* 1995). This is the cytoplasmic enzyme which provides carbon for respiration and cell wall polysaccharide and starch synthesis (Tobias *et al.* 1992; Zrenner *et al.* 1995; Wang *et al.* 1993).

The isoforms of SUCS found in many plant species examined to date are encoded by a small multigene family. Arabidopsis gene structure and amino acid sequences indicate the SUCS family consists of six SUCS genes displaying different development expression patterns known as: *suc1/ suc2/ suc3/ suc4/ suc5/ suc6*. SUCS are actively involved in sucrose breakdown. Two genes in maize (*Sh1* and *Sus1*) encode sucrose synthase

isozymes (Koch *et al.*, 1992). The *Shrunken (Sh)* locus on chromosome 9 of *Zea mays* encodes the enzyme sucrose synthase (Werret *et al.*, 1985). In the *Musa acuminata* and *Musa balbisiana* genomes the SUCS gene has been identified at chromosomes 2, 3, 6 and 10 (Davey *et al.* 2013; D'Hont *et al.* 2012).

SNP based variation arises in DNA sequences of different *Musa* accessions as a result of somatic mutation, which will help to understand the variations in cultivars and their wild ancestors. Single nucleotide substitutions of one base for another in DNA sequences are potential useful molecular markers to reveal the genetic variation which has applications for plant breeding (Huang *et al.* 2013; Santosh *et al.* 2012). Mutations have occurred in the plant genome during gene duplication and selection by evolutionary processes. Genetic variations such as SNPs are the basis to improve both quantitative and qualitative traits of starch metabolism in *Musa* cultivars. In order to improve and manipulate the enzymes of starch metabolism in bananas and plantains, it is necessary to investigate how many isoforms are available based on the variations at the molecular level in Sucrose synthase. To investigate the number of isoforms available in this starch metabolism enzyme, amplicons of SUCS gene fragments were sequenced. The objective of this work was to investigate the Single Nucleotide Polymorphisms (SNPs) in these sequences in both coding and non-coding regions and find their evolutionary relationships.

Single Nucleotide Polymorphisms of gene SUCS involved in starch metabolism is associated with the phenotypic variation observed in different *Musa* genotypes and accessions. Thus, the objective is to detect Single nucleotide polymorphism (SNPs) in the partial sequence of key starch metabolism gene SUCS of different *Musa* genotypes and accessions using a PCR based methodology.

Materials and methods

Sample collection : Plant material of ten accessions representative of bananas and plantain, including wild species belonging to the edible *Eumusa* and *Australimusa* sections (Table1), were obtained from the International Transit Centre (ITC, <http://www.cropdiversity.org/banana/#AvailableITCAccessions>) hosted by the Catholic University of Leuven in Belgium. These are maintained as field plants at the *Musa* germplasm collection of CICY located in the Experimental Station of the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP) research station at Uxmal (Lat. 20° 24' 27.72"N, Long. 89° 45' 06.66" W) in Yucatán, México.

Samples of "cigar leaves" from each accession were collected, dipped in a solution containing three parts citric

Table-1 : List of the *Musa* accessions used in this study.

No.	Section	Species/hybrid	Subspecies/Subgroup	Genome	Wild/ Cultivar	Accession Name	Abbreviation	ITC ^a
1.	Eumusa	<i>M. acuminata</i>	banksii	AA	Wild	banksii	Ban	0623
2.		<i>M. acuminata</i>	malaccensis	AA	Wild	Pisang Kra	P.kra	1345
3.		<i>M. acuminata</i>	—	AA	Cultivar	Pisang lilin	P.li	1121
4.		Dessert banana	Neypoovan	AB	Cultivar	Safet velchi	S.ve	0245
5.		<i>M. balbisiana</i>	—	BB	Wild	BB-CICY	BB-Cicy	—
6.		Desert banana	Gros Michel	AAA	Cultivar	Gros Michel	GMI	0484
7.		East African cooking	Mutika/Lujigria	AAA	Cultivar	Mbwazirume	Mbw	0084
8.		Cooking banana	—	ABB	Cultivar	Bluggoe	BLU	0767
9.		Pacific Plantain	Maoli/Popolou	AAB	Cultivar	Popotou	Pop	0335
10.	Australimusa	<i>M. beccari</i>	—	W	Wild	beccari	BEC	1070

*Collected from Teapa, Tabasco, Mexico.

^aAll the plant materials that have an ITC were provided by the Biodiversity International Centre for Musa Located at the Laboratory for Tropical Plant Improvement in the Catholic University of Leuven, Belgium.

acid (75mg/100ml H₂O) and one-part ascorbic acid (25mg/100ml H₂O) and transported in a cooler from the field to the laboratory. The tissues were disinfected with sodium hypochlorite 6% (v/v) and ethanol 70% (v/v) for one minute each, followed by three rinses with distilled water; the excess water was removed with a sterile-paper towel. Subsequently, 100 mg of leaf sample was weighed, wrapped in aluminum foil, frozen with liquid nitrogen and stored at -80°C until use.

Primer design : For SUCS, the primers were designed from *Musa acuminata* sucrose synthase mRNA (AF079523.1) and the sequence for the forward primer sequence of Sucrose synthase 5'-GGTGGTCAGGTTGT TTACATCTTGG-3' and the reverse sequence was 5'-GGTAAGGCCATACTTCAAAACGGG-3' and expected size amplicon was 400 bp.

DNA extraction, PCR amplification and Electrophoresis : Total genomic DNA was extracted from 100 mg of frozen samples according to the protocol of Dellaporta *et al.*, 1983 with minor modifications. The DNA quality and concentration were determined using a spectrophotometer according to the method described by Stulnig and Amberger, 1994 using the tools of Krishyat 1.0 (Youssef, 2012).

Samples were normalized to a concentration of approximately 10ng/ L prior to PCR amplification. The PCR mixture (25 μ L) contained 500 μ M each dNTP (Invitrogen, USA), 0.5 μ M each specific primer, ~ 10 ng of DNA, 1-X PCR buffer (Invitrogen, USA), 1.5 mM MgCl₂ (Invitrogen, Brazil), and 5U *Taq*-DNA polymerase (Invitrogen, USA). The PCR reaction was performed in an Eppendorf Master Cycler (Life Sciences Biotech, USA) with initial denaturation at 94 °C for 5 min, followed by 35 cycles of 94 °C for 40 s, with an annealing temperature of 55 °C for 50 s and, 72 °C for 1 min, and a final extension at

72°C for 8 min. The amplified PCR products were electrophoresed on 1% w/v ultrapure agarose gels (Invitrogen, Spain) with 1-X Tris Acetate EDTA (TAE) buffer; 0.1 μ g/L of 1 kb plus DNA ladder (Invitrogen, USA) was included as a size-standard marker. After electrophoresis, the gel was stained with ethidium bromide. The PCR fragments were excised using a UV transilluminator 2000 (BioRad, USA), and the DNA was extracted and purified using the Gene Clean II Kit (MP Biomedicals, LLC, France).

Cloning of DNA fragments and sequencing : The purified ~810 bp amplicons were cloned using the TOPO-TA Cloning Kit (Invitrogen, USA) according to the manufacturer's instructions. The plasmid DNAs were extracted and purified using a Qiagen Spin Miniprep kit (Qiagen, Germany) according to the manufacturer's protocol. The presence of inserts was confirmed by digestion of the plasmid DNA with the *Eco* R1 restriction enzyme (Invitrogen, USA), and the digestion products were analyzed on a 1.2% w/v agarose/EtBr gel with 1X TAE buffer; a 1 kb DNA ladder (Invitrogen, USA) was used to estimate the insert size. For each *Musa* accession, 10 clones were sequenced on a 3730XL DNA Analyzer at the University of Arizona Genetics Core Sequencing Facility Services, USA.

Construction of phylogenetic trees : The sequences were edited to remove vector sequences at both ends, and low-quality end regions (Q score<20). The forward and reverse primers were identified. The sequences were automatically aligned using Sequencher 5.1 (Gene Codes). A 1X depth coverage was employed for all isolates. The aligned chromatograms were manually curated to check whether the observed Single Nucleotide Polymorphisms (SNPs) were miscalled bases (accepted if Q score>30). Subsequently, the Sequencher 5.1

alignment file was exported in the FASTA format. In addition to the *Musa acuminata* sucrose synthase mRNA partial cds gene sequence, related external (monocots and dicots) plant species were retrieved from GenBank. The chosen sequences were aligned using ClustalW and manually adjusted. A distance matrix was computed, according to the Kimura 2 Parameter model, chosen as the best DNA model. An unrooted phylogenetic tree was constructed using the MEGA 5.05 program (Tamura *et al.*, 2011) based on the nucleotide sequence alignments under the Neighbor-Joining method. The ancestor reliability was tested by 1000 bootstrap replications of the data. The Dot Matrix analysis was performed using the two-sequence alignment option at the NCBI BLAST website. The analyses of haplotype diversity in the DNA sequence polymorphism data were generated from a Nexus formatted file in DnaSP 5.10.

DNA isolation and concentration : High quality and good concentration of genomic DNA was obtained and is shown in Figure-1. DNA concentration value of the samples ranged from 100 ng to 250 ng/ μ l. The ratio of absorbance of OD260/OD280 was 1.8 - 2.0. Nucleic acid preparations free of phenol showed OD260/OD270 ratios of ~1.2. 230nm which indicates contamination by phenolateion, thiocyanates. To confirm the concentration and quality of DNA samples, 100ng from each sample were run in 1% agarose gel stained in ethidium bromide solution and compared visually with 1Kb ladder standard under UV illumination. This DNA was used for the amplification of SUCS gene fragments.

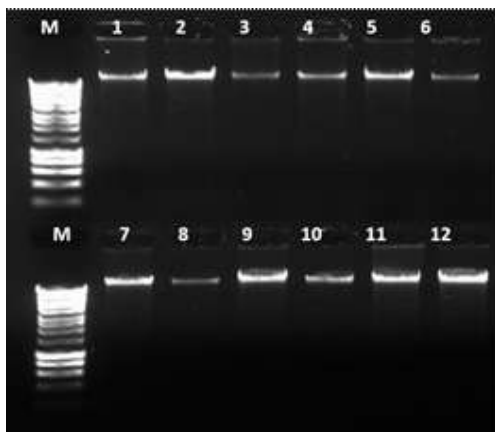


Figure-1 : DNA isolation from ten *Musa* accessions in 1% agarose gel.

From the above left : M-Marker (HyperLadderTM I) 1Kb, 1- *Musa acuminata* spp. *bansikii* (AA), 2- *Musa acuminata* spp. *malaccensis* Pisang kra (AA), 3- Pisang linin (AA) 4- Safetvelchi (AB), 5- BB CICY. **From the below left:** M-Marker (HyperLadderTM I) 1Kb, 6-GrosMichel (AAA), 7-Mbwazirume (AAA), 8- Bluggoe (ABB), 9- Popolou (AAB), and 10- *Musa beccari*.

Amplification of SUCS gene fragments : Using the designed primers several tests were carried out to determine the optimal annealing temperature T_m and conditions for each set of primers. The primers and DNA were used in different concentration levels as well as different temperatures by using a Gradient PCR in order to obtain the expected amplicons. The optimal (T_m) annealing temperature for primer sets for SUCS is 50°C and the amplified product of the expected size was obtained for sucrose synthase (400 bp). The amplicons were isolated for the next transformation and cloning experiments.

Analysis of sucrose synthase (SUCS) gene fragments : In order to analyse the variation in SUCS gene fragments at the molecular level, 6 *Musa* cultivars and 4 *Musa* wild ancestors were selected as representatives in this study (Table1). For SUCS, the designed primers amplified a fragment of 400 bp from *Musa acuminata* sucrose synthase mRNA (AF079523.1) and this amplicon contains two exons and an intron region, because our template was gDNA (Figure-2).

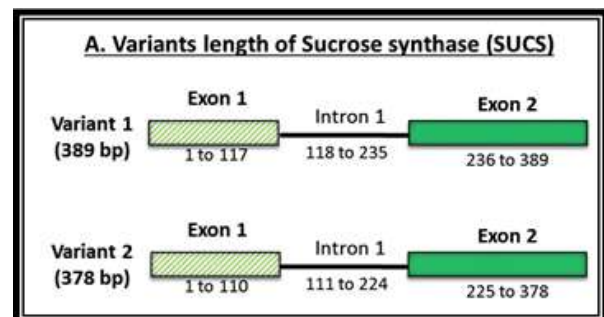


Figure-2 : Consensus regions of Exons 1 to 2 and Intron 1 of two SUCS *Musa* variants.

At least ten clones from each accession were sequenced for the bioinformatics analyses. For SUCS enzyme, from a total of 130 cloned sequences, 123 sequences were obtained with a sufficient length and used in the bioinformatics analysis; remaining sequences were removed because of their low quality and contamination of the sequences. After the removal of vectors, the sequences were cleaned and from multiple sequence alignment, two contigs (henceforth, known as variants) were obtained (Figure-2).

Variant 1 contained 45 clones, and Variant 2 contained 78 clones. A total of 123 sequences were analyzed in their intron regions; the introns were 130 nucleotides in length. Dot matrix analysis of SUCS shows the similarities in exons and intron regions of two variants. Both variants were most similar in their exon sequences, but in the intron regions they showed vast differences. SNPs present in non-coding regions do not lead to changes in the amino acids of the protein sequences in

Table-2 : Sequenced Clones & Variants distribution of SUCS gene fragments within 10 *Musa* accessions.

No.	Accession Name	*ITC	Genome	Sucrose synthase (SUCS)		
				Variant 1 (no. of Clones)	Variant 2 (no. of Clones)	Total no. of Clones
1.	<i>M.a. banksii</i>	0623	AA	—	12	12
2.	<i>M.a. malaccensis</i>	1345	AA	—	12	12
3.	<i>M.a. cv. Pisang lili</i>	1121	AA	—	13	13
4.	Safet velchi	0245	AB	4	8	12
5.	<i>Musa balbisiana</i>	—	BB	12	—	12
6.	Gros Michel	0484	AAA	—	11	11
7.	Mbwzriumbe	0084	AAA	—	11	11
8.	Bluggoe	0767	ABB	12	—	12
9.	Popolou	0335	AAB	5	9	14
10.	<i>Musa beccari</i>	1070	—	12	2	14
Total clones		—	—	45	78	123

* ITC : International Transit Centre, Belgium.

The sequenced clones were distributed into 2 variants for SUCS enzyme.

open reading frame (ORF), but because of their presence 2 SUCS variants were identified. This variation is shown in theDot matrix analysis (Figure-2 and Supplementary Figure-1).

This region has 2 exons and in between an intron region, as per the designed primers. In the intron regions, we have found 3 microsatellites in SUCS gene fragments. Both SUCS variants showed 84% sequence identity and 4% gaps within them in blasted results (data not shown). The presence of SNPs was higher in exons and lower in introns for SUCS (Supplementary table-1).

Cloned sequence distribution of the partial sequences in *Musa* SUCS.

From the multiple alignments the variants of SUCS were identified from ten *Musa* accessions. The bioinformatics analyses revealed the presence of variants in SUCS gene fragments. Two variants have been identified from the bioinformatics analyses and are shown in Table 2. The lowest number of clones were obtained in Gros Michel and Mbwzriumbe (11 clones) and highest number of clones were obtained from Popolou and *Musa beccari* (14 clones). Another six accessions had between 12 and 13 clones. Variant 1 was not found in five AA genome accessions; including both wild species and cultivars *M. a. banksii*, *M.a.malaccensis*, *M.a.cv. Pisang lili* (AA), Gros Michel (AAA) and Mbwzriumbe (AAA). However variant 1 was found in 4 out of its 12 sequences in cv. Safet velchi (AB). However, *Musa balbisiana*, cv., Bluggoe (ABB) and *Musa beccari* had all of their sequences in variant 1 alone.

Distribution of SNPs in *Musa* SUCS variants : SNPs were found in both exons and introns of SUCS gene fragments. Variant 1 of SUCS, had 15 SNPs in its exons, 6 SNPs in its intron regions, and variant 2 had 10 SNPs in its coding region and 4 SNPs in the intron regions. A total 35

SNPs were found in two variants of the SUCS gene fragment, 25 SNPs occurred in the exon regions and 10 SNPs were present in the intron regions (Supplementary table1).

Phylogenetic analysis and haplotype diversity of SUCS sequences :

One hundred and fifteen sequences were analyzed in the exon regions of SUCS, and 31 haplotypes were obtained for the phylogenetic analysis (Figure3). Although there are 2 clades, within them are some subclades. The numbers of SNPs in exons are higher than in the intron regions. The phylogenetic tree was made for 31 haplotypes obtained from SUCS exon consensus along the external plant species with 95% partial deletion, because some of the analyzed *Musa* haplotype sequences are incomplete. In order to find the SNPs based variations in the intron region of SUCS, the non-coding sequences were analyzed and a dendrogram was created. In order to avoid redundancy, haplotypes were created from the consensus sequences. Analysis with DnaSP 5.0 detected 31 haplotypes out of 115 sequences in SUCS exon regions for 10 *Musa* accessions from their nucleotide alignments, which indicates 31 different sequences in the consensus of the coding region.

The phylogenetic tree of SUCS coding regions in Figure-3 showed that the haplotypes and external plant species were grouped into 2 Clades. Clade 1 divided into 3 sub-clades.

Scale bar represents 0.05 nucleotide substitution per site and all nodes have 1000 Bootstrap support. Kimura-2 (K2 plus +I) parameter model was used with 95% partial deletion in this Phylogenetic tree.

The external (monocots and dicots) plant species used in this phylogenetic tree are given below :

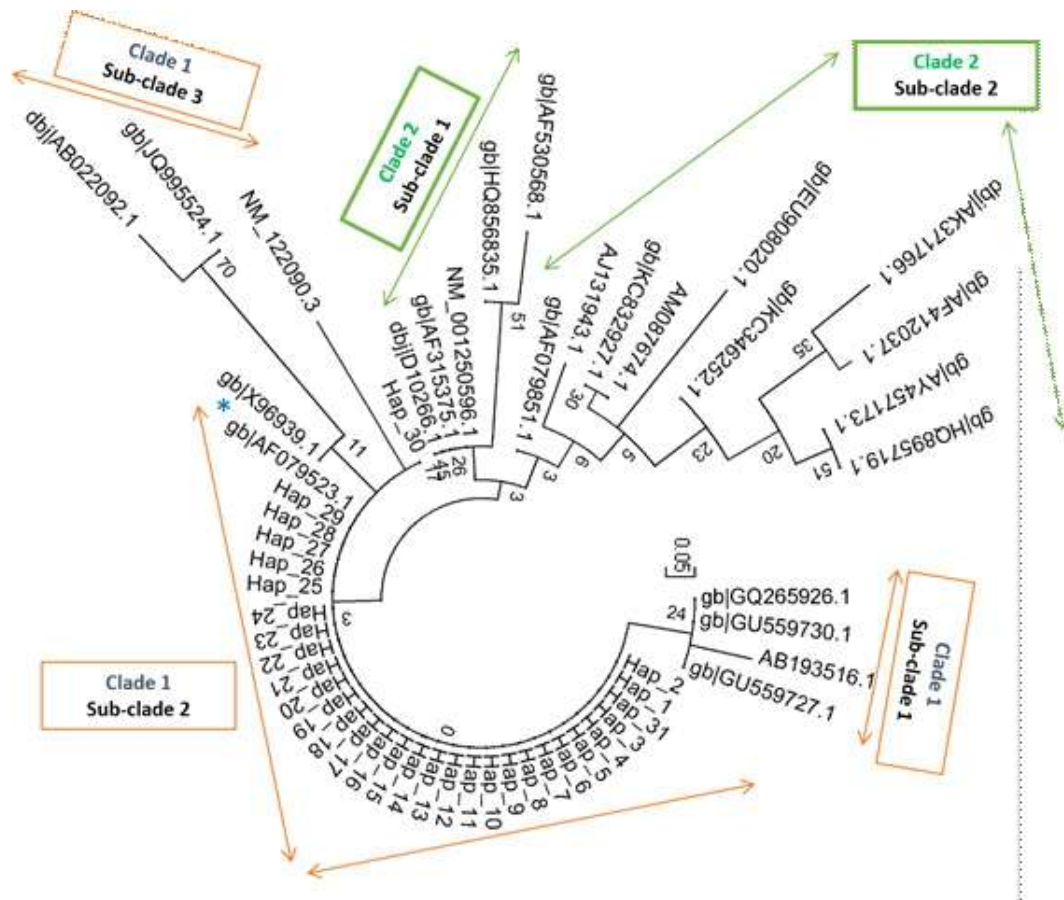


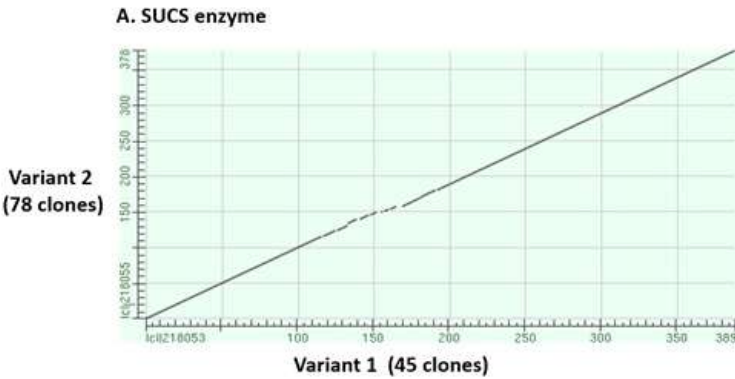
Figure-3: Neighbor-Joining tree showing the phylogenetic position of two variants contains 31SUCS haplotypes of exons 1 and 2 sequences with external plant species.

gb| GU559727.1: *Populus tomentosa* sucrose synthase 1 (SuS1) mRNA complete cds, gb|EU908020.1: *Ipomoea batatas* cultivar Yusu 303 sucrose synthase mRNA complete cds, dbj|AK371766.1: *Hordeum vulgare* subsp. vulgare mRNA for predicted protein complete cds, gb|HQ856835.1: *Dendrobium officinale* sucrose synthase (SS1) mRNA complete cds, gb|GQ265926.1: *Borassus flabellifer* sucrose synthase (SUS) mRNA partial cds, gb|AF530568.1: X Mokara cv. Yellow sucrose synthase (sus) mRNA complete cds, AB193516.1: *Potamogeton distinctus* PdSUS2 mRNA for sucrose synthase complete, gb|AF412037.1: *Bambusa oldhamii* clone BoSUS3 sucrose synthase mRNA complete cds, gb|X96939.1: *T. gesneriana* mRNA for sucrose-synthase, gb|AF079523.1: *Musa acuminata* sucrose synthase mRNA partial cds, gb|KC346252.1: *Jatropha curcas* sucrose synthase (SuSy) mRNA complete cds, gb|KC832927.1: *Hevea brasiliensis* sucrose synthase 1 (SS1) mRNA complete cds, gb|GU559730.1: *Populus trichocarpa* sucrose synthase 2 (SuS2) mRNA complete cds, AJ131943.1: *Medicago truncatula* mRNA for sucrose synthase, gb|AF030231.1: *Glycine max* sucrose synthase (SS) mRNA, NM_001250596.1: *Glycine*

max sucrose synthase (SS) mRNA complete cds, gb|JQ995524.1: *Gossypium arboreum* putative sucrose synthase_3 mRNA complete cds, dbj|D10266.1: *Vigna radiata* var. radiata vss1 mRNA for sucrose synthase complete cds, gb|AF079851.1: *Pisum sativum* nodule-enhanced sucrose synthase (ness) mRNA complete cds, gb|AY457173.1: *Beta vulgaris* sucrose synthase (SBSS2) mRNA complete cds, AM087674.1: *Coffea arabica* mRNA for sucrose synthase (sus1 gene), NM_122090.3: *Arabidopsis thaliana* sucrose synthase 1 mRNA complete cds, gb|HQ895719.1: *Oryza sativa* Japonica Group sucrose synthase 1 mRNA complete cds, dbj|AB022092.1: *Citrus unshiu* CitSUS1 mRNA for sucrose synthase complete cds, gb|AF315375.1: *Phaseolus vulgaris* sucrose synthase mRNA complete cds.

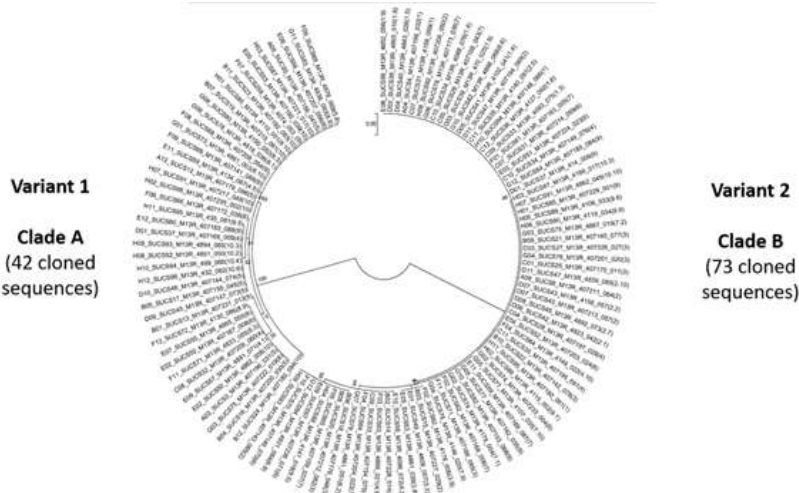
Sub-clade-1 consists of dicots such as *Populus trichocarpa* (GU 559730.1), *Populus tomentosa* (GU 559727.1) and monocots *Potamogeton distinctus* (AB 193516.1), *Borassus flabellifer* (GQ 265926.1). Sub-clade 2 contains all the haplotypes (except haplotype 30) with *Musa acuminata* sucrose synthase mRNA partial cds gb|AF079523.1. Sub-clade 3 has 4 plant species;

Supplementary Figures and Table



Supplementary Figure 1: Two variants of SUCS gene fragment in Dot Matrix analysis.

Dot Matrix comparison of nucleotide sequence similarity of two *Musa* SUCS variants found here. This matrix showed the distribution of indels in each variant. This analysis was performed using the Dotter program in NCBI database. Transversal lines represent the similarity of the variants with the deposited *Musa* clone (AF079523.1). Deviation from this line results from indels and other changes.



Supplementary Figure 2: Dendrogram of SUCS intron regions for 113 gene fragments in 10 *Musa* accessions. This tree was generated by using the Neighbor-Joining method, used with Jukes-Cantor (JC) parameter model. 1000 bootstrap replications were used.

Scale bar represents 0.05 nucleotide substitution rate per site.

Supplementary Table 1 Singe Nucleotide Polymorphism (SNPs) arrangements in introns and exons of two SUCS variants within *Musa*

Variants	Exon 1 Intron 1 Exon 2					Total SNPs
	Exon 1	Intron 1	Exon 2	Total SNPs in exons	Total SNPs in introns	
Variants 1	1	6	14	15	6	21
Variants 2	4	4	6	10	4	14

35 SNPs were found in total for two variants (25 in exons and 10 in introns)

T.gesneriana (X96939.1), *Citrus unshiu* (AB 022092.1), *Gossypium arboreum* (JQ 995524.1) and *Arabidopsis thaliana* (NM_122090.3) and haplotype 30. Clade 2 was divided into 2 sub-clades. Sub-clade 1 consists of 5 plant species including dicots such as *Phaseolus vulgaris* (AF 315375.1) and *Glycine max* (NM_001250596.1) and monocots as *Dendrobium officinale* (HQ 856835.1), *X. Mokara* (AF530568.1) and *Vigna radiata* (D 10266.1). All the other plant species and their accession numbers were presented in sub-clade 2. The dendrogram indicates the sequence arrangements of the SUCS intron region and can be seen in Supplementary Figure-2.

Discussion

Starch metabolism is a complex and important physiological process in higher plants, especially in bananas (Ball *et al.*, 2003). For the amplification of SUCS, since no *Musa* sequence was known, the primers were designed from mRNA which was deposited in NCBI-GenBank databases. Without information about the exact number of copies or paralogous sequences for each enzyme, since the primers were designed on the most conserved regions, the amplification products are most likely mixes of fragments originating from each of the copies. For this reason, we were able to recover two different variants (probably paralogous) for the SUCS enzyme. The SUCS enzyme showed no differences in their coding regions but large differences in the introns, which indicated that the intron region could change during the duplication process.

Currently 123 clones from 10 *Musa* accessions have been sequenced for SUCS. From multiple alignments we have identified 2 variants of SUCS gene present of the analyzed accessions. Phylogenetic tree was constructed for this enzyme with 2 SUCS variants and sequences of the external plant species.

From our results, two variants were identified out of 4 SUCS isoforms (chromosome 2, 3, 6 and 10) which were found in the *Musa acuminata* and *Musa balbisiana* genome database (Davey *et al.* 2013; D'Hont *et al.* 2012). Our variant 1 was matched with chromosome 6 with 98.20% identity, and variant 2 showed 98.15% identity with chromosome 3. So, these two known variants were considered as paralogous genes of SUCS in *Musa* accessions. This analysis confirmed that there are two variants presented in SUCS gene fragments. If we sequenced the whole gene, we could get all the possible isoforms. This work may assist in distinguishing the extent of paralogous genes in the starch metabolism of *Musa*.

The variant 2 of SUCS contains only the A genome, which may be associated with differences in the starch content and quality of the *Musa acuminata* and *Musa*

balbisiana fruits, and suggests that the variants of SUCS reported here are paralogous genes. It could be possible to design polymorphic microsatellite markers from those intron regions. An explanation for this is that the wild *M. acuminata* species were diverse, differentiated into several subspecies and that the triploid AAA cultivars were subsequently derived from wild AA by interspecific hybridizations (Perrier *et al.*, 2011).

This study reveals the variants (isoforms) of SUCS gene fragments in starch metabolism in bananas and plantains. It might be possible to detect further isoforms in studies on the whole population. More isoforms might also be detected by sequencing more clones. In banana, it may also be possible to select for starch quantity and quality using microsatellite markers developed from SUCS introns. The transcripts can be obtained and analyzed to characterize the expression of these genes. Further studies of these genes may lead to valuable insights of starch metabolism in bananas and plantains.

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Effect of Integrated Nutrient Management on Growth and Yield of Barley (*Hordeum vulgare* L.)

Paribhasha, P.K. Sharma, Mahaveer Prasad Ola* and N.K. Sharma

Department of Agriculture, Vivekananda Global University, Jaipur, Rajasthan

*Corresponding Author Email : mahaveerprasadola37@gmail.com

Abstract

The present investigation was carried out at the crop research farm, Department of Agronomy, Vivekananda Global University, Jaipur, Rajasthan. The experiment was laid out in randomized block design with eight treatments replicated thrice. The experiment was comprised with eight treatment viz., T₁-control, T₂- RDF 100%, T₃- Vermicompost 10 t/ha, T₄- FYM 20 t/ha, T₅- RDF 75% + FYM 5 t/ha, T₆- RDF 50% + FYM 10 t/ha, T₇- RDF 50% + Vermicompost 5 t/ha and T₈- RDF 75% + Vermicompost 2.5 t/ha. The treatment with application of T₈- RDF 75% + Vermicompost 2.5 t/ha was recorded significantly higher plant height (107.63 cm), number of tillers/running row meter (66.32), plant dry weight (22.31 g/plant) and crop growth rate (25.73 g/m²/day). Treatment RDF 75% + Vermicompost 2.5 t/ha (T₈) significantly improved the yield attributes viz., number of effective tillers per plant (278.85) and number of grain per spike (52.27). However, T₇- RDF 50% + Vermicompost 5 t/ha, T₆- RDF 50% + FYM 10 t/ha and T₅- RDF 75% + FYM 5 t/ha was found to be statistically at par with T₈- RDF 75% + Vermicompost 2.5 t/ha. For test weight difference between treatments was observed non-significant.

The maximum cost of cultivation (INR 40755.10 /ha), maximum gross return (INR 1,30,130.17/ha), maximum gross return (INR 1,30,130.17/ha), maximum net return (INR 89,375.07/ha) and maximum benefit cost ratio (2.19) was observed in T₈- RDF 75% + Vermicompost 2.5 t/ha. Whereas the minimum cost of cultivation ((INR 38399.10 /ha), minimum net return ((INR 68,870.27/ha)) and minimum benefit cost ration (1.79) was observed in treatment T₁-control.

Key words: nutrient vermicompost yield

Introduction

Barley (*Hordeum vulgare* L.) is the world's 4th most important cereal crop after wheat, rice and then maize with a share of about seven percent of the global cereals production and fifteen percent of coarse grains consumption (Giraldo *et al.* 2019). Barley is a hardy crop and can be successfully grown in adverse climatic conditions of drought, salinity, and alkalinity. Barley is an ancient cereal grain crop, which after domestication evolved from largely a food grain to a malting and feed grain after domestication be originated in Abyssinia and South East Asia. Both the two-row and six-row cultivars are used for malting. Six-rowed cultivars are ideal for beer, and two-rowed are suitable for pure malts. Barley is generally grown on marginal and sub-marginal land because of its low inputs requirement. In India, barley is mainly grown in the northern plains and concentrated in the states of Uttar Pradesh, Haryana and Rajasthan. In India, barley was cultivated on 609 thousand ha area with 1818 thousand ton of production at an average productivity of 29.88 q/ha. In India, Rajasthan is the largest state having more than 52 % in production and 46% area followed by Uttar Pradesh (IIWBR, 2021-22).

Biofertilizers approach pose lots of such benefits from an economic, social, and environmental point of view (Carvajal-Muñoz and Carmona-Garcia, 2012).

Bio-fertilizers containing useful micro-organisms instead of synthetic chemicals are known to enhance plant growth by the supply of plant nutrients and may help environmental health and soil productivity. Further, the use of bio-fertilizers can raise productivity per unit area in a short time, use smaller amounts of energy, reduce contamination of soil and water, increase soil fertility, and encourage antagonism and biological control of phytopathogenic organisms (Yasin *et al.*, 2012). Bio fertilizer production is cheap and does not create pollution in the natural system (Farnia and Hasanpoor, 2015).

Among the bio fertilizers, vermicomposting is a process that uses earthworms to transform organic residues into a secondary product named vermicompost, which can be used as a fertilizer for crop production (Dominguez and Edwards, 2004). Vermicomposting is therefore an interesting solution for both recycling the increasing amount of organic waste and reducing the use of fertilizers. Application of vermicompost increased growth, improved plants nutrient content, and improved the quality of the fruits and seeds (Olle, 2019). Farmyard manure (FYM) is a decomposed mixture of dung, urine, litter, and leftover materials from roughages and fodder fed to animals. FYM is a good source of organic carbon, which activates the biotic life of the soil flora and fauna. FYM improves soil physical, chemical and biological properties. Improvement in the soil structure due to FYM

application leads to a better environment for root development. Emerging evidence indicated that integrated soil fertility management involving the judicious use of combined organic and inorganic sources is a feasible approach to overcome soil fertility constraints (Yadav *et al.*, 2000).

Materials and Methods

The experiment was conducted during rabi season of 2022-2023 at the Crop Research Farm, Department of Agronomy, Vivekananda Global University, Jaipur Rajasthan. The Crop Research Farm is situated at 25.57° N latitude, 87.19° E longitudes and at an altitude of 98 m above mean sea level. All the facilities required for crop cultivation were available. The experiment was laid out in Randomized block design with eight treatments replicated thrice. The experiment was comprised with eight treatment viz., T1-control, T2- RDF 100%, T3- Vermicompost 10 t/ha, T4- FYM 20 t/ha, T5- RDF 75% + FYM 5 t/ha, T6- RDF 50% + FYM 10 t/ha, T7- RDF 50% + Vermicompost 5 t/ha and T8- RDF 75% + Vermicompost 2.5 t/ha.

Statistical analysis : Data obtained on various variables were analyzed by analysis of variance method (Panse and Sukhatme, 1967). The total variance and degree of freedom (n-1) were partitioned into different possible sources. The variance due to various treatments of mulching were compared with error of variance to find out 'F' values and ultimately for testing the significance at $p = 0.05$. The standard errors for the treatment based on error variance were calculated. Whenever, the results were found to be significant, critical differences were also calculated for comparison of treatment means at 5 per cent level of significance (CD at $P = 0.05$).

Results

Plant height (cm) : At 30 DAS, there was non-significant difference between the treatments. The maximum plant height (29.47 cm) was observed the applications of T8 (RDF 75% + Vermicompost 2.5 t/ha), whereas the lowest value (23.30 cm) was observed in treatment of T1 (control). At 60 DAS, there was significant difference between the treatments and maximum plant height (65.92 cm) was observed the applications of T8. However, the all the treatments was found to be statistically at par with T8 except T1-control and T2- RDF 100%. At 90 DAS, there was significant difference between the treatments and maximum plant height (95.41 cm) was observed the applications of T8. However, the all the treatments was found to be statistically at par with T8 except T1-control and T2- RDF 100%. At 120 DAS, there was significant difference between the treatments and maximum plant height (107.63 cm) was observed the applications of T8.

Except T1-control, T2- RDF 100% and T3- Vermicompost 10 t/ha all the treatments was found to be statistically at par with T8.

Number of tillers/running row meter : At 30 DAS, there was non-significant difference between the treatments and maximum number of tillers/running row meter (39.74) was observed the applications of T2 (RDF 100%), whereas the lowest value (28.95) was observed in treatment T1 (control). At 60 DAS, there was significant difference between the treatments and maximum number of tillers/running row meter (60.75) was observed the applications of T2 (RDF 100%). However, the treatment T2 was found to be statistically at par with all treatments except T1, T3 and T4. At 90 DAS, there was significant difference between the treatments and maximum number of tillers/running row meter (71.92) was observed the applications of T2. However, the treatment T2 was found to be statistically at par with T1, T3 and T4. At 120 DAS, there was significant difference between the treatments and maximum number of tillers/running row meter (66.32) was observed the applications of T2. However, the treatment T2 was found to be statistically at par with T1 and T3.

Plant dry weight (g) : At 30 DAS, there was non-significant difference between the treatments and maximum dry weight (0.84 g) was observed the applications of T8 (RDF 50% + FYM 10 t/ha), whereas the lowest value (0.65 g) was observed in treatment T1 (control). At 60 DAS there was significant difference between the treatments. The maximum dry weight (8.26 g) was observed in the applications of T8. However, the treatments T8 was found to be statistically at par with T7 (7.12 g) and T6 (7.02 g). At 90 DAS, there was significant difference between the treatments and maximum dry weight (13.44 g) was observed the applications of T8. However, the treatments T8 was found to be statistically at par with T7 (12.70 g), T6 (12.46 g) and T5 (12.02 g). At 120 DAS, there was significant difference between the treatments and maximum dry weight (22.31g) was observed the applications of T8. However, the treatments T8 was found to be statistically at par with T7 (21.25 g), T6 (20.89 g), T5 (20.89 g) and T4 (20.15 g).

Crop growth rate (g/m²/day) : At 60-90 DAS, there was non-significant difference between the treatments and the maximum crop growth rate (16.19) was observed in the applications of T7, whereas the lowest value (13.18) was observed in treatment T1-control. At 90-at harvest, there was non-significant difference between the treatments and maximum crop growth rate (25.73) was observed in the applications of T8, whereas the lowest value (22.84) was observed in treatment T1 (control).

Relative growth rate (g/g/day) of barley : The

Table-1 : Effect of integrated nutrient management on plant height, number of tillers/running row meter and dry weight (g) of barley.

Symbol	Treatment combination	Plant height (cm)				Number of tillers/running row meter				Dry weight (g)			
		30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
T1	Control	23.30	51.13	80.15	88.27	28.95	45.15	56.32	50.25	0.65	5.58	10.27	18.15
T2	RDF 100%	27.04	56.87	87.37	92.80	39.74	60.75	71.92	66.32	0.69	6.12	10.74	19.25
T3	Vermicompost 10 t/ha	27.73	59.12	89.27	97.00	33.17	52.32	62.98	58.58	0.71	6.45	11.12	19.73
T4	FYM 20 t/ha	28.13	60.12	90.24	99.10	34.53	54.16	64.83	61.43	0.73	6.61	11.62	20.15
T5	RDF 75% + FYM 5 t/ha	28.63	60.92	91.11	100.70	35.65	55.54	66.21	61.11	0.76	6.82	12.02	20.53
T6	RDF 50% + FYM 10 t/ha	28.78	61.86	91.77	102.67	36.91	56.80	67.46	62.36	0.78	7.02	12.46	20.89
T7	RDF 50% + Vermicompost 5 t/ha	29.08	62.12	92.21	103.70	37.65	57.90	69.06	63.46	0.81	7.12	12.70	21.25
T8	RDF 75% + Vermicompost 2.5 t/ha	29.47	65.92	95.41	107.63	38.56	59.37	70.53	64.93	0.84	8.26	13.44	22.31
	F-test	NS	S	S	S	NS	S	S	S	NS	S	S	S
	SEm ($\pm$)	1.438	2.638	2.673	3.487	1.871	2.069	2.197	2.074	0.072	0.42	0.571	0.783
	CD (p=0.05)	—	7.838	7.942	10.361	-	6.150	6.528	6.164	-	1.26	1.698	2.345

Table-2 : Effect of integrated nutrient management on crop growth rate (g/m²/day), relative growth rate (g/g/day), number of effective tillers/m², number of grain per spike, test weight (g) and yields of barley.

Symbol	Treatment combination	Crop Growth Rate (g/m ² /day)			Relative Growth Rate (g/g/day)			Number of effective tillers/m ²	Number of grain per spike	Test weight (g)	Grain yield	Straw yield	Harvest index
		30-60 DAS	60-90 DAS	90-at harvest	30-60 DAS	60-90 DAS	90-at harvest						
T1	Control	14.29	13.18	22.84	0.071	0.020	0.019	188.25	42.49	41.33	3.58	4.78	42.80
T2	RDF 100%	15.73	13.41	24.66	0.072	0.018	0.019	207.75	46.35	41.70	3.87	5.64	40.69
T3	Vermicompost 10 t/ha	16.65	13.53	24.95	0.073	0.018	0.019	213.16	47.78	42.17	3.90	5.74	40.48
T4	FYM 20 t/ha	17.03	14.54	24.71	0.073	0.018	0.018	224.51	48.86	41.91	3.77	5.82	39.33
T5	RDF 75% + FYM 5 t/ha	17.56	15.08	24.66	0.073	0.018	0.017	234.85	49.37	43.03	4.09	5.92	40.87
T6	RDF 50% + FYM 10 t/ha	18.07	15.78	24.43	0.073	0.019	0.017	236.98	50.04	43.63	4.06	6.06	40.09
T7	RDF 50% + Vermicompost 5 t/ha	18.28	16.19	24.77	0.072	0.019	0.017	238.10	50.62	44.27	4.11	6.22	39.82
T8	RDF 75% + Vermicompost 2.5 t/ha	21.51	15.00	25.73	0.078	0.016	0.017	278.85	52.27	46.50	2.29	6.72	38.96
	F-test	S	NS	NS	NS	NS	NS	S	S	NS	S	S	NS
	SEm ($\pm$)	1.10	1.23	1.12	0.0027	0.0019	0.0007	15.84	1.54	1.24	0.12	0.21	1.43
	CD (p=0.05)	3.27	-	-	-	-	-	47.07	4.59	-	0.36	0.64	-

Table-3 : Effect of integrated nutrient management on economic of barley.

Symbol	Treatment combination	Economics			
		Cost of cultivation (INR/ha)	Gross return (INR/ha)	Net Return (INR/ha)	B:C
T1	Control	38399.10	107269.37	68870.27	1.79
T2	RDF 100%	40355.10	116820.00	76464.90	1.89
T3	Vermicompost 10 t/ha	40755.10	117833.00	77077.90	1.90
T4	FYM 20 t/ha	39955.10	114323.33	74654.23	1.86
T5	RDF 75% + FYM 5 t/ha	40355.10	123357.67	83002.57	2.05
T6	RDF 50% + FYM 10 t/ha	40755.10	122658.00	81902.90	2.00
T7	RDF 50% + Vermicompost 5 t/ha	39955.10	124517.00	84561.90	2.11
T8	RDF 75% + Vermicompost 2.5 t/ha	40755.10	130130.17	89375.07	2.19

observations for relative growth rate are being presented in the table-2. At 30-60 DAS, there was non-significant difference between the treatments and maximum relative growth rate (0.078) was observed the applications of T8, whereas the lowest value (0.071) was observed in treatment T1 (control). At 60-90, there was non-significant difference between the treatments and maximum relative growth rate (0.020) was notice in the applications of T1 (control). Whereas the lowest value (0.016) was observed in treatment T8. At 90-120 DAS, there was non-significant difference between the treatments and maximum relative growth rate (0.019) was observed in the applications of T1 (control), T2 (RDF 100%) and T3 (vermicompost 10 t/ha) whereas the lowest value (0.017) was observed in treatment T5, T6, T7 and T8. Maximum crop growth rate (21.51) was observed at 30-60 DAS, there was significant difference between the treatments and the applications of T8. However, the treatment T8 was found to be statistically at par with T7 (18.28) and T6 (18.07).

Yield and yield attributes : At harvest, there was significant difference between the treatments and maximum number of effective tillers per m² (278.85) was observed in the applications of T8. However, the treatments T7 (238.10), T6 (236.98) and T5 (234.85) was found to be statistically at par with of T8. The lowest effective tillers per m² (188.25) was observed the applications of T1-control. Maximum number of grain per spike (52.27) was observed at harvest, there was significant difference between the treatments and the applications of T8. However, the treatments T7 (50.62), T6 (50.04), T5 (49.37) and T4 (48.86) was found to be statistically at par with T8. The perusal of the data of test weight was recorded at harvest, is presented in Table 2. The data reveals that there was non-significant effect among different treatments on test weight. However, maximum test weight (46.50 g) was observed at harvest due to application of T8 and minimum test weight (41.33 g) was observed in T1 (control). Maximum seed yield (4.29 t/ha) was observed, there was significant difference between the treatments and the applications of T8.

However, the treatments T7 (4.11), T6 (4.06) and T5 (4.09) was found to be statistically at par with T8. Maximum straw yield (6.72 t/ha) was observed, there was significant difference between the treatments and the applications of T8. However, the treatments T7 (6.22 t/ha) was found to be statistically at par with T8. The data reveals that there was non-significant effect among different treatments on harvest index. Maximum harvest index (42.80 %) was observed in T1-control, while maximum harvest index (38.96 %) was observed in T8-RDF 50% + FYM 10 t/ha.

Economics : Maximum cost of cultivation (INR 40755.10 /ha) was observed, there was significant difference between the treatments and the applications of T8- RDF 75% + Vermicompost 2.5 t/ha. Whereas the lowest value ((INR 38399.10 /ha)) was observed in treatment T1-control. Maximum gross return (INR 1,30,130.17/ha) was observed, there was significant difference between the treatments and the applications of T8- RDF 75% + Vermicompost 2.5 t/ha. Whereas the lowest value ((INR 1,07,269.37/ha)) was observed in treatment T1-control. Maximum net return (INR 89,375.07/ha) was observed, there was significant difference between the treatments and the applications of T8- RDF 75% + Vermicompost 2.5 t/ha. Whereas the lowest value ((INR 68,870.27/ha)) was observed in treatment T1-control. Maximum benefit cost ratio (2.19) was observed, there was significant difference between the treatments and the applications of T8- RDF 75% + Vermicompost 2.5 t/ha. Whereas the lowest value (1.79) was observed in treatment T1-control.

Discussion

Effect on growth parameters : Application of integrated nutrient management significantly increased the plant height at 60 DAS, 90 DAS and 120 DAS, number of tillers/running row at 60 DAS, 90 DAS and 120 DAS, dry weight at 60 DAS, 90 DAS and 120 DAS and crop growth rate 30-60 DAS (Table 1). Treatment T8- (RDF 75% + Vermicompost 2.5 t/ha), being remained at par for most of the growth parameters with T7-(RDF 50% +

Vermicompost 5 t/ha), T6- (RDF 50% + FYM 10 t/ha) and T5- (RDF 75% + FYM 5 t/ha) and produced significantly highest of barley. The lack of a statistically significant impact of integrated nutrient management on plant height, number of tillers/running row and dry weight at 30 DAS may be attributed to the crop's first stage of development's sluggish growth habits. Vermicompost and FYM being a source of organic manure it improve all the properties of the soil. Therefore crop plant attain better for growth. Similar finding were also reported by Arancon *et al*, 2004, Samavat *et al*, 2019 and yadav *et al*, 2019 in barley.

Due to the fact that vegetative growth of plants is primarily influenced by the formation of somatic cells, which result in the growth and development of new leaves, stems, and roots, as well as the fact that these meristematic tissues have a very active metabolism and that photosynthate transported to these sites is primarily used in the synthesis of nucleic acids and proteins, an increase in plant height at higher levels of biofertilizer may be possible

Biofertilizer encourage formation of new cells, promote plant vigour and hastens leaf development, which help in harvesting more solar energy and better utilization of nitrogen, which help towards higher growth attributes. The plant can develop more quickly since these nutrients help to increase metabolic rate, cell division, and cell elongation. In addition, given the confirmed improvement in development traits demonstrated by (Bhagchand and Gautam 2000).

Effect on yield and yield attributes : Based upon the results of present investigation it was observed that RDF 75% + Vermicompost 2.5 t/ha (T8) significantly improved the yield attributes viz., number of effective tillers per plant (278.85) and number of grain per spike (52.27). However, T7- RDF 50% + Vermicompost 5 t/ha, T6- RDF 50% + FYM 10 t/ha and T5- RDF 75% + FYM 5 t/ha was found to be statistically at par with T8- RDF 75% + Vermicompost 2.5 t/ha. For test weight difference between treatments was observed non-significant, which indicated that test weight was not influenced by application of different treatments.

The results of present investigation indicating positive response of various yield components to fertility levels corroborates finding of several researchers (Sepat *et al*., 2010 and Chesti *et al*., 2013 in wheat and Shantveerayya *et al*., 2017 in barley).

The perusal of the data of grain yield and straw yield was recorded at harvest, is presented in Table-2. The data reveals that there was significant effect among different treatments on seed yield as well as straw yield. Maximum seed yield (4.29 t/ha) was observed, in

applications of T8 (RDF 75% + Vermicompost 2.5 t/ha). However, the treatments T7- RDF 50% + Vermicompost 5 t/ha (4.11), T6- RDF 50% + FYM 10 t/ha (4.06) and T5- RDF 75% + FYM 5 t/ha (4.09) was found to be statistically at par with T8 (RDF 75% + Vermicompost 2.5 t/ha). It could be ascribed due to its profound influence on vegetative and reproductive growth of crop. Under the present investigation estimated positive interrelationship between grain yield and yield components clearly suggest that grain yield is dependent on several component which are interrelated with each other. . Hence marked increase in grain yield with RDF 75% + Vermicompost 2.5 t/ha fertilization seems to be due to exploitation of crop genetic potential for vegetative and reproductive growth up to higher level. The results of present investigation are in close agreement with the finding of Kotangale *et al*. (2009), Meena *et al*. (2012), Jat, *et al*. (2013) and Singh *et al*. (2013)

Similarly, maximum straw yield 6.72 t/ha was observed in the applications of T8- RDF 75% + Vermicompost 2.5 t/ha. However, the treatments T7- RDF 50% + Vermicompost 5 t/ha was found to be statistically at par with T8- RDF 75% + Vermicompost 2.5 t/ha. It could be ascribed to their direct influence on dry matter production at successive stages by virtue of increased photosynthetic efficiency. While indirect influence seems to be due to increase in plant height and number of tillers. The higher nutrient uptake with adequate fertilization seems to be another reason for observed improvement in straw yield. The profound influence of RDF + vermicompost on biological yield seems to be on account of its significance on vegetative (straw) and reproductive growth (grain). The results of present investigation corroborated finding of several researchers (Rai *et al*., 2013 and Prasad *et al*., 2019).

Economics : When deciding whether to implement a technology, farmers' economic interests are their first priority. Therefore, for integrated nutrient management practices, net return and cost benefit ratio were calculated. Maximum cost of cultivation (INR 40755.10 /ha) was observed in T8- RDF 75% + Vermicompost 2.5 t/ha. Whereas the lowest value ((INR 38399.10 /ha)) was observed in treatment T1-control. Whereas maximum gross return (INR 1,30,130.17/ha) was observed also in T8- RDF 75% + Vermicompost 2.5 t/ha. Maximum net return (INR 89,375.07/ha) was observed, there was significant difference between the treatments and the applications of T8- RDF 75% + Vermicompost 2.5 t/ha. Whereas the lowest value (INR 68,870.27/ha) was observed in treatment T1-control. Maximum benefit cost ratio (2.19) was observed, there was significant difference between the treatments and the applications of T8- RDF 75% + Vermicompost 2.5 t/ha. Whereas the lowest value

(1.79) was observed in treatment T1-control. Economics play an important role in deciding the adoption of a particular treatment by the farmers.

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Mycelial Compatibility of *Athelia rolfsii* fungus using Different ISSR Markers

Anjali Kumari¹, Om Prakash Verma^{1*} and Prashant Ankur Jain²

¹Deptt. of Molecular and Cellular Engineering, Jacob Institute of Biotechnology & Bioengineering, SHUATS, Prayagraj, U.P.

²Department of Computational Biology and Bioinformatics, Jacob Institute of Biotechnology & Bioengineering, SHUATS, Prayagraj, U.P.

*Corresponding Author Email : om.verma@shiats.edu.in

Abstract

Athelia rolfsii is a polyphagous, ubiquitous facultative parasite that survives in the soil. The study was carried to look into the variability of *A. rolfsii* and to find the appropriate markers for studying their variability. A total of 67 *A. rolfsii* isolates were obtained from infected fields across different states of Indian subcontinent, including New Delhi, Rajasthan, Chhattisgarh, Kolkata, Maharashtra, and Uttar Pradesh. Five Mycelial compatibility groups (MCGs) were identified among the 67 isolates and were designated as I to V in this study. Based on the ISSR analysis with 3 primers, isolates were grouped into four main clusters at 0.79 similarity co-efficient. Despite the genetic diversity of all the isolates of *A. rolfsii*, they all shared certain common bands indicating a phylogenetic relationship among them. The ISSR markers showed the highest degree of genetic polymorphism between the isolates. The current study revealed that ISSR molecular markers can be used for assessing variability, so ISSR can be recommended as the best marker system for *A. rolfsii* variability analysis.

Key words : *Athelia rolfsii*, morphology, molecular markers, issr, fungal variation.

Introduction

The second-most widely grown vegetable crop worldwide is the tomato (*Lycopersicon esculentum* L.), which is a member of the Solanaceae family and is native to the Andean area of South America. Approximately 181 million tonnes were produced from a 5 Mha area, according to statistics from the Food and Agriculture Organization (FAOSTAT, 2019). China is the world's largest tomato grower, followed by India, Pakistan, Turkey, and the United States, Iran, Italy, Turkey, Spain, Mexico, Brazil, Egypt, and Spain (FAOSTAT, 2019). Whereas Andhra Pradesh, Madhya Pradesh, Karnataka, Gujarat, Odisha, West Bengal, Chhattisgarh, Bihar, Telangana, Tamil Nadu, Uttar Pradesh, Maharashtra, Haryana, and Himachal Pradesh are the major tomato-producing states in the nation. About 90% of the nation's total production is produced in these states. *Sclerotium rolfsii* Sacc., also known as *Athelia rolfsii* (Curzi) C. C. Tu & Kimbr., is a dangerous soil-borne fungal plant pathogen that affects a variety of crops worldwide, but is most prevalent in tropical and subtropical regions (Xie, 2012).

It is one of the most destructive pathogens in the world due to its wide host range; in fact, it affects 500 plant species from 100 families, including tomatoes (*Solanum lycopersicum*), potatoes (*Solanum tuberosum*), chilli peppers (*Capsicum annuum*), carrots (*Daucus carota*), cabbage (*Brassica oleracea* var. capitata), sweet potatoes (*Ipomoea batatas*) etc. The abundance of hyphae, mycelium, and sclerotia that the fungus generates allows the infection to thrive without the host.

Sclerotia typically have a spherical shape, are 1–3 mm long, initially white, and eventually become brown. They resemble mustard or solanaceous plant seeds. The root system is destroyed once the mycelium invades it. In rare cases, the initial withering of the damaged plants can be reversed. The fungus typically starts off on the collar region or stems close to the soil surface, then it spreads over the entire plant or fruit and stays on the soil surface (Mullen, 2001; Mahadeva Kumar *et al.*, 2016). Sclerotia are formed on hosts, which then infect the same host crop or other surrounding crops after surviving and overwintering for a lengthy period. The shape, size, and quantity of sclerotia generated were used to identify *A. rolfsii* historically (Mullen, 2001). During vegetative adaptability, the mycelial consistency is a crucial process in the development of stable heterokaryons in fungi. Thus, in fungal species where the teleomorph stage has little bearing on the disease cycle, the function of mycelial compatibility groups (MCGs) and vegetative compatibility groups (VCGs) is crucial in identifying field populations of fungi and promoting genetic exchange. Based on interactions between different isolates' mycelium, *A. rolfsii* isolates can be redirected into various MCGs. *A. rolfsii* and other fungal populations have recently been identified using a variety of molecular methods (McDonald, 1993; Bruns, 1991; Okabe, 2001; Tyson 2002). This uses the internal transcribed spacer (ITS) as a frequent genetic target to assess the variety of fungi (Ycock, 1996). Although the ITS rDNA sequences used to analyse species, strains, or within-species divergence is modest, this technique exhibits better sensitivity at the genus level

(Harlton, 1991). Small phylogenetic variations are apparent in the ITS and large subunit (LSU) of taxa that are closely related to *A. rolfsii*, such as *S. coffeicola* and *S. delphinii* (Xu, 2008). Due to the high amount of polymorphism in *Athelia* species, the Inter Simple Sequence Repeat (ISSR) methodology can be considered a different method for studying comparative genetics and examining the genetic diversity of these species (Moulin *et al.*, 2012). A collection of ISSR markers, for random amplification of polymorphic DNA, are better suited for diversity investigations, than RAPD which was earlier claimed by Jebaraj *et al.*, (2017). To evaluate genetic relatedness and diversity among several *Athelia* species, ISSR markers are more enlightening and effective (Darakshanda *et al.*, 2007; Gawande *et al.*, 2013). To explore the variation among *A. rolfsii* from tomato hosts of Indian origin, only a little amount of research has been done. Therefore, the current study's objective was to assess *A. rolfsii*'s mycelia compatibility using ISSR markers.

Materials and Methods

Collection and isolation from diseased samples : The investigation was carried out in the spring of February 2019 to May 2020. The samples were randomly taken from tomato plants infected with the southern blight disease in several Indian states (New Delhi, Rajasthan, Chhattisgarh, Kolkata, Maharashtra, and Uttar Pradesh). Using hyphal tip approach, the pure culture of *A. rolfsii* isolates were obtained (Prasad, 2012 and maintained at 4 °C. A total of 67 isolates were collected, and utilising ITS markers, molecular and morphological description were given for each isolates Table 1 contains information on the *A. rolfsii* isolates used for the investigation. The mycelial compatibility of each isolate, as well as a variation assay utilising ISSR (Inter Simple Sequence Repeat) markers were investigated.

Mycelial compatibility assay : Mycelial discs of 5 mm in diameter were taken from the edge of a colony that was 3 to 4 days old vigorously growing culture. They were again arranged roughly 25 to 35 mm apart on opposite sides of Petri dishes with a 9 cm diameter and they were incubated at 25°C. Due to the existence of an antagonistic zone between the two isolates, then we tested three isolates together on a single PDA containing dish, and after 15 days, the PDA plates were examined microscopically for the presence of an antagonistic (barrage or aversion) zone (El Komy MH, 2015).

DNA isolation and molecular characterization : The CTAB (cetyltrimethylammonium bromide) technique was modified to extract genomic DNA. Utilizing a DNA purification kit, genomic DNA was cleaned, and the

quantified, pure DNA samples were kept at -20° C for further use. For all the DNA samples, the extracted DNA was diluted with Tris EDTA buffer and measured using a Thermo scientific nanodrop. Using ISSR (Inter Simple Sequence Repeat) primers as reported by the genetic similarities and differences between sixty-seven variable isolates of *Athelia* spp. were evaluated. Table 2 provides information on the primers utilised in this investigation. Each isolate was cultured on Potato Dextrose Broth for 7 days and the mycelia mat was harvested for DNA.

Variability among the different isolates of *A. rolfsii* using different ISSR Markers :

Three ISSR primers were used to amplify the genomic DNA prior to performing the ISSR analysis. The 25 µl total reaction volume of the PCR reactions contained 2.5 µl of 10X buffer, 1.5 µl of each dNTP, 2 µl of primer, 2.5 µl of MgCl₂ (250 mM), and 1 U (0.3 µl) of Taq polymerase. The following conditions were used throughout the PCR amplification process: initial denaturation at 94 °C for 5 min, followed by 35 cycles of step of denaturation missing primer annealing at 53 °C for 2 min, primer extension at 72 °C for 2 min, and a final primer extension at 72 °C for 7 min. The standard solution was divided among the PCR tubes (23 µl /tube), except the template, and then 100–200 ng of template DNA from the relevant isolates was added, bringing the total amount to 25 µl. In a 1.2% agarose gel, the amplification product was separated. To verify DNA amplification, the gel was stained with ethidium bromide (0.50 g/ml) and seen under UV light. Profiling of DNA for each ISSR primer was carried out at least twice. Based on informative banding patterns, clarity and repeatability, three primers were chosen for the final study.

Scoring the amplified fragments : In order to create the "0" and "1" matrices, the amplified profiles for each primer were compared to one another, and the bands of DNA fragments were scored as either 1 or 0, for the presence or absence of band. A gel documentation system (BIO RAD) was used to photograph the gels.

Data analysis : Only DNA bands that could be clearly identified were used in the study. We also scored faint bands. NTSYS-PC was used to analyse binary matrices (version 2.0; Exeter Biological Software, Setauket, NY). Using the SAHN clustering programme and the unweighted pair group technique with arithmetic average (UPGMA) algorithm in NTSYS-PC, Jaccard's coefficients were grouped to produce a dendrogram (Rohlf, 2000).

Results and Discussion

The soil-borne fungal plant disease caused by *A. rolfsii* harms several crops worldwide. Due to its extensive host range, it is one of the most devastating diseases in the world. The plants rot and wilt as a result of the fungus

Table-1 : *Athelia rolfsii* isolates collected from different climatic zone of India.

Sample Name	Location	Sample Name	Location
SR1	Nainital	SR36	Kanpur, UP
SR2	New Delhi	SR37	New Delhi
SR3		SR38	
SR4	Mumbai	SR39	
SR5	Lucknow	SR40	
SR6	Junagarh	SR41	
SR7	Jamnagar	SR42	
SR8	Jammu	SR43	Allahabad, UP
SR9	Pune	SR44	
SR10	New Delhi	SR45	
SR11	MPKV, Maharashtra	SR46	
SR12		SR47	
SR13		SR48	Kanpur, UP
SR14		SR49	New Delhi
SR15		SR50	
SR16		SR51	
SR17		SR52	Allahabad, UP
SR18		SR53	
SR19		SR54	
SR20		SR55	
SR21		SR56	
SR22	Hyderabad	SR57	
SR23	Aligarh, UP	SR58	
SR24	Navsari	SR59	
SR25	Sajeena	SR60	
SR26	Navsari	SR61	
SR27	Kadiri	SR62	
SR28	Navsari	SR63	
SR29	Kolkata	SR64	
SR30	Junagarh	SR65	
SR31	Jhansi	SR66	
SR32	Raipur, Chhattisgarh	SR67	
SR33			
SR34			
SR35			

Table-2 : Sequences of primer used in ISSR analysis for different isolates of *A. rolfsii*.

Primer	Sequences 5'-3'
ISSR 1	(GAGA) ₄ GAT
ISSR 3	(GAGA) ₄ GAAT
ISSR 4	(ACC) ₄ Y

Table-3 : Grouping of isolates of *A. rolfsii* based on mycelial compatibility.

MCG Group	Isolates
MCG 1	1, 2, 3, 4, 11, 16, 17, 20, 21, 23, 24, 25, 26, 39, 51, 35, 42, 32, 53, 34, 47 and 48
MCG 2	12, 13, 14, 15, 18, 27, 28, 40, 36, 29, 30, 31, 33, 60 and 61
MCG 3	7, 8, 9, 10, 19, 22, 36, 37, 38, 41, 45 and 46
MCG 4	5, 6, 43, 44, 49, 50, 58, 57, 62 and 64
MCG 5	52, 55, 56, 59, 63, 65, 66 and 67

invasion into the root system. The entire plant becomes infected when the infection starts in the collar area close to the soil surface. Mycelial compatibility is an essential to produce stable heterokaryons in fungi stage. It also aids in the investigation of the genetic variability among *A. rolfsii* isolates. As far as we are aware, there is no research work regarding MCG of *A. rolfsii* on tomato in India. However, some research has been done on several other crops. MCG tests were performed on isolates of the bacterium *A. rolfsii* from a variety of hosts and geographical locations, as well as from the same hosts and locations. The degree of variation among these 67 isolates of *A. rolfsii* is demonstrated by the high rate of antagonistic responses in the mycelial compatibility test.

Variability in growth characters testing for mycelial compatibility among the isolates : Among the 67 isolates of *A. rolfsii* utilised in the study, a total of five MCGs were found. MCGs were numbered I through V in roman numerals. Table-1 displays the isolates MCGs as well as their locations. Mycelia mixing at the zone of contact without aversion were a sign of mycelia compatibility between isolates of MCGs. On the other hand, isolates belonging to various MCGs displayed aversion in the contact zone, along with thinned mycelium and the development of a reaction line. All 67 isolates were self-compatible and exhibited a response like that of compatible isolates. A mating type examination of 67 isolates revealed the compatible or incompatible reactions. The 67 isolates were paired in 22 pairs, and only 14 of those pairings had a compatible reaction. The remaining 52 pairings displayed incompatible reactions, where the mycelia of the one isolate intermixed at the zone of contact. A narrow ring of either living or dead mycelia developed, and they reacted negatively to one another. Consequently, it may be said that *A. rolfsii* contained five MCGs (Fig. 1), among Group 1 has twenty-two isolates, group 2 has fifteen isolates, Group 3 has twelve, Groups 4 and 5 have 10 and 8 isolates, respectively (Table-3)

ISSR Markers : Due to the prevalence of microsatellites regions across genomes, inter simple sequence repeats (ISSR) are a useful and alternative method for examining the genetic diversity of any living creature (Pharmawati, 2005). ISSR markers were employed in the current study to examine the genetic diversity of isolates obtained from various geographical locations.

The 67 *A. rolfsii* isolates were investigated for ISSR fingerprinting. To explore the genetic diversity among the isolates, a total of three unique ISSR primers, designated as ISSR-1 (GAGA)₄ GAT, ISSR-3 (GAGA)₄ GAAT, and ISSR-4 (ACC)₄ Y, were developed in the current work. The chosen primers produced 571 ISSR bands, with

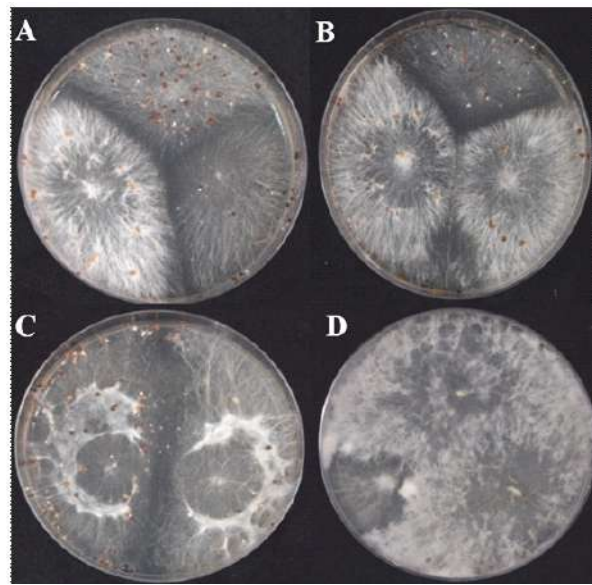


Fig.-1 : PDA plates showing compatible and incompatible reactions between three different isolates of *A. rolfsii*. A. In-compatible with three isolates, B. One compatible, C. Two compatible, D. All three isolates are compatible.

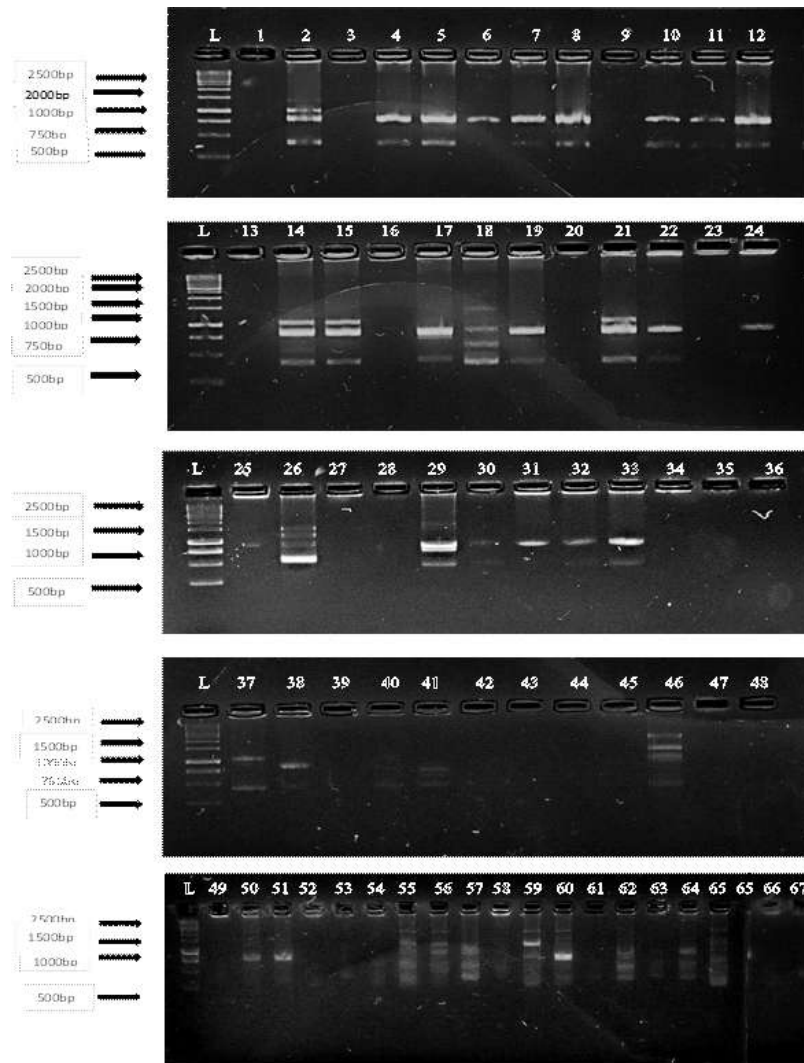


Fig.-2 : Amplification profiles of *A. rolfsii* isolates using ISSR-1 primer. Isolates numbers are shown as 1 to 67. L-1Kb molecular marker.

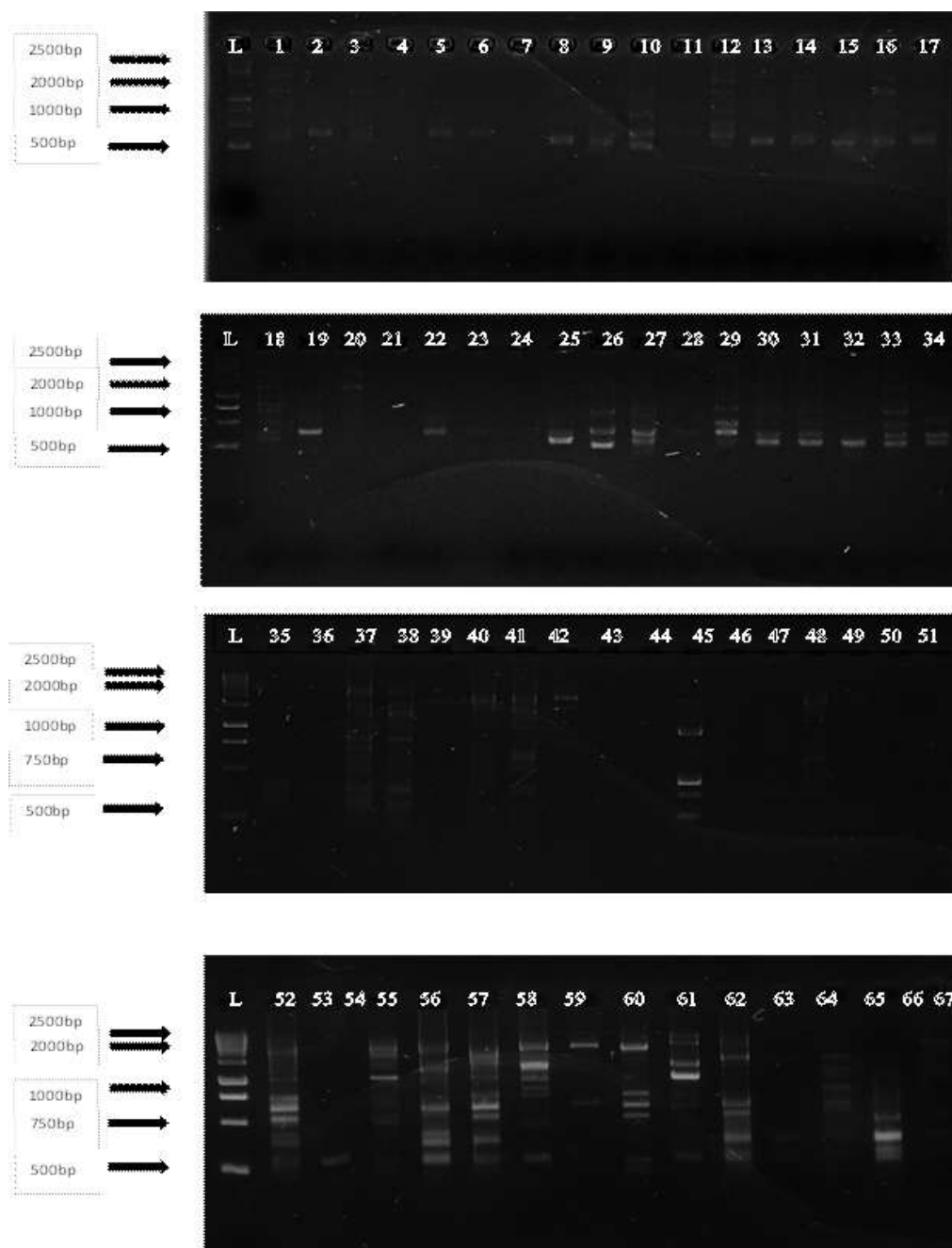


Fig-3 : Amplification profiles of *A. rolfsii* isolates using ISSR-3primer. Isolates numbers are shown as 1 to 67. L- 1Kb molecular marker

amplification products ranging in size from 250 to 1 kb. Maximum bands produced by the ISSR1 primer (GAGA)₄ GAT were 162, all of which were polymorphic. Only 31 of the 67 isolates had polymorphism, which was grouped into 4 major categories. Sixty-seven pure isolates produced a total of 439 reproducible and scoreable polymorphic bands, with sizes ranging roughly from 100 bp to 2500 bp. 3 primers were used, and the ISSR-1 primer generated the maximum bands of 162, followed by ISSR-3 of 152 bands, and ISSR-4 of 125 bands (Fig. 2, 3 and 4). The population had polymorphism of about

80-90%. The ISSR marker's Jaccard similarity coefficient has a mean value of 0.79.

The isolates of *A. rolfsii* were divided into 4 main clusters by the dendrogram based on the ISSR sequence data, with similarity values ranging from 76 to 98%. (Fig.5). The isolates viz., S1, S4, S21, S39, S51, S35, S42, S14, S32, and S53 make up Cluster I, with genetic similarity values ranging from 0.82 to 0.98. The ten isolates in Cluster II, S15, S17, S16, S40, S20, S22, S23, S24, S25, and S46 shared genetic characteristics showing similarity, ranging from 0.76 to 0.95. Cluster III

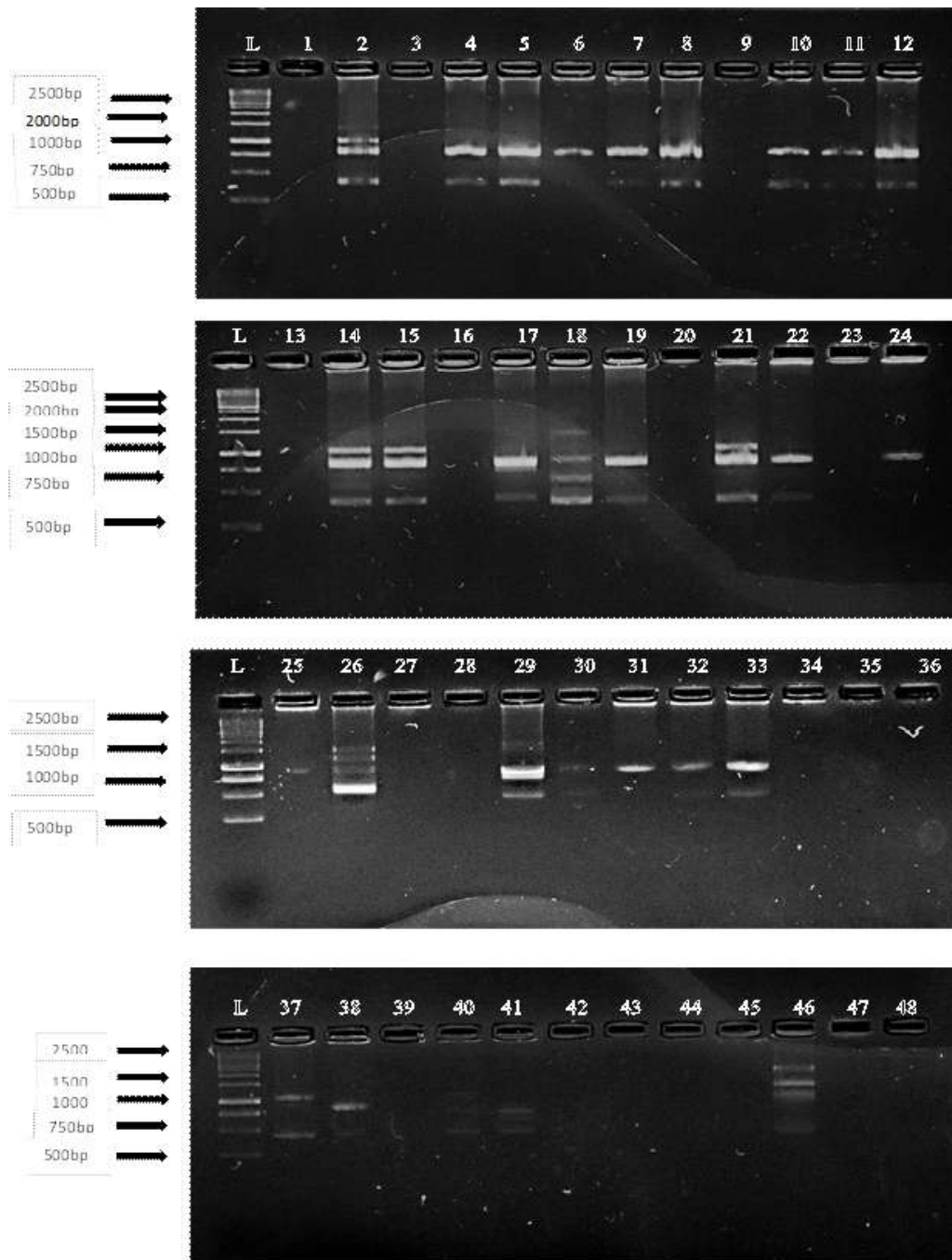


Fig-4 : Amplification profiles of *A. rolfsii* isolates using ISSR-4 primer. Isolates numbers are shown as 1 to 67. L-1Kb molecular marker

consists of 8 isolates (S27, S28, S36, S43, S44, S50, S49, and S58.) with genetic similarity values between 0.76 and 0.95: Cluster IV had two isolates (S62 and S64) with genetic similarity values between 0.82 and 100.

Using Jaccard's method index, the genetic similarity matrix was created from binary marker data. A 16 to 78% genetic similarity coefficient was observed. The S22-S23 and S43-S44 isolates had the most similarities (98%) whereas the S46 isolation shared the least similarities (76%) (Fig.-5).

This investigation demonstrated that high polymorphism is typically shown by ISSR primers based on di-nucleotide repeats (Blair *et al.*, 1999; Joshi *et al.*, 2000). The three ISSR primers showed that, in most cases, morphological and molecular identification of the species based on mycelial compatibility group were in good agreement. Despite the limited genetic similarity in several situations, isolates from the same species were grouped together.

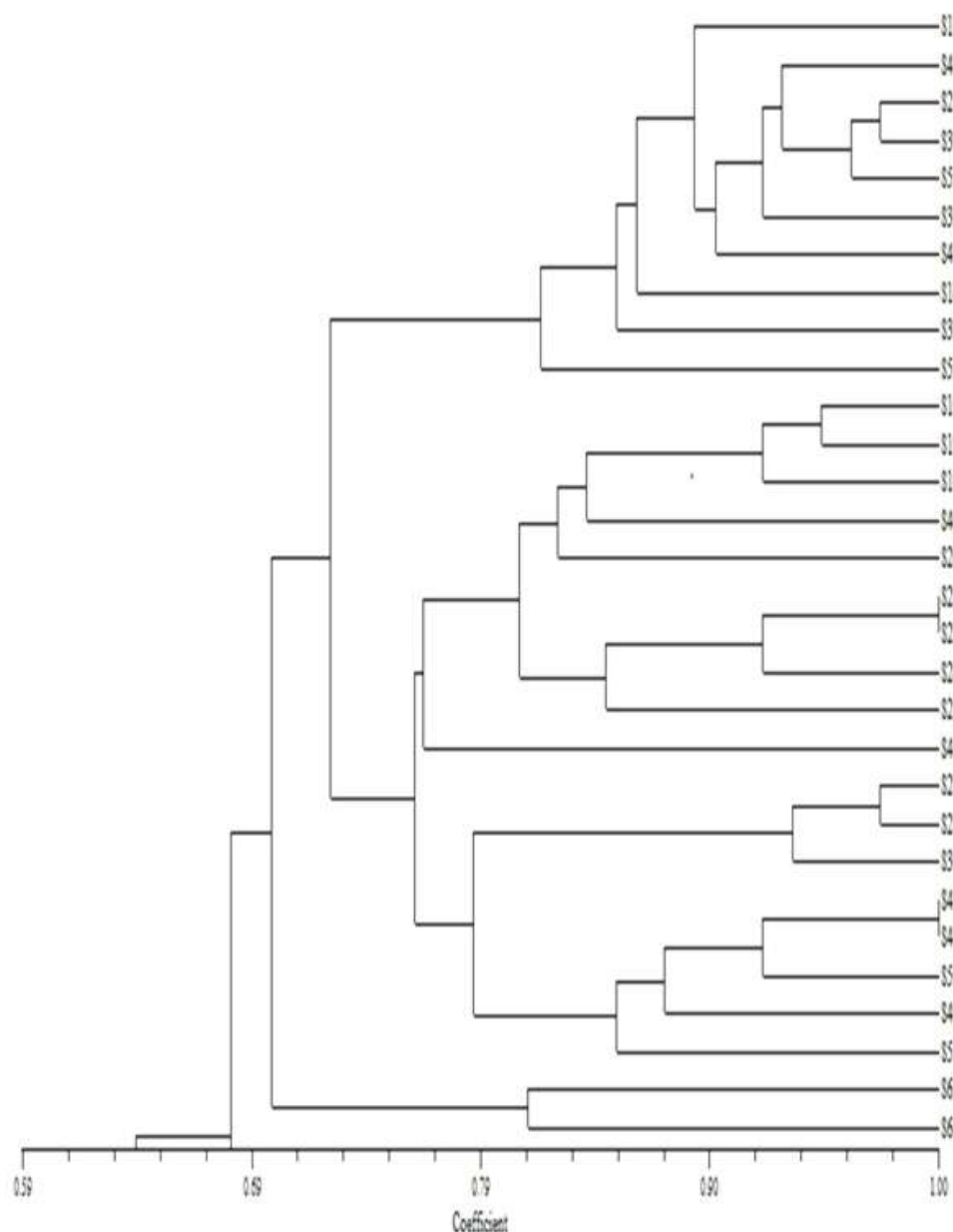


Fig.-5 : Jaccard's similarity based dendrogram of *A. rolfsii* isolates for ISSR markers.

Conclusions

The current investigation found that the isolates of *A. rolfsii* obtained from various geographical locations varied from one another. The 67 isolates of *A. rolfsii* produced a total of five MCGs. Different levels of polymorphism are present in ISSR markers, which are useful for estimating the genetic diversity of *A. rolfsii*. The use of ISSR molecular markers might be a useful method for analysing *A. rolfsii* variability. To learn more about the pathogenic variability in *A. rolfsii*, nevertheless, in-depth researches with a larger number of isolates are necessary.

Principal Coordinates Analysis (PCoA) : The scatter

plot from the PCoA of *A. rolfsii* isolates from different regions of India revealed that the second and third principal axis account for 18.80% and 33.47%, respectively, and all three axes together explained 43.64% cumulative variation.

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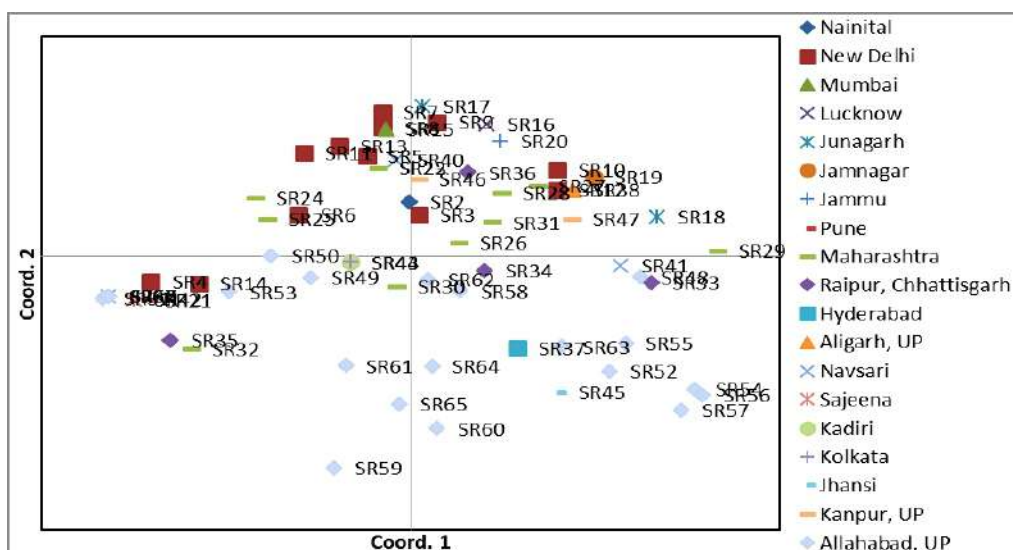


Fig. Principal coordinate analysis (PCoA) *A. rolfsii* isolates from different regions of India.

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Paddy Grower's Perception towards Climate Variability in Prayagraj District of Uttar Pradesh

Himanshu Upadhyay, K.D. Singh*, U.A. Siddiqui and Kamala Kant

¹Department of Agricultural Extension, CBG Agriculture PG College, BKT

*Corresponding Author Email : skapildev8@gmail.com

Abstract

A study was conducted in Prayagraj District of Uttar Pradesh to study Paddy Grower's Perception towards Climate Variability. Data were collected through personal interview and focus group discussion from the total 120 respondents. The findings of present investigation revealed that about 100 per cent of farmers have said that changes in rainfall pattern in the rainy season which acts as an extra stress to them during cultivation of paddy. majority of farmer's 72.50 per cent voiced to Heat Stroke, which is getting unconscious during exposure to intense heat, then after AB, BC, CA 26.25 & 1.25 per cent to Heat Exhaustion of farmers in intense heat. Almost of the farmers (91.25%) emphasized that they have feel that the rainfall in season making it's advent Late than actual dates, Whereas 8.75 per cent have said that they have never feel that advent if rain is late than their actual dates. Late onset of rain augments the input cost of farmers due to frequent prerequisite of water for cultivation of paddy crop.

Key words : Climate variability, paddy grower's, perception.

Introduction

Climate variability is the term used to describe any variation in the climatic conditions over time, whether as a result of natural variability or human activity. Changes in several climatic factors, such as cloud cover, precipitation, temperature, and an increase in greenhouse gas (GHG) emissions from human activities, cause variance. It is a deviation from the mean and fluctuation of its qualities over a lengthy time, usually decades or more (Anonymous). The global climate variability, which has drawn researchers from nearly every field, now poses a threat to have significant and long-lasting effects on human society. As we all know, agriculture is a very delicate sector on which we depend for the food, fibre, and other necessities that enable us to live sustainably. The most vulnerable sector to climate change is this one. Climate can be rationally viewed as a resource in agriculture, and changes in the climate can affect a region's ability to produce food (Darwin 2004).

Agriculture and food security are among the major casualties of climate variability in India because they are interrelated to each other and the pace and extent of warming across India is thoroughly. Impact of climate variation is very serious & have of several faces of it, such as unseasonal monsoon, variation in agricultural zones, spread of tropical diseases, augmentation in sea water, lack of freshwater, unintended floods, downpours, flash droughts, heat waves, storms, frequent thunderstorms, etc. India is likely to bear the highest agricultural productivity losses in the world due to climate variability.

Climate variability projections to 2100 for our Country India cue an overall augmentation in temperature by 2-4°C with no ample change in precipitation quantity (Kumar 2010).

As we know that at every place production of crops is mainly influenced by weather and its alteration, and therefore any variation in climate will have immense impact at crop yield and its productivity also. Several analysis have been accomplished for prediction of crop yield on seasonal basis, it has been observed that maximum temperature may cause the reduction in yield of rice in Eastern Uttar Pradesh by 1.0 to 1.1% per ha by 2020. In Eastern Uttar Pradesh, the minimum temperature may reduce rice yield by 1.5 to 1.9 percent per ha. According to the projected rainfall, the south-west monsoon would be the main driver of fluctuating temperatures by 2020, which could result in a 1.0 to 1.1 percent per ha decrease in rice yield in Eastern Uttar Pradesh. Similar to how the maximum temperature is expected to rise by the end of 2080, the lowest temperature may reduce the production of rice. However, this decrement in Eastern Uttar Pradesh may be less severe. Rice has significant attention for food security because it fulfills approximately one third of the caloric intake of one third world population. In the northern region of India, increase in carbon dioxide and a low increase in temperature is projected to favour rice crop growth which at last amplify the rice yield, whereas a rapid augment in temperature and slow increase in carbon dioxide consequences low rice yield which is due to adverse effect of it in paddy crop production (Ramirez 2010).

Research Methodology

Prayagraj District was selected randomly. Two tehsils were selected randomly. From each selected tehsil, four villages were selected by simple random sampling technique. . Complete enumeration was done of Paddy farmers having at least one acre land. From each village, 20 respondents were selected randomly. Thus, the total number of respondent was 80.

Results and Discussion

Paddy Grower's perception towards climate variability

Indicators of temperature change

Table-1 : Longest months with high day time temperature.

Sl. No.	Month	Frequency	Percentage
1.	July	45	56.25
2.	August	19	23.75
3.	September	16	20.00
	Total	80	100.00

Here, we have referred that the months having longest month with high day temperature where majority of farmers have responded 56.23% to have emphasized on month July. Subsequently, 23.75%farmers have responded to both July as well as August as month with high day time temperature during cultivation of Paddy & 20% during September (Table-1).

The main issue is that here to focus on the month which farmers are facing change than prior in temperature, which consequences loss for them.

Table-2 : Frequent occurrence of heat induced crop disease.

Sl. No.	Disease	Frequency	Percentage
1.	Spikelet sterility	38	47.50
2.	Early Maturity	34	42.50
3.	Heat Stess	8	10.00
	Total	80	100.00

Here, we have placed the question with Farmer's that several crop diseases are introduced due to change in average temperature at a juncture, by which production & productivity of crop abated, so majority of farmers 47.50% emphasized on Spikelet sterility(during pollen formation/ flowering stage)having while 42.50% are assented on mixed response of Early Maturity of pollen grains during cultivation of paddy crop (Table-2).

Table-3 : Heat Tolerant Crop varieties.

Sl. No.	Tolerant variety	Frequency	Percentage
1.	Nagina 22	32	40.00
2.	Azad Basmati	27	33.75
3.	Both	21	26.25
	Total	80	100.00

Here, we have represented the data of utilizing the heat tolerant paddy varieties by farmers to reduce the damage faced by climate change , where majority of farmers 40% emphasized on Nagina22 with most prompted crop by farmers then after, Azad Basmati 33.75% as second most favorable crop for production with lean affect of climate on productivity. While 26.25% assented on both varieties as favorable for cultivation during heat stress (Table-3).

Table-4 : Frequent occurrence of heat-induced livestock effects.

Sl. No.	Effects	Livestock No	Percentage
1.	Weak Immune system	35	43.75
2.	Laziness (less active)	4	05.00
3.	Anger	3	03.75
4.	Both	39	48.75
	Total	80	100.00

Here we have referred that majority of farmers 48.75% have agreed on All Disorders as their main livestock ailments of farmers. While the effect of heat induced effect occurred at livestock at 43.75% of weak Immune system%. Subsequently, Laziness 5% less active livestock or diminished fluency in livestock invites several kinds of diseases to them consequences seldom demise of animals and extra financial input by farmers. Heat induces giggle to 3.75% animals leads them to an angry animal .Seldom, harmful to Farmer's as well as for their family members (Table-4).

Table-5 : Frequent occurrence of heat-induced human disorders.

Sl. No.	Disorder	Frequency	Percentage
1.	Heat cramp		
2.	Heat Stroke	58	72.50
3.	Heat Exhaustion	1	01.25
4.	All	21	26.25
	Total	80	100.00

Here, we have talked about the human disorders induced by heat caused to farmers leadscto several ailments if exposed beyond a time limit.

Here, majority of farmer's 72.50% voiced to Heat Stroke, which is getting unconscious during exposer to intense heat, then after AB,BC,CA 26.25% & 1.25% to Heat Exhaustion of farmer personnels in intense heat (Table-5).

Table-6 : Emergence new plant species/invasive species in form of weed.

Sl. No.	Nature of species	Frequency	Percentage
1.	Temporary	26	32.50
2.	Permanent	54	67.50
	Total	80	100.00

As we see here that, the due to climate change and pattern of rainfall & temperature several new invasive species have been introduced in the Locale automatically which act as a bottlenecks to farmers during paddy cultivation. Here majority of farmers 67.505 agreed that these invasive species of weeds & unwanted plants are having permanent residing rainfall feature, which becomes too costly during their eradication process. & also 32.50% farmers agreed to their ephemeral in nature (Table-6).

Table-7 : Disappearance of water sources.

Sl. No.	Type of Disappearance	Frequency	Percentage
1.	Temporary	37	46.25
2.	Permanent	18	22.50
3.	El-Nino		
4.	All (AB, BC, CA)	15	18.75
	Total	80	100.00

Here, the type of water source Disappearance have been discussed, where majority of farmers agreed on Temporary Disappearance is having 46.25% then after, on Permanent depletion having 22.50%. While 18.75% of them have all consent on water Disappearance of sources (Table-7).

Table-8 : Change in precipitation.

Sl. No.	Rainfall	Farmer's consent	Percentage
1.	Erratic Rainfall	3	03.75
2.	Flash Drought	4	05.00
3.	Downpour at a time	13	16.25
4.	All (AB,BC,CA)	60	75.00
	Total	80	100.00

Here, consent of farmers towards change in precipitation is recorded. Where majority of farmers 75% emphasized on All (AB,BC,CA) types, Subsequently, 16.25% have agreed on excess downpour at a juncture, 5% have Assent on Flash Drought & Remaining 3.75% have mere assent on Erratic Rainfall (Table-8).

Table-9 : Shortened length of rainy season.

Sl. No.	Abated days	Farmer's consent	Percentage
1.	20 days	6	07.50
2.	27days	53	66.25
3.	40days	7	08.75
4.	ABC (AB,BC,CA)	14	17.50
	Total	80	100.00

Here, shortened length of days of rainfall in a rainy season are represented, where majority of farmers 66.25% emphasized that they have feel that 27days are abated in a rainy season. Subsequently 17.50% farmer's said all days that 20 days, 27days & then 40 days. nearly 8.50% farmers have 40days perception towards decreased in length of rainy season during cultivation of

crop & 7.5% have 20 days consent of decreased days of rainfall. Which have immense effect on cultivation of paddy crop (Table-9).

Table-10 : Change in planting time of paddy crop.

Sl. No.	Planting Time	Frequency	Percentage
1.	Before onset of Rainfall	72	90.00
2.	After Rainfall	8	10.00
	Total	80	100.00

As we have seen that farmers are using several practices to wane the ill effects of climate on paddy production. Here, majority of farmer's 90% voiced to have planted their crop seedlings before onset of rainfall and quickly transplanted it to the intended field for better utilization of rainfall when it comes. While 10% farmers still believed in traditional practice of after rainfall due to their personal reluctance and seldom due to non-availability of personal resources at adequate amount (Table-10).

Table-11 : Late onset of Rainfall in season.

Sl. No.	Late rainfall in season	Frequency	Percentage
1.	Yes	73	91.25
2.	No	7	08.75
	Total	80	100.00

Here, farmer's consent Late onset of Rainfall have been taken out. where, majority of farmers 91.25% emphasized that they have feel that the rainfall in season making it's advent Late than actua dates, Whereas 8.75% have said that they have never feel that advent if rain is late than their actual dates. Late onset of rain augments the input cost of farmers due to frequent perquisite of water for cultivation of paddy crop (Table-11).

Table-12 : Crop failure due to water shortage.

Sl. No.	Amount Failed	Farmer's assent	Percentage
1.	Complete	13	16.25
2.	Minimal	24	30.00
3.	Average crop failure	43	53.75
	Total	80	100.00

Here, table referred to amount of crop loss induced by water shortage afflicts farmer's output as well as their productivity, here, majority of farmer's 53.75% have seen that their produce have average failure, while 30% emphasized on minimal crop failure & approx 16.25% feels that complete crop failure due to water stress (Table-12).

Table-13 : Switch to draught/heat tolerant varieties are.

Sl. No.	Farmer's Assent	Frequency	Percentage
1.	Helpful	76	95.00
2.	Not Helpful	4	05.00
	Total	80	100.00

Here, Majority of farmer's 95% said that their switch to varieties is Helpful for them. It abated their loss of produce & productivity. While 5% farmer's feel that these varieties are not helpful for them as they intended (Table-13).

Conclusions

It can be concluded from the study that about all 100% famers have said that changes in rainfall pattern in the rainy season which acts as an extra stress to them during cultivation of paddy. Majority of farmers 66.25% have responded that they have seen a decline of near about 27

days in rainy days during season, which consequences heavy downpour in less interval of time.

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Accessibility and Perceived Attributes of ICT among Dairy Farmers in Lucknow District of Uttar Pradesh

Surya Prakash Shukla, Kamala Kant, K.D. Singh* and U.A. Siddiqui

Department of Agricultural Extension, CBG Agriculture PG College, BKT

***Corresponding Author Email :** kant.kamala@gmail.com

Abstract

A study was conducted in Lucknow District of Uttar Pradesh to study the Accessibility and Perceived Attributes of ICT among Dairy Farmers. Data were collected through personal interview and focus group discussion from the total 120 respondents. The findings of present investigation show that accessibility of ICT, majority of the farmers were internet through mobile phones is 100 per cent followed by Mobile phone (81.66%). In case of perceived attributes of ICTs among dairy farmers, 88.33 per cent of respondents ICT were used for rural communication to increase participation dissemination information to share knowledge and skills followed by (84.16) per cent people using ICT to access market information sold a lot more and received relatively better prices

Key Words : *Accessibility, attributes, dairy farmers, perceived.*

Introduction

The importance of information in advancement of all societies. It increases the value and productivity of land, labor and capital to meet people's needs and wants. It is one of the key inputs in agriculture and information deficits constrain agricultural productivity. Relevant, reliable, useful and timely available information can augment the agricultural productivity. The world is undergoing an Information Communication Technology (ICT) revolution which has greatly affected the socio-economic life of the people towards more advancement. ICT is a crucial element in determining the new global economy and producing rapid changes in society.

These different tools are now able to work together, and combine to form our "networked world" - a massive infrastructure of interconnected telephone services, standardized computing hardware, the ICTs, which encompass a wide range of goods, programmes, and services used in the generation, archiving, processing, distribution, and interchange of data, are essentially information-handling technologies. They include both the "old" ICTs of radio, television, and telephone as well as the "new" ICTs of computers, satellite and wireless technologies, and the Internet. Internet, radio and television, which reaches into every region in the world (UNDP, 2001). ICT, has potential to change the economy of livestock and agriculture, thus contribute towards the improvement of rural livelihood. It is the prime basis for future economic development. It helps in rapid dissemination of information and minimizes time and distance barriers. ICT can be seen as contributing to the socio-cultural system of rural areas, with impact on both

behavior and knowledge. It is believed that ICT will become the prime basis for the future economic development of livestock industry and failure to adopt could cause major problems (Sasidhar and Sharma, 2006). Effects of ICT at the community level has a social dimension in which access to information is uneven across the social groups. Information disadvantaged groups are distanced from ICT networks, with the possibility of increased polarization (Gibbs and Tanner, 1997). a significant disparity Due to wide disparity Geographical factors, resource accessibility and availability, human understanding, and the far-reaching and uneven effects of ICTs on society are all factors that contribute to the Digital Divide. Economic growth will proceed unevenly as a result of the digital divide.

Research Methodology

Uttar Pradesh was selected purposively because of livestock sector supports livelihoods of nearly 80.00 per cent of the rural households in the state. Two tehsils were selected randomly. From each selected tehsil, three villages were selected by simple random sampling technique. . Complete enumeration was done of dairy farmers rearing at least one dairy animal and possessing a mobile phone or landline, for increased possibility of usage of ICT, was done. From each village, 20 respondents were selected randomly. Thus, the total number of respondent was 120.

Results and Discussion

Accessibility of ICTs towards the respondents : Result observed in table-1 indicate that the accessibility of ICT, majority of the farmers were internet through mobile

Table-1 : Accessibility of ICT by dairy farmers. [n=120]

S. No.	ITC facilities	Frequency	Per centage
1.	Internet connection in home through mobile phone	120	100
2.	Internet connection in home through laptop/desktop	38	31.66
3.	Internet café in the village	13	10.83
4.	Internet connection in some houses in village	95	79.16
5.	Community radio/village knowledge centre in village	4	3.33
6.	Computer/ laptop in your home	20	16.66
7.	Mobile phone	98	81.66
8.	DVDs/CDs for agriculture and dairy information	25	20.83
9.	DVD players	61	50.83
10.	Landline telephone in home	5	4.16
11.	Television in home	112	93.33
12.	Radio	49	40.83

Table-2 : Perceived attributes of ICTs among dairy farmers. [n=120]

S. No.	Perceived Attributes	Frequency	Per centage
1.	Relative Advantage		
A	More subject matter coverage by internet than any other sources of information	100	83.33
B	Minimize time and distance barriers	80	66.66
C	Reduce transaction cost	55	45.83
D	ICTs can be used for getting the information about Agriculture and Animal Husbandry Practices	89	74.16
E	Speedy communication	60	50.00
2.	Compatibility		
A	ICTs are affordable	86	71.16
B	Internet is feasible in current infrastructure facilities available	30	25.00
3.	Complexity		
A	Difficult to find out relevant material on Internet	86	71.66
B	Difficult to use mobile phones for getting information	88	73.33
C	Complexity of operation in using ICTs	90	75.00
D	Internet is costly affair for the Farmers	82	68.33
E	Information available on Internet is easy to understand	70	58.33
F	After training, it is easy to use	69	57.50
4.	Triability		
A	ICTs can be used to meet the dairy information needs of the community	68	56.66
B	Dairy farmers can try to access information in a village internet café before purchasing own computer/internet service in mobile	21	17.50
5.	Observability		
A	ICTs are used for rural communication To increase participation dissemination Information to share knowledge and Skills	100	88.33
B	People using ICTs to access market information sold a lot more and received relatively better prices	101	84.16
C	Commercial and economic development opportunities are made effective through ICT communication	83	69.16
D	Use of ICT have positively enhanced dairy production	79	65.83

phones is 100 per cent, Mobile phone (81.66%), Internet connection in some houses in village (79.16%), DVD player (50.83%), Radio (40.83%), mobile phone, DVDs/CDs of dairy information 20.83 per cent, Computer/laptop in home of respondent 16.66 per cent, cafe in the village 10.83 per cent, landline telephone 4.16 per cent community respectively.

Perceived attributes of ICTs among dairy farmers :

Table-2 reveals that 88.33 per cent of respondents ICT were used for rural communication to increase participation dissemination information to share knowledge and skills followed by (84.16) per cent people using ICT to access market information sold a lot more and received relatively better prices, 83.33 per cent more

subject matter coverage by internet than any other sources of information, 79.16 per cent Commercial and economic development opportunities are made effective through ICT Communication, 75.00 per cent Complexity of operation in using ICT 74.16 per cent ICT can be used for getting the information about agriculture and animal husbandry practices, 73.33 per cent difficult to use mobile phones for getting information, 71.66 per cent difficult to find out relevant material on internet, 71.16 percent ICT are affordable, 68.33 per cent farmers considered that internet is costly affair for the farmers. 58.33 per cent respondents using internet perceived that information available on Internet is easy to understand, 57.50 per cent perceived that internet is easy to use after training, 25.00 per cent respondents considered that ICTs help in others available, 10.00 per cent respondents considered that ICTS were others and 2.50 per cent respondents used other source for getting information.

Conclusions

It can be concluded from the study that accessibility of

ICT, majority of the farmers were internet through mobile phones is 100 per cent followed by Mobile phone (81.66%). In case of perceived attributes of ICTs among dairy farmers, 88.33 per cent of respondents ICT were used for rural communication to increase participation dissemination information to share knowledge and skills followed by (84.16) per cent people using ICT to access market information sold a lot more and received relatively better prices.

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Exploring the Impact of Sowing Dates on Performance of Cotton Hybrid Varieties

Ankush B. Chougule¹, Priyanka K. Patil¹, Sujeet S. Deshmukh^{2*}, Shantanu S. Dhawase¹ and Swapnali V. Mahude³

¹Department of Agricultural Meteorology, CoA, V.N.M.K.V. Parbhani

²Department of Agricultural Meteorology, CoA, Pune. M.P.K.V. Rahuri

³Department of GPB, CoA, V.N.M.K.V. Parbhani

*Corresponding Author Email : sujeetdeshmukh99@gmail.com

Abstract

The investigation of impact of sowing dates on a cotton hybrid was carried out during the *Kharif* season of 2021-22 at the experimental farm of the Department of Agricultural Meteorology, AICRP on Agrometeorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The research employed a Split plot design featuring three replications and 12 treatments. These treatments included four sowing dates (D1: 25 MW, D2: 26 MW, D3: 27 MW, and D4: 28 MW) and three Bt. cotton varieties (V1: Ajeet-155, V2: Ankur, and V3: Mallika), with a spacing of 120 cm x 45 cm. A total of 36 plots were established, each with a net area of approximately 5.4 x 2.4 m² and a gross area of 7.2 x 3.6 m². Cotton seeds were sown using the dibbling method. Recognizing that a crop's water requirement vary throughout its developmental stages, the study acknowledged the influence of weather variables at different phases of the crop's life cycle. Early sowing (D1: 25 MW) resulted in the highest seed cotton yield, tallest plants, and increased leaf, branch, and boll numbers compared to later sowing dates. Seed cotton yield (Kg ha⁻¹) and related factors, such as yield per plant (gm), stalk yield (Kg ha⁻¹), and biological yield (Kg ha⁻¹), as well as harvest index (%), exhibited a declining trend from D1 to D4. Specifically, D1 (25 MW) had the highest yield, followed by D2 (26 MW) and D3 (27 MW), with D4 (28 MW) showing the lowest yield. Among the cultivars, Ajeet-155 outperformed Ankur and Mallika, with Mallika exhibiting the lowest yield. Delayed sowing beyond D1 led to a decline in seed cotton yield.

Key words : *Bt. cotton, growth and yield, dry matter, plant height, Number of leaves, Number of bolls plant⁻¹, yield attributing characters.*

Introduction

Cotton is one of the most important fiber and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. It provides the basic raw material (cotton fibre) to cotton textile industry. Cotton in India provides direct livelihood to 6 million farmers and about 40 -50 million people are employed in cotton trade and its processing. It belongs to the family 'Malvaceae', genus 'Gossypium' and native to tropical and sub-tropical region around the World. This genus has 50 species out of which only four are cultivated whereas the rest 46 species are wild crop. These 4 species include *Gossypium hirsutum*, *Gossypium barbadense*, *Gossypium arboreum*, *Gossypium* (Anonymous, 2016).

In India cotton growing major states are Maharashtra, Gujrat, Telngana, Rajsthan, Karnataka, Haryana, Madhya Pradesh and Andhra Pradesh. Maharashtra has the largest area under cotton in the India. The area under cotton in Maharashtra was 4.29 million hectares with production 9.59 million bales each of 170 kg and productivity is 380 kg ha⁻¹ during 2020-21. In Maharashtra Vidhrbha region contributes 30% of the crop. Marathwada is accounting of 16.88 lakh hectares area with a production of 35.26 lakh

bales and productivity of 359 kg lint ha⁻¹ (Anonymous, 2012).

In Maharashtra, the production is about 95.575 lakh tonnes (170 Kg of each bale) having a maximum area under cultivation of 42.86 lakh hectares with a productivity of 379.9 kg ha⁻¹ (Anonymous, 2020c). Cultivated cotton is an herbaceous plant which attains a height if 75-200 cm. Cotton plant has a tap root system with secondary root that branched laterally from primary root. The main stem is erect and much branched; the branches develop from buds located at the nodes of the main stem. There are 2 buds at the base of each cotton leaf petiole. The true axillary buds develop in a vegetative branch, which only bear leaves and no flowers. The accessory bud generally develops into sympodial or fruiting branch. Vegetative branch may arise either from axillary or an accessory bud. There is tendency for the lower branches to be vegetative and the upper fruiting. The leaves are spirally arranged on the main stem and vegetative branches, except on fruiting branches. Where they form 2 alternate rows. The leaves are petiolate. The out line of leaf is more or less cordate with 3-9 lobes depending on variety. The leaves are green but in some species such as arborium leaves contain some purplish colour. The flowers develop at the opposite to a leaf in fruiting branches only.

Materials and Methods

The experiment was carried out at the farm of AIRCPAM, Department of Agricultural Meteorology, College of Agriculture, Vasant Rao Naik Marathwada Krishi Vidyapeeth, Parbhani, during the *Kharif* season 2021–22 on the experimental farm, Parbhani, which extends from 19° 16' N Latitude and 76° 47' E Longitude and from sea level to as high as 409 m elevation. This region is dominated by hot and dry summer, wet humidity with mild precipitation during monsoon season and cold winter. The experimental field topography was homogeneous and well-leveled. The weather data for the appropriate time of the experiment was recorded at Central Meteorological Observatory, AIRCPAM, Vasant Rao Naik Marathwada Krishi Vidyapeeth, Parbhani.

The area of experiment was set out in the split plot design with three variation of replication and 12 treatment combination consisting of four sowing dates D₁: 25 MW, D₂: 26, D₃: 27 MW, D₄: 28 SMW and three distinct *Bt.* cotton hybrid. (V₁ : Ajeet 155, V₂ : Ankur, V₃ : Mallika) with gross plot size 7.2m*3.6m and net plot size 5.4m*2.4m.

Plant height (cm) : This observation was done at 15 days interval starting from 30 DAS to 150 DAS and at harvest by measuring the height of those five selected plants in each net plot from its base to its apex.

Number of Leaves plant⁻¹: This observation was done at 15 days interval starting from 30 DAS to 150 DAS and at harvest by counting the number of leaves of those five selected plants in each net plot.

Number of developed bolls plant⁻¹ : This observation was done at 15 days interval starting from 75 DAS to 150 DAS and at harvest by counting the number of good and healthy bolls from each net plot.

Seed cotton yield (gm plant⁻¹) : This particular seed cotton yield was calculated by taking the average of the weight of cotton bolls of five represented plant at each picking and the overall weight after picking was the final seed cotton yield expressed in gram per hectare.

Seed cotton yield (Kg ha⁻¹) : In this case, the seed cotton yield was calculated by measuring the weight of the cotton bolls after picking from each net plot including that of five represented plant and expressed in kilogram per hectare.

Stalk yield (Kg ha⁻¹) : The stalk yield was calculated by measuring the weight of dried stalk at harvest from each net plot that has already been uprooted and sun dried for four weeks. The weight of dried stalk of each net plot was measured in kilogram which was converted into hectare basis.

Biological yield (Kg ha⁻¹) : The combination of yield

attributes of seed cotton yield and cotton stalk yield were used to determine the overall biological yield of cotton.

Mean total dry matter accumulation gm plant⁻¹ : This observation was done by carefully uprooting one selected plant at each phenological stage from each net plot after which the uprooted plant are being dried in a shady condition for 3-4 days and finally it is dried in an oven at 65 °C for 48 hours till the dried weight remain constant. Hence, the dry matter accumulation was recorded. The dry matter weight per plant is the indicator of the overall growth and performance of the plant.

Results and Discussion

In this chapter, the data obtained during the experiment was evaluated using suitable statistical techniques, and the findings are presented under the heading below.

Growth Studies

This observation includes the collection of data that explains the daily growth and development of different hybrid of crop in responses to different dates of sowing as well as comparison of growth and development between hybrid in 15 days periodical interval from the first observation to until harvest observation.

Plant height (cm)

The data on plant height (cm) as influenced by different treatment combinations at a periodical interval of 15 days from 30 DAS to till harvest are given in Table 3. According to data, it was found that the plant height of *Bt.* cotton hybrid gradually increases from 30 DAS to till harvest and the geometric mean plant height at 15 days periodical interval from 30 DAS to till harvest was 12.8, 17.8, 24.8, 40.5, 49.0, 52.0, 71.8, 84.5, 93.5 and 98.0 cm, respectively, with mean plant height at harvest was the highest (98.0 cm).

Effect of sowing dates : The effect of sowing dates on mean plant height was found statistically significant during 30, 45, 60, 75, 90, 105, 120, 135, 150 DAS and at harvest. According to data from Table 4.7 and Fig. 4.6, it was found that D₁ has recorded significantly higher plant height of 115.2 cm, over rest of all sowing dates. As a data result, varied dates of sowing were found to have statistically significant effects on plant height, with the early sowed crop (D₁) growing taller than the late sown crops (D₄). This is due to the fact that the early sowed crop received sufficient rainfall and adequate moisture to aid in the crop's growth and development. This similar result was reported by Waghmare *et al.* (2016), Omer and Hassan (2003) and Ali *et al.* (2011) that the plant height was significantly influenced due to sowing dates and maximum plant height was observed in early sowing dates and decreases in late sowing dates. Dakhore and

Kadam (2018) and Gaikwad (2019) also reported that sowing dates during 25th SMW recorded significantly higher plant height than the other sowing date at VNMKV, Parbhani.

Effect of hybrids : The data revealed that plant height was statistically significant from 45 DAS till harvest, exception of 30 DAS was recorded non-significant. It was found that V₁ (Ajeet-155) has recorded significantly higher plant height of 103.6 cm, over rest of all hybrids. Dakhore and Kadam, (2018) also reported that, Ajeet-155 recorded significantly higher plant height than Mallika at VNMKV, Parbhani and Shivani (2020) reported that, Ajeet-155 recorded significantly higher plant height than Ankur at VNMKV, Parbhani. This may be due to genetic interval of the hybrids.

Interaction effects : The interaction effects of different dates of sowing and hybrids during crop growth period was no significant related to plant height.

Number of leaves plant⁻¹

Observation was start from 30 days after sowing at 15-day periodical intervals up to at harvest as shown in Table 4 to determine the effect of different sowing dates and hybrid by counting the number of leaves plant⁻¹. According to data, the number of leaves of the *Bt.* cotton crop continuously increases from 30 DAS to till harvest. From 30 DAS to harvest, the geometric mean number of leaves at 15 days periodical interval was 6.2, 7.5, 15.6, 26.3, 36.0, 47.0, 51.0, 54.0, 56.3 and 65.6, with the mean number of leaves at harvest being the highest (65.6).

Effect of sowing dates : The effect of sowing dates on mean number of leaves plant⁻¹ was found to statistically significant at all the growth stages. According to data from Table 4.8 and Fig. 4.8, it was found that sowing date D₁ has recorded significantly highest number of leaves which was 69.7, over other sowing dates except D₂ at 30 DAS to 135 DAS. The analyzed data of weather and number of leaves shows that the early sown crop has higher growth rate and number of leaves due to availability of longer period sunshine duration, soil moisture, temperature and humidity for its vegetative growth. However, in late sown crop the vegetative growth was restricted (with condition of no pre seasonal or seasonal agricultural drought) due to shorter period of sunshine, soil moisture, low temperature and high humidity.

Effect of hybrid : Different *Bt.* cotton hybrids had a statistically significant impact on mean number of leaves plant⁻¹ from 30 Days after sowing to harvest. Among different hybrids. V₁, (Ajeet 155) recorded significantly highest number of functional leaves which was 65.9, over rest of all hybrid at all periodical interval except at 30 DAS. It could have been related to varietal characteristics.

Interaction effects : The interaction effects of different dates of sowing and hybrids during crop growth period was non-significant with number of functional leaves plant⁻¹.

Number of bolls plant⁻¹

The data as illustrated in Table 5 was taken 75 days after sowing at 15-day periodical intervals up to at harvest. According to data, the number of bolls of the *Bt.* cotton crop continuously increases number from 75 DAS to till harvest. From 75 DAS to harvest, the geometric mean number of bolls plant⁻¹ was 4.9, 8.4, 10.3, 12.0, 13.3, 14.8 and 15.4 with the mean maximum number of bolls at harvest was the highest (*i.e.*, 15.4).

Effect of sowing dates : The effect of sowing dates on mean number of bolls plant⁻¹ was found to be statistically significant at all the growth stages. According data from Table 5 D₁ has found significantly higher number bolls plant⁻¹ which was 16.4, over rest of all sowing dates except it was found at par with D₂ during 90, 105, 135 DAS and with D₂ and D₃ during 150 DAS and at harvest.

As a result, varied dates of sowing were found to have statistically significant effects on number of bolls plant⁻¹, with the early sown crop (D₁) generate highest number of bolls plant⁻¹ while late sown crops (D₄) produced lowest number of boll plant⁻¹. This is due to the fact that late sown crop received heavy rain and overcast weather during crop growth period and results into boll creation and boll bursting stages, that inhibit pollination resulting in the dropping of flowers and young bolls, resulting in fewer number bolls plant⁻¹. Late sown crop could not develop a full canopy surface area that is required to receive and use maximum of incoming solar radiation due to low temperature induced growth reduction at squaring and flowering. The heat units needed to produce open bolls from flowers were significantly reduced in late sown crop under rainfed condition (Hebbbar *et al.*, 2002). Gaikwad (2018), Hebbbar *et al.*, (2002) and Ahuja (2006), Omer and Hassan (2003) found similar findings that early-planted *Bt.* cotton have more number of bolls than late-planted *Bt.* cotton, resulting in maximum yield.

Effect of hybrids : A different *Bt.* Cotton hybrid was a significant impact on mean number of bolls plant⁻¹ from 75 Days after sowing to harvest. Among different treatments of hybrid V₁, Ajeet 155 has found significantly higher number of bolls plant⁻¹ which was 16.4, over rest of all hybrids at all periodical intervals. Shivani (2020) reported the same results.

Interaction : The interaction effects of different dates of sowing and hybrid during crop growth period had non-significant effect on mean number of bolls plant⁻¹.

Table-1 : Schedule of biometric observations as follows.

Sr. No.	Particular	Frequency	Days after Sowing (DAS)	Sampling unit
Pre harvest observation				
1.	Emergence count (%)	1	08	Net plot
2.	Final Plant stand (%)	1	At harvest	Net plot
3.	Plant height (cm)	10	30, 45, 60, 75, 90, 105, 120, 135, 150 DAS and at Harvest	5 Plants plot ⁻¹
4.	No. of leaves plant ⁻¹	10	30, 45, 60, 75, 90, 105, 120, 135, 150 DAS and at Harvest	5 Plants plot ⁻¹
5.	No. of Branches plant ⁻¹	9	45, 60, 75, 90, 105, 120, 135, 150 DAS and at Harvest	5 Plants plot ⁻¹
6.	No. of Bolls plant ⁻¹	7	75, 90, 105, 120, 135, 150 DAS and at Harvest	5 Plants plot ⁻¹
7.	Dry matter (gm)	5	Stage wise	
Post harvest observation				
7.	Seed cotton yield (gm plant ⁻¹)	1	At harvest	5Plants plot ⁻¹
8.	Seed cotton yield (kg ha ⁻¹)	1	At harvest	Net plot
9.	Stalk yield (kg ha ⁻¹)	1	At harvest	Net plot
10.	Biological yield (kg ha ⁻¹)	1	At harvest	Net plot
11.	Harvest index (%)	1	At harvest	Based on biological yield and seed cotton yield

Table-3 : Periodical mean plant height (cm) as influenced by various treatments.

Treatments	Days after sowing									Harvest
Date of sowing	30	45	60	75	90	105	120	135	150	
D1-25th MW	14.22	26.33	33.50	47.67	56.56	58.44	75.22	104.18	109.11	115.2
D2-26th MW	13.00	17.56	25.50	42.11	51.11	54.22	87.04	90.35	100.44	106.8
D3-27th MW	12.67	15.56	23.39	40.39	49.44	51.44	71.22	81.93	91.93	93.8
D4-28th MW	11.56	12.00	17.11	31.83	39.11	44.00	54.07	62.18	72.78	76.0
S.E. m±	0.45	0.91	0.78	1.18	1.40	0.88	2.09	2.54	2.90	2.1
C.D. @ 5%	1.57	3.13	2.71	4.07	4.85	3.04	7.24	8.80	10.04	7.3
Hybrid										
V1- AJEET-155	13.33	18.50	26.00	42.13	51.08	55.42	77.95	91.86	100.69	103.0
V2-ANKUR	13.42	18.08	25.42	40.71	49.58	51.75	72.75	84.82	94.92	100.6
V3-MALLIKA	11.83	17.00	23.21	38.67	46.50	48.92	64.97	77.30	85.08	90.3
S.E. m±	0.56	0.40	0.55	0.87	1.04	1.12	2.57	2.59	2.73	2.1
C.D. @ 5%	NS	1.20	1.64	2.61	3.13	3.37	7.69	7.77	8.19	6.2
Interaction (D×V)										
S.E. m±	1.126	0.80	1.09	1.74	2.09	2.25	5.13	5.18	5.47	4.1
C.D. @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G.M.	12.86	17.86	24.88	40.50	49.06	52.03	71.89	84.66	93.56	98.0

Total dry matter plant⁻¹ (gm)

The recorded data on mean total dry matter output plant⁻¹ increase gradually at all growth phases. Dry matter was the peak at flowering, boll formation, and boll development, the rate of increase in total dry matter accumulation was gradual from seedling to boll formation stage and then quickly increased between boll formation and boll bursting stage. At the boll bursting stage, the

average total dry matter production plant⁻¹ was 98.36 gm at harvest.

Effect of sowing dates : At all growth stages, sowing dates was a significant impact on total dry matter production plant⁻¹. The early sowing, D₁ has recorded significantly higher mean total dry matter production which was 101.7 gm, over rest of all sowing dates except found at par with D₂ during square formation to boll bursting. These results support those of Bozbek *et al.* (2006), who

Table-4 : Periodical mean number of leaves per plant as influenced by various treatments.

Treatments Date of sowing	Days after sowing									Harvest
	30	45	60	75	90	105	120	135	150	
D1-25th MW	6.22	8.44	16.44	27.44	37.11	48.11	52.11	55.11	60	69.7
D2-26th MW	6.11	7.78	15.78	26.56	36.22	47.22	51.22	54.22	57.3	67.6
D3-27th MW	6.56	7.44	15.44	26.22	36.11	47.11	51.11	54.11	54.7	64.1
D4-28th MW	6.00	6.56	14.56	25.11	34.78	45.78	49.78	52.78	53.1	61.1
S.E. m±	0.19	0.40	0.44	0.50	0.41	0.49	0.38	0.41	0.43	0.53
C.D. @ 5%	0.95	1.18	1.31	1.49	1.23	1.45	1.13	1.22	1.5	1.83
Hybrid										
V1-AJEET-155	6.25	10.00	18.00	28.67	38.33	49.33	53.33	56.33	56.3	65.9
V2-ANKUR	6.33	7.17	15.17	26.17	35.83	46.83	50.83	53.83	56.7	65.6
V3-MALLIKA	6.08	5.50	13.50	24.17	34.00	45.00	49.00	52.00	55.8	65.3
S.E. m±	0.15	0.35	0.34	0.24	0.37	0.36	0.48	0.61	0.2	0.13
C.D. @ 5%	NS	1.03	0.99	0.72	1.09	1.07	1.43	1.81	0.6	0.4
Interaction (D × V)										
S.E. m±	0.55	0.69	0.76	0.87	0.72	0.85	0.66	0.71	0.4	0.27
C.D. @ 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
G.M.	6.22	7.56	15.56	26.33	36.06	47.06	51.06	54.06	56.3	65.6

Table-5 : Mean number of bolls plant⁻¹ as influenced by various treatments.

Treatments Date of sowing	Days after sowing						Harvest
	75	90	105	120	135	150	
D1-25th MW	5.67	9.33	11.22	13.00	14.56	15.78	16.44
D2-26th MW	4.78	8.78	10.78	12.78	13.78	15.44	16.11
D3-27th MW	4.67	8.44	10.44	12.44	13.67	15.11	15.78
D4-28th MW	4.67	7.33	9.11	9.78	11.33	13.11	13.44
S.E. m±	0.18	0.32	0.39	0.25	0.35	0.37	0.46
C.D. @ 5%	0.64	1.09	1.35	0.86	1.21	1.28	1.57
Hybrid							
V1-AJEET-155	5.75	9.25	11.17	12.92	14.25	15.75	16.42
V2-ANKUR	4.83	8.17	9.67	11.58	12.92	14.50	15.08
V3-MALLIKA	4.25	8.00	10.33	11.50	12.83	14.33	14.83
S.E. m±	0.17	0.30	0.38	0.41	0.41	0.39	0.42
C.D. @ 5%	0.52	0.91	1.14	1.22	1.24	1.17	1.25
Interaction (D × V)							
S.E. m±	0.35	0.61	0.76	0.82	0.83	0.78	0.83
C.D. @ 5%	NS	NS	NS	NS	NS	NS	NS
G.M.	4.94	8.47	10.39	12.00	13.33	14.86	15.44

found that early sowings produced much more dry matter than late sowings due to a lower availability of soil moisture, relative humidity, and high temperature, all of which reduce dry matter formation.

Effect of Hybrids : Table 6 shows that hybrid had a statistically significant impact on mean total dry matter production plant⁻¹ at all growth stages, whereas V₁ has

found significantly higher mean dry matter production was 100.5 gm, over rest of all hybrids except V2 square formation, flowering and boll formation.

Interaction : At all growth stages of the crop, the effect of interaction between sowing dates and hybrids on dry matter buildup was found to be non-significant.

Table-6 : Dry matter production plant⁻¹ (gm) of cotton as influenced by various treatments.

Treatments	Seedling	Square Formation	Flowering	Ball Formation	Ball Bursting
Date of sowing					
D1-25th MW	0.35	3.29	11.28	56.01	101.78
D2-26th MW	0.28	3.04	11.16	51.32	99.89
D3-27th MW	0.22	2.64	10.41	44.82	99.56
D4-28th MW	0.73	2.65	10.65	45.12	92.22
S.E. m±	0.02	0.17	0.23	2.91	1.41
C.D. @ 5%	0.07	0.51	0.68	8.63	4.86
Hybrid					
V1- AJEET-155	0.88	3.08	11.00	52.13	100.58
V2-ANKUR	0.23	3.00	10.99	51.04	97.92
V3-MALLIKA	0.11	2.63	10.63	44.78	96.58
S.E. m±	0.02	0.05	0.05	0.88	0.64
16 C.D. @ 5%	0.05	0.14	0.15	2.60	1.91
Interaction (D × V)					
S.E. m±	0.04	0.30	0.40	5.04	1.27
C.D. @ 5%	NS	NS	NS	NS	NS
G.M.	0.40	2.91	10.88	49.31	98.36

Table-7 : Seed cotton yield (gm plant⁻¹), Seed cotton yield (kg ha⁻¹), Stalk yield (kg ha⁻¹), Biological yield, (kg ha⁻¹) Harvest index (%) of Cotton as influenced by different treatments.

Treatments	Seed cotton yield (gm plant ⁻¹)	Seed cotton yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Biological Yield (kg ha ⁻¹)	Harvest Index (%)
Date of Sowing					
D ₁ - 25 th SMW	43.1	709.8	3654.2	4364.0	16.9
D ₂ - 26 th SMW	33.8	574.3	3293.7	3868.0	14.8
D ₃ - 27 th SMW	31.2	530.1	3159.7	3689.8	14.3
D ₄ - 28 th SMW	26.9	476.0	2897.3	3383.7	14.3
S.E.m±	1.1	15.2	76.3	85.8	0.4
C.D. @ 5%	3.7	52.6	264.2	296.9	1.5
Hybrids					
V ₁ - AJEET 155	38.5	641.2	3386.3	4027.4	16.0
V ₂ - Ankur	33.9	575.3	3250.2	3825.5	15.0
V ₃ - Mallika	28.9	501.2	3117.3	3626.2	14.1
S.E.m±	0.7	13.2	57.0	66.2	0.4
C.D. @ 5%	2.2	39.6	171.0	198.4	1.4
Interaction (D × V)					
S.E.m±	1.4	26.4	114.0	132.4	1.0
C.D. @ 5%	NS	NS	NS	NS	NS
G.M.	33.8	572.6	3251.2	3823.8	15.1

Postharvest studies

These studies had collected after harvest picking of bolls of the crop to record the data which is relevant to yield attributing features like seed cotton yield (gm plant⁻¹), seed cotton yield (kg ha⁻¹), stalk yield (kg ha⁻¹), biological yield (kg ha⁻¹), and harvest index (per cent). This data was shown in Table 7.

Seed cotton yield plant⁻¹ (gm plant⁻¹)

The seed cotton yield recorded in gram per plant was presented in Table-7.

Effect of sowing dates : There is significant effects between different sowing dates and seed cotton yield in gram per plant, D₁ has recorded significantly higher seed cotton yield (gm plant⁻¹) was 43.1 gm plant⁻¹, over rest of

all sowing dates. Huang (2016) reported that the earlier sowing date produced higher yield and biomass because more heat resources were obtained for the earlier sowing date to prompt growth.

Effect of hybrids : Different hybrids have a significant impact on seed cotton yield (gm plant^{-1}), with V_1 (Ajeet-155) has recorded significantly higher seed cotton yield (gm plant^{-1}) which was 38.5 gm, over rest of all hybrids.

Interaction : The interaction between different planting dates and hybrids found non-significant effect on seed cotton yield in gram per plant.

Seed cotton yield (kg ha^{-1})

Effect of sowing dates : Among different sowing dates, seed cotton yield in kg plant^{-1} had statistically significant effect between them, where the D_1 (25 MW) has found significantly higher seed cotton yield (kg ha^{-1}) which was 709.8 kg ha^{-1} , over rest of all sowing dates. Falling of flower buds and young bolls or impair pollination by insect was due to heavy rainfall during flowering and boll opening, therefore yield was low as compare to normal season. Strong winds may also reduce the yield due to boll shedding (Cetin and Basbag, 2010). Decrease in yield had been mainly due to significant decrease in yield per plant, boll weight, and number of bolls harvested plant^{-1} and growth parameters (Hallikeri et al. 2009). Bozбек et al. (2006) found that when the plant has less boll retention, dry matter accumulations between flowering-boll retention had adverse effect on seed cotton yield. However, both number of bolls and boll weight plant^{-1} contributed for the yield reduction (Hebbar et al. 2002). Hallikeri et al. (2009) discussed the same finding that early sown crop produced significantly higher yield than late sowing. However, the yield attributing characters like Plant height, number of leaves, number of branches, and number of bolls that was higher in early sown crop resulted in higher seed cotton yield.

The yield in the previous years was greater than yield in the year 2021 on the same location, this might be due to the fact that the crop growth phenophase like the squaring and flowering stage does not meet its appropriate temperature requirement of 21–27 °C for vegetative growth and 27–32 °C during fruiting period (Waghmare and Singh, 2017). The average temperature of *Kharif* 2021 for vegetative stages of early sown cotton crop was 27.4°C and late sown crop was 27.2 °C, respectively, whereas, that of fruiting period of early and late sown crop was 26.4 °C and 26.6 °C, respectively, which shows that the temperature exceed the appropriate temperature requirement of the crop during vegetative growth but get reduced during fruiting period of the crop.

The average maximum temperature of early and late sown crop range was 31.1 °C and 32.3 °C, respectively, which shows that the data agreed with the results of Buttar, et al. (2012) who also reported that seed cotton yield decreases to half when temperature increase from 28 °C to 32 °C, especially, during sowing to flowering stage than the rest of phenol phases. Reddy et al. (1996) also reported that young bolls shed or drop with temperature rise to -32.2 °C. The result confirmed the findings of Cetin and Basbag (2010) that high temperature (30 °C) reduces boll retention and final yield.

This year, the number of days taken for the crop to develop from boll formation to boll bursting (P_6) was good moisture in the soil and long duration due to heavy rainfall. Liakatas et al. (1998) discussed that rain lengthened cotton developmental stages, particularly when falling between sowing and anthesis or boll opening and harvest. Cetin and Basbag, (2010) stated that Climatic factors such as temperature, wind, rainfall and relative humidity significantly affect the boll production of cotton. Reduction in the yield due to boll shedding caused due to strong winds. Similarly, continuous rain during flowering and boll opening will impair the pollination and may thus reduce fiber quality. However, increasing amount of rainfall in early growing period of cotton can result in higher yield. Fruiting of cotton plant is determined and influenced by climatic conditions, cultivars, management practices and pests. In addition, the water requirement of cotton depends on length of the total growing period and climate.

Another reason of the low seed cotton yield was due to the infestation of Pink bollworm (*Pectinophora gossypiella*) which is one of the most dangerous pest of cotton during the boll formation of the crop. However, due to the infestation of Pest, the 3rd picking of cotton was not done for D_1 , D_2 , D_3 and D_4 . Santosh et al. (2009) reported that *Bt*. cotton had 9.08 per cent mean green boll damage compared to 23.59 per cent for non-*Bt* cotton. Green boll damage had been recorded at 12.35 and 30.85 per cent in *Bt* and non-*Bt* cotton, respectively, during the peak boll growing period (up to December). During the peak boll development period, *Bt*. cotton showed a 61.50 per cent lowering in boll damage compared to non-*Bt*. cotton.

Effect of hybrids : Different hybrids had a significant effect on seed cotton yield (kg ha^{-1}) whereas among hybrid, V_1 (Ajeet-155) has recorded significantly higher seed cotton yield (kg ha^{-1}) which was of 641.2 kg ha^{-1} , over rest of all hybrids. Hebbar et al. (2002) also stated that delayed in sowing of hybrid Ajeet-155 significantly reduced the yield and yield attributing character due to low temperature during canopy development, surface area

development, squaring and flowering. Waghmare *et al.* (2016) reported the same finding.

Interaction : The interaction between different sowing dates and hybrids had no significant effect on seed cotton yield (kg ha^{-1}).

Stalk yield (kg ha^{-1})

Effect of sowing dates : The differing sowing dates had a substantial impact on the amount of stalk produced. The early-sown crop, D₁ (25th SMW), has recorded significantly higher stalk yield, which was $3654.2 \text{ kg ha}^{-1}$, over rest of all sowing dates. The similar result was reported by Waghmare *et al.* (2016).

Effect of hybrids : Differences in hybrids have a considerable impact on stalk yield (kg ha^{-1}), with V₁ (Ajeet-155) has found significantly higher stalk yield (kg ha^{-1}), which was $3386.3 \text{ kg ha}^{-1}$, except V₂.

Interaction : There is no significant interaction effect between different sowing dates and hybrids on stalk yield of cotton kg ha^{-1} .

Biological yield (kg ha^{-1})

Effect of sowing dates : The early sowing date, D₁ (25th SMW), has recorded significantly higher biological yield of $4364.0 \text{ kg ha}^{-1}$, over rest of all sowing dates. The similar results were reported by Waghmare *et al.* (2016), who found that the 25th SMW sowing produced the highest seed cotton yield ($907.62 \text{ kg ha}^{-1}$) compared to the 27th SMW sowing ($677.36 \text{ kg ha}^{-1}$) which was comparable to earlier sowing in terms of all yield attributing characters.

Effect of hybrids : The biological yield kg ha^{-1} of the cotton varies significantly between three *Bt* cotton hybrids with V₁ has recorded significantly higher biological yield which was $4027.4 \text{ kg ha}^{-1}$ over rest of all hybrids.

Interaction : Different sowing dates and *Bt* cotton hybrids did not significantly affect the biological yield.

Harvest index (per cent)

Effect of sowing dates : Different sowing dates have a significant impact on the harvest index of a crop. D₁ (25 MW) has found significantly higher harvest index of 16.9%, over rest of all sowing dates. The same finding was reported by Waghmare *et al.* (2016), Dakhore and Kadam (2018).

Effect of hybrids : The harvest index of the crop varies significantly between the three *Bt* Cotton hybrids, with V₁ (Ajeet-155) has significantly higher harvest index which was 16.0%, highest over rest of all hybrids. The similar finding was reported by Dakhore and Kadam (2018).

Interaction : Different sowing dates and *Bt* cotton hybrids had no discernible influence on the harvest index.

Conclusions

Various growth characteristics, including plant height, number of leaves per plant, branches per plant, bolls per plant, and dry matter per plant, were significantly affected by different sowing dates and hybrid variations throughout the crop stages. The only exception was the plant height at 30 days after sowing (DAS), which showed no significant influence from hybrids. Notably, Ajeet-155, a cotton variety (V₁) planted on the earliest sowing date (D₁: 25 MW), demonstrated superiority over other hybrids in all growth parameters, except for plant height, where it recorded the highest values.

The interaction of different sowing dates and hybrids was non-significant.

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Analysing the Impact of Weather Parameters on Growth of *Bt*. Cotton Hybrid

Ankush B. Chougule¹, Suresh P. Kausalye², Sujeet S. Deshmukh^{3*}, Priyanka K. Patil¹ and Shantanu S. Dhawase¹

¹Department of Agricultural Meteorology, CoA, V.N.M.K.V. Parbhani

²Department of Agronomy, CoA, V.N.M.K.V. Parbhani

³Department of Agricultural Meteorology, CoA, Pune. M.P.K.V. Rahuri

*Corresponding Author Email : sujeetdeshmukh99@gmail.com

Abstract

A study was conducted during the Kharif season of 2021-22 to investigate the influence of weather parameters on the growth of *Bt*. cotton hybrid. The research trial took place at the experimental farm of the Department of Agricultural Meteorology, AICRP on Agrometeorology, College of Agriculture, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani. This study was carried out in a Split plot design with three replications and 12 treatments, i.e., four sowing dates: D₁ (25 MW), D₂ (26 MW), D₃ (27 MW), and D₄ (28 MW), as well as three *Bt*. cotton Varieties: V₁ (Ajeet-155), V₂ (Ankur), and V₃ (Mallika) with spacing of 120 cm x 45 cm. The total number of Plot was 36 with the net plot of about 5.4 x 2.4 m² and the gross plot was 7.2 x 3.6 m². Cotton seeds were sown using the dibbling method. Because a crop's water requirement fluctuates depending on its stage of development, the weather variables affect the crop at various phases of development and throughout its life cycle. In the context of *Bt*. cotton hybrids, the relationship between crop and weather parameters reveals certain patterns. Rainfall demonstrated a favorable connection with seed cotton yield during the P₂, P₆, and P₇ stages but exhibited a negative correlation at the P₃ stage across all *Bt*. cotton hybrids. Maximum temperature exhibited a positive correlation with seed cotton yield at the P₁, P₂, P₄, P₇, and P₈ stages, while the lowest temperature showed a favorable correlation at the P₂, P₆, and P₇ stages. Relative humidity (RH-I) displayed positive correlations at the P₅, P₆, and P₇ stages but negative correlations at P₃, P₄, P₅, and P₈ stages. RH-II showed positive correlations at the P₅, P₆, and P₇ stages but negative correlations at P₁, P₄, and P₅ stages. Evaporation (EVP) was positively correlated at P₁, P₂, P₄, and P₈ stages but negatively correlated at P₅, P₆, and P₇ stages. Biomass (BSS) exhibited positive correlations at the P₂, P₄, P₇, and P₈ stages but negative correlations at P₃, P₅, and P₆ stages. Wind velocity demonstrated a favorable correlation at the P₁, P₄, P₆, and P₈ stages but exhibited a negative correlation at the P₂ and P₇ stages.

Key words : *Bt* cotton, correlation studies, weather parameters, seed cotton yield.

Introduction

Cotton (*Gossypium* spp.), often referred to as the "White Gold," stands out as a premier fiber globally, playing a pivotal role in the economic, political, and social landscape. Cottonseed cake, derived from cotton seeds, serves as a significant by-product, serving dual purposes as a crucial livestock feed and a valuable fertilizer. Renowned for its organic composition, the cottonseed cake provides essential nutrients such as nitrogen, phosphorus, potash, and various minor elements vital for plant nutrition.

During the 2020-21 period, cotton cultivation in India covered an extensive 13.01 million hectares, yielding a production of 35.38 million bales (each weighing 170 kg) with a productivity rate of 462 kg ha⁻¹, as reported by the Directorate of Economics & Statistics, DA&FW. The primary cotton-producing states in India include Maharashtra, Gujarat, Telangana, Rajasthan, Karnataka, Haryana, Madhya Pradesh, and Andhra Pradesh, with Maharashtra having the largest cultivation area. Specifically, Maharashtra contributed 4.29 million

hectares to the overall cotton cultivation, resulting in a production of 9.59 million bales, each weighing 170 kg, and achieving a productivity rate of 380 kg ha⁻¹ during the same period. Within Maharashtra, the Vidarbha region played a significant role, contributing 30% to the overall cotton crop. Marathwada, a region in Maharashtra, covered 16.88 lakh hectares, producing 35.26 lakh bales, and achieving a productivity of 359 kg lint ha⁻¹ in 2020-21. The state of Maharashtra, as a whole, produced approximately 95.575 lakh tonnes (with each bale weighing 170 kg) across a maximum cultivation area of 42.86 lakh hectares, boasting a productivity rate of 379.9 kg ha⁻¹, according to Anonymous (2020).

Cotton, as a rule, is not well-suited for extensive irrigation, necessitating careful irrigation scheduling due to the scarcity and high cost of water. Excessive watering not only poses financial and resource challenges but also promotes excessive vegetative growth, hindering the reproductive phase. Overgrown cotton is more susceptible to pests and diseases, limiting air circulation and sunlight exposure, ultimately leading to decreased reproductive growth and lower yields. Varying irrigation at

different moisture levels creates distinct soil moisture conditions at different crop stages. Global studies indicate that transgenic cotton and maize under stress conditions exhibit reduced cry protein levels, providing insights into the impact of diverse moisture regimes on cry protein levels and pest responses. Given the distinct growth habits and durations of Bt-cotton compared to non-Bt cotton, the existing irrigation schedules may prove inadequate, highlighting the need for a revised irrigation plan.

Materials and Methods

The experiment was carried out at the farm of AIRCPAM, Department of Agricultural Meteorology, College of Agriculture, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani, during the *Kharif* season 2021–22 on the experimental farm, Parbhani, which extends from 19° 16' N Latitude and 76° 47' E Longitude and from sea level to as high as 409 m elevation. This region is dominated by hot and dry summer, wet humidity with mild precipitation during monsoon season and cold winter. The experimental field topography was homogeneous and well-leveled. The weather data for the appropriate time of the experiment was recorded at Central Meteorological Observatory, AIRCPAM, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani.

The area of experiment was set out in the split plot design with three variation of replication and 12 treatment combination consisting of four sowing dates D₁: 25 MW, D₂: 26 MW, D₃: 27 MW, D₄: 28 MW and three distinct *Bt* cotton hybrid. (V₁: Ajeet 155, V₂: Ankur, V₃: Mallika) with gross plot size 7.2m*3.6m and net plot size 5.4m*2.4m.

Correlation studies : To determine the relationship between the weather parameter and seed cotton yield, a simple correlation was determined using weather parameter, i.e., rainfall, rainy days, maximum temperature, minimum temperature, morning humidity and evening humidity, evaporation, bright sunshine hours and wind speed, on cotton growth and development at different phenophase and the seed cotton yield of *Bt* cotton hybrid are worked out.

The procedure and formula described by Snedecor and Cochran (1968) were used and significance was tested.

$$r = \frac{KF}{\sqrt{(K)(F)}}$$

where,

r = Correlation coefficient

X = Independent (attributes)

Y = Dependent variable (Yield)

Seed cotton yield (gm plant⁻¹) : This particular seed cotton yield was calculated by taking the average of the weight of cotton bolls of five represented plant at each picking and the overall weight after picking was the final seed cotton yield expressed in gram per hectare.

Seed cotton yield (Kg ha⁻¹) : In this case, the seed cotton yield was calculated by measuring the weight of the cotton bolls after picking from each net plot including that of five represented plant and expressed in kilogram per hectare.

Stalk yield (Kg ha⁻¹) : The stalk yield was calculated by measuring the weight of dried stalk at harvest from each net plot that has already been uprooted and sun dried for four weeks. The weight of dried stalk of each net plot was measured in kilogram which was converted into hectare basis.

Biological yield (Kg ha⁻¹) : The combination of yield attributes of seed cotton yield and cotton stalk yield were used to determine the overall biological yield of cotton.

Harvest index (%) : The ratio of seed cotton yield and the biological yield was calculated at harvest time and express in percentage to obtain the harvest index of the plant.

Results and Discussion

In this chapter, the data obtained during the experiment was evaluated using suitable statistical techniques, and the findings are presented under the heading below

Number of days required to 1st flowering

Effect of sowing dates : The time took to flower for the first time varied between 51 and 64 days in case sowing dates, as shown in Table 1. The D₄ has found significantly higher number of days required for first flowering which was 64 days, sowing dates except D₃.

Effect of hybrids : The number of days required for the first flowering ranges between 56 to 59 as gave in Table 1. It is found that V₁ (Ajeet-155) has found significantly higher number of days required for first flowering which was 59 days, than the other hybrids.

Interaction : The interaction of different date of sowing and hybrids was found non-significant effect on the mean number of days required for first flowering.

Number of days required to 1st boll formation

The impact had various treatments to number of days required for the initial boll formation in a cotton crop are presented as shown in Table 1.

Effect of sowing dates : There were statistically significant effects between different date of sowing on number of days required for first boll formation where the both D₃ and D₄ has recorded significantly highest number

Table-1 : Days required to 1st flowering and days required to 1st boll formation.

Treatments	Days required for 1 st Flowering	Days required for 1 st Boll formation
Date of Sowing		
D ₁ - 25 th SMW	51	67
D ₂ - 26 th SMW	54	70
D ₃ - 27 th SMW	63	79
D ₄ - 28 th SMW	64	79
S.E.m±	0.66	0.27
C.D. @ 5%	2.30	0.96
Hybrid		
V ₁ - AJEET 155	59	75
V ₂ - Ankur	58	74
V ₃ - Mallika	56	72
S.E.m±	0.57	0.24
C.D. @ 5%	1.73	0.72
Interaction (D × V)		
S.E.m±	1.15	0.48
C.D. @ 5%	NS	NS
G.M.	58	73

Table-2 : Seed cotton yield (gm plant⁻¹), Seed cotton yield (kg ha⁻¹), Stalk yield (kg ha⁻¹), Biological yield, (kg ha⁻¹) Harvest index (%) of Cotton as influenced by different treatments.

Treatments	Seed cotton yield (gm plant ⁻¹)	Seed cotton yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Biological Yield (kg ha ⁻¹)	Harvest Index (%)
Date of Sowing					
D ₁ - 25 th SMW	43.1	709.8	3654.2	4364.0	16.9
D ₂ - 26 th SMW	33.8	574.3	3293.7	3868.0	14.8
D ₃ - 27 th SMW	31.2	530.1	3159.7	3689.8	14.3
D ₄ - 28 th SMW	26.9	476.0	2897.3	3383.7	14.3
S.E.m±	1.1	15.2	76.3	85.8	0.4
C.D. @ 5%	3.7	52.6	264.2	296.9	1.5
Hybrids					
V ₁ - AJEET 155	38.5	641.2	3386.3	4027.4	16.0
V ₂ - Ankur	33.9	575.3	3250.2	3825.5	15.0
V ₃ - Mallika	28.9	501.2	3117.3	3626.2	14.1
S.E.m±	0.7	13.2	57.0	66.2	0.4
C.D. @ 5%	2.2	39.6	171.0	198.4	1.4
Interaction (D × V)					
S.E.m±	1.4	26.4	114.0	132.4	1.0
C.D. @ 5%	NS	NS	NS	NS	NS
G.M.	33.8	572.6	3251.2	3823.8	15.1

of days to boll formation which was 79 days, over rest D₁ and D₂ sowing dates.

Effect of hybrids : There was a statistically significant effect between hybrids on highest number of days required for first boll formation where V₁ has found significantly higher days which was 75 days, over rest of all hybrids.

Interaction : The interaction between different sowing dates and hybrids found non- significant effect on the number of days required for boll formation.

Postharvest studies

These studies had collected after harvest picking of bolls of the crop to record the data which is relevant to yield attributing features like seed cotton yield (gm plant⁻¹), seed cotton yield (kg ha⁻¹), stalk yield (kg ha⁻¹), biological yield (kg ha⁻¹), and harvest index (per cent). This data was shown in Table-2.

Seed cotton yield plant⁻¹ (gm plant⁻¹)

The seed cotton yield recorded in gram per plant was presented in Table-2.

Table-3 : Correlation between Seed cotton yield and weather parameters of different phenophases of V₁ (AJEET 155).

Weather Parameter	Phenophase of V ₁ Cotton (AJEET 155)							
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈
Rainfall (mm)	-0.327	0.502*	-0.603*	-0.808**	-0.109	0.735**	0.884**	-0.829**
Tmax (°C)	0.937**	0.664*	0.397	0.883**	-0.725**	-0.909**	0.978**	0.736**
Tmin (°C)	-0.938**	0.504	-0.127	-0.754**	-0.173	0.756**	0.752**	0.381
RH I (%)	-0.512	-0.257	-0.577**	-0.900**	0.599*	0.570*	0.932**	-0.961**
RH II (%)	-0.776**	-0.305	-0.443	-0.865**	0.591*	0.830**	0.588*	-0.103
EVP (mm)	0.831**	0.595*	0.417	0.781**	-0.868**	-0.779**	-0.324	0.960**
BSS (hrs)	0.520	0.198	0.123	0.432	-0.938**	-0.869**	0.617*	0.918**
WS (Kmph)	0.636*	-0.436	0.558	0.920**	0.267	0.938**	-0.884**	0.554

* Significant at 5 percent (0.567)

** significant at 1 percent (0.708)

P₁-Sowing to Emergence,P₂

- Emergence to Seedling stage

P₃-Seedling stage to Square FormationP₄

- Square Formation to Flowering

P₅-Flowering to Boll FormationP₆

- Boll formation to Boll Bursting

P₇-Boll Bursting to Ist PickingP₈- Ist Picking to IInd PickingTable-4 : Correlation between Seed cotton yield and weather parameters of different phenophases of V₂ (ANKUR).

Weather Parameter	Phenophase of V ₂ Cotton (ANKUR)							
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈
Rainfall (mm)	-0.414	0.629*	-0.630*	-0.870**	-0.346	0.919**	0.982**	-0.965**
Tmax (°C)	0.992**	0.765**	0.252	0.982**	-0.518	-0.982**	0.973**	0.919**
Tmin (°C)	-0.878**	0.765**	-0.452	-0.699*	0.154	0.857**	0.551	0.613*
RH I (%)	-0.770**	-0.197	-0.500	-0.962**	0.314	0.707*	0.917**	-0.836**
RH II (%)	-0.934**	-0.274	-0.286	-0.978**	0.329	0.944**	0.335	0.214
EVP (mm)	0.876**	0.694*	0.234	0.855**	-0.653*	-0.922**	-0.112	0.959**
BSS (hrs)	0.357	0.494	-0.131	0.618*	-0.767**	-0.970**	0.813**	0.997**
WS (Kmph)	0.853**	-0.694*	0.774**	0.941**	-0.072	1.000**	-0.990**	0.795**

* Significant at 5 percent (0.567)

** significant at 1 percent (0.708)

P₁-Sowing to Emergence,P₂

- Emergence to Seedling stage

P₃-Seedling stage to Square FormationP₄

- Square Formation to Flowering

P₅-Flowering to Boll FormationP₆

- Boll formation to Boll Bursting

P₇-Boll Bursting to Ist PickingP₈- Ist Picking to IInd Picking

Effect of sowing dates : There is significant effects between different sowing dates and seed cotton yield in gram per plant, D₁ has recorded significantly higher seed cotton yield (gm plant⁻¹) was 43.1 gm plant⁻¹, over rest of all sowing dates. Huang (2016) reported that the earlier sowing date produced higher yield and biomass because more heat resources were obtained for the earlier sowing date to prompt growth.

Effect of hybrids : Different hybrids have a significant impact on seed cotton yield (gm plant⁻¹), with V₁ (Ajeet-155) has recorded significantly higher seed cotton yield (gm plant⁻¹) which was 38.5 gm, over rest of all hybrids.

Interaction : The interaction between different planting dates and hybrids found non-significant effect on seed cotton yield in gram per plant.

Seed cotton yield (kg ha⁻¹)

Effect of sowing dates : Among different sowing dates, seed cotton yield in kg plant⁻¹ had statistically significant effect between them, where the D₁ (25th SMW) has found significantly higher seed cotton yield (kg ha⁻¹) which was 709.8 kg ha⁻¹, over rest of all sowing dates. Falling of flower buds and young bolls or impair pollination by insect was due to heavy rainfall during flowering and boll opening, therefore yield was low as compare to normal

Table-5 : Correlation between Seed cotton yield and weather parameters of different phenophase of V₃ (Mallika).

Weather Parameter	Phenophase of V ₃ Cotton (Mallika)							
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈
Rainfall (mm)	-0.355	0.558	-0.482	-0.905**	-0.664*	0.644*	0.965**	-0.849**
Tmax (°C)	0.989**	0.847**	0.210	0.908**	0.418	-0.951**	0.974**	0.830**
Tmin (°C)	-0.900**	0.702*	-0.919**	-0.994**	0.724**	0.800**	0.793**	0.076
RH I (%)	-0.680*	-0.535	-0.343	-0.930**	-0.804**	0.498	0.972**	-0.953**
RH II (%)	-0.893**	-0.644*	-0.118	-0.892**	-0.642*	0.892**	0.694*	-0.391
EVP (mm)	0.888**	0.843**	-0.277	0.820**	0.561	-0.936**	-0.804**	0.906**
BSS (hrs)	0.397	0.691*	-0.772**	-0.104	0.290	-0.964**	0.710**	0.976**
WS (Kmph)	0.788**	-0.538	0.831**	0.991**	0.346	0.936**	-0.947**	0.101

* Significant at 5 percent (0.567)

** significant at 1 percent (0.708)

P₁-Sowing to Emergence,P₂

- Emergence to Seedling stage

P₃-Seedling stage to Square FormationP₄

- Square Formation to Flowering

P₅-Flowering to Boll FormationP₆

- Boll formation to Boll Bursting

P₇-Boll Bursting to Ist PickingP₈- Ist Picking to IInd Picking

season. Strong winds may also reduce the yield due to boll shedding (Cetin and Basbag, 2010). Decrease in yield had been mainly due to significant decrease in yield per plant, boll weight, and number of bolls harvested plant⁻¹ and growth parameters (Hallikeri *et al.* 2009). Bozbek *et al.* (2006) found that when the plant has less boll retention, dry matter accumulations between flowering-boll retention had adverse effect on seed cotton yield. However, both number of bolls and boll weight plant⁻¹ contributed for the yield reduction (Hebbar *et al.* 2002). Hallikeri *et al.* (2009) discussed the same finding that early sown crop produced significantly higher yield than late sowing. However, the yield attributing characters like Plant height, number of leaves, number of branches, and number of bolls that was higher in early sown crop resulted in higher seed cotton yield.

The yield in the previous years was greater than yield in the year 2021 on the same location, this might be due to the fact that the crop growth phenophase like the squaring and flowering stage does not meet its appropriate temperature requirement of 21–27 °C for vegetative growth and 27–32 °C during fruiting period (Waghmare and Singh, 2017). The average temperature of *Kharif* 2021 for vegetative stages of early sown cotton crop was 27.4°C and late sown crop was 27.2 °C, respectively, whereas, that of fruiting period of early and late sown crop was 26.4 °C and 26.6 °C, respectively, which shows that the temperature exceed the appropriate. Temperature requirement of the crop during vegetative growth but get reduced during fruiting period of the crop.

The average maximum temperature of early and late sown crop range was 31.1 °C and 32.3 °C, respectively, which shows that the data agreed with the results of Buttar, *et al.* (2012) who also reported that seed cotton yield decreases to half when temperature increase from 28 °C to 32 °C, especially, during sowing to flowering stage than the rest of phenol phases. Reddy *et al.* (1996) also reported that young bolls shed or drop with temperature rise to -32.2 °C. The result confirmed the findings of Cetin and Basbag (2010) that high temperature (30 °C) reduces boll retention and final yield.

Effect of hybrids : Different hybrids had a significant effect on seed cotton yield (kg ha⁻¹) whereas among hybrid, V₁ (Ajeet-155) has recorded significantly higher seed cotton yield (kg ha⁻¹) which was of 641.2 kg ha⁻¹, over rest of all hybrids. Hebbar *et al.* (2002) also stated that delayed in sowing of hybrid Ajeet-155 significantly reduced the yield and yield attributing character due to low temperature during canopy development, surface area development, squaring and flowering. Waghmare *et al.* (2016) reported the same finding.

Interaction : The interaction between different sowing dates and hybrids had no significant effect on seed cotton yield (kg ha⁻¹).

Stalk yield (kg ha⁻¹)

The stalk yield of the crop was recorded and presented in Table-2.

Effect of sowing dates : The differing sowing dates had a substantial impact on the amount of stalk produced. The early-sown crop, D₁ (25th SMW), has recorded

significantly higher stalk yield, which was 3654.2 kg ha⁻¹, over rest of all sowing dates. The similar result was reported by Waghmare *et al.* (2016).

Effect of hybrids : Differences in hybrids have a considerable impact on stalk yield (kg ha⁻¹), with V₁ (Ajeet-155) has found significantly higher stalk yield (kg ha⁻¹), which was 3386.3 kg ha⁻¹, except V₂.

Interaction : There is no significant interaction effect between different sowing dates and hybrids on stalk yield of cotton kg ha⁻¹.

Biological yield (kg ha⁻¹)

The seed yield of cotton (kg ha⁻¹) and stalk yield of cotton (kg ha⁻¹), which are shown in Table 2 were used to calculate the biological yield of the crop.

Effect of sowing dates : The early sowing date, D₁ (25th SMW), has recorded significantly higher biological yield of 4364.0 kg ha⁻¹, over rest of all sowing dates. The similar results were reported by Waghmare *et al.* (2016), who found that the 25th SMW sowing produced the highest seed cotton yield (907.62 kg ha⁻¹) compared to the 27th SMW sowing (677.36 kg ha⁻¹) which was comparable to earlier sowing in terms of all yield attributing characters.

Effect of hybrids : The biological yield Kg ha⁻¹ of the cotton varies significantly between three *Bt* cotton hybrids with V₁ has recorded significantly higher biological yield which was 4027.4 kg ha⁻¹ over rest of all hybrids.

Interaction : Different sowing dates and *Bt* cotton hybrids did not significantly affect the biological yield.

Harvest index (per cent)

This information, which is reported in Table 2 was computed using information on cotton seed yield and biological yield.

Effect of sowing dates : Different sowing dates have a significant impact on the harvest index of a crop. D₁ (25th SMW) has found significantly higher harvest index of 16.9%, over rest of all sowing dates. The same finding was reported by Waghmare *et al.* (2016), Dakhore and Kadam (2018).

Effect of hybrids : The harvest index of the crop varies significantly between the three *Bt* Cotton hybrids, with V₁ (Ajeet-155) has significantly higher harvest index which was 16.0%, highest over rest of all hybrids. The similar finding was reported by Dakhore and Kadam (2018).

Interaction : Different sowing dates and *Bt* cotton hybrids had no discernible influence on the harvest index.

Correlation studies between weather parameters and seed cotton yield

The correlation study was done to find the relationship

between two variables, *i.e.*, seed cotton yield of *Bt* cotton hybrid and Weather Parameter at different Phenological stage. It is presented in Table 3 and 4.

Hybrid (V₁) Ajeet-155 : According to data from Table 3, it was found that during sowing to emergence stage (P₁), maximum temperature, evaporation and wind speed was positively significance, whereas, minimum temperature and RH-II was negatively significance. During emergence to seedling stage (P₂), rainfall, maximum temperature and evaporation was positively significance, whereas, there was no any parameter negatively significance. During seedling to square formation (P₃), rainfall and RH-I was negatively significance, whereas there was no any parameter positively significance. During square formation to flowering stage (P₄), minimum temperature, RH-II, RH-I and rainfall were positively significance, whereas, maximum temperature, evaporation and wind speed was negatively significance.

Hybrid (V₂) Ankur : According to data from Table 4, it was found that during sowing to emergence stage (P₁), maximum temperature, evaporation and wind speed was positively significance, whereas, minimum temperature, RH-I and RH-II was negatively significance.

During emergence to seedling stage (P₂), rainfall, maximum temperature, minimum temperature and evaporation was positively significance, whereas, wind speed was negatively significance. During seedling to square formation (P₃), rainfall was negatively significance, whereas wind speed was positively significance. During square formation to flowering stage (P₄), minimum temperature, RH-II, RH-I and rainfall was negatively significance, whereas, maximum temperature, evaporation, bright sunshine hrs and wind speed was positively significance. During flowering to boll formation stage (P₅), evaporation and bright sunshine hrs was negatively significance. During boll formation to boll bursting (P₆), rainfall, minimum temperature, RH-I, RH-II and wind speed was positively significance, whereas, maximum temperature, evaporation and bright sunshine hrs was negatively significance. During boll bursting to 1st picking (P₇), rainfall, maximum temperature, RH-I and bright sunshine hrs was positively significance, whereas wind speed was negatively significance. During 1st picking to 2nd picking (P₈), maximum temperature, minimum temperature, RH-I, bright sunshine hrs and wind speed was positively significance, whereas, rainfall and RH-II was negatively significance.

Hybrid (V₃) Mallika : According to data from Table 5, it was found that throughout sowing to emergence stage (P₁), maximum temperature, EVP and wind speed was positively significant, whereas, minimum temperature, RH-I and RH-II was negatively significant. During the

emergence to seedling stage (P_2), maximum temperature, minimum temperature, EVP and bright sunshine hrs was positively significant, whereas, RH-I, RH-II and wind speed was negatively significant. Minimum temperature and BSS was negatively significant during seedling to square development (P_3), whereas, wind speed was positively significant. Only maximum temperature, EVP and wind speed was positively significant, whereas, rainfall, minimum temperature, RH-I, RH-II was negatively significant. During square formation to flowering stage (P_4). Only minimum temperature was positively significant whereas, rainfall, EVP, Bright sunshine hrs was negatively significant throughout the flowering to boll formation stage (P_5). During boll development to boll bursting (P_6), rainfall, minimum temperature, wind speed and RH-II was positively significant, whereas, maximum temperature, EVP and bright sunshine hrs negatively significant.

Conclusions

The number of days required for first flowering and boll formation was significantly affected by different sowing dates and hybrids where more number of days for first flowering was recorded in D_4 (28MW) and lesser in D_1 (25 MW) sowing date, whereas, in term of first Boll formation, more number of days required by D_3 (27 MW) and D_4 (28 MW) and lesser in D_1 (25 MW). Similarly, Ajeet-155 (V_1) took longer days to start flowering and develop bolls than NHH-44 (V_2) and Mallika (V_3). This year, the number of days taken for the crop to develop from boll formation to boll bursting (P_6) was long due to heavy rainfall and good moisture in the soil. The low yield is because of heavy rainfall and strong wind during flowering and boll opening that caused the flower buds and young bolls to fall or impair pollination by insect. Also, the reduction of average temperature during fruiting period and the infestation of Pink bollworm (*Pectinophora gossypiella*), thrips and whitefly limit the seed cotton yield.

D_1 (25 MW) had the highest seed cotton yield (43.1 gm plant⁻¹), seed cotton yield (709.8 kg ha⁻¹), stalk yield (3654.2 kg ha⁻¹), biological yield (4364 kg ha⁻¹) and harvest indexes (16.9 per cent) among all the sowing dates. Among the hybrids, Ajeet- 155 (V_1) produced the highest seed cotton yield (38.5 gm plant⁻¹), seed cotton yield (641.2 kg ha⁻¹), stalk yield (3386.3 kg ha⁻¹), biological yield (4027.4 kg ha⁻¹) and harvest index (16.0 per cent), whereas, Mallika (V_3) produced the lowest.

The rainfall was positively correlated with seed cotton yield at P_2 , P_6 and P_7 stages and negatively correlated at P_3 , P_4 and P_8 stages when all BG II hybrids were included, namely, Ajeet-155, Ankur and Mallika. At the P_1 , P_2 , P_4 , P_7 and P_8 stages, maximum temperature was positively affected with seed cotton yield, but lowest

temperature were positively correlated at the P_2 , P_5 , P_6 , P_7 and P_8 stages. At the P_5 , P_6 and P_7 stage, RH-I was positively correlated and negatively correlated in P_1 , P_3 , P_4 , P_5 and P_8 whereas, RH-II was positively correlated at P_5 , P_6 and P_7 and negatively correlated at P_1 , P_4 and P_5 stage. Evaporation was positively correlated at stage P_1 , P_2 , P_4 and P_8 , and negatively correlated in P_5 , P_6 and P_7 , whereas BSS was positively correlated at stage P_2 , P_4 , P_7 and P_8 but negatively correlated at stage P_3 , P_5 and P_6 . The wind speed was positively correlated at stage P_1 , P_3 , P_4 , P_6 and P_8 but negatively correlated at stage P_5 and P_7 .

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Impact of Different Planting Times on Thermal Heat Indices in *Bt.* Cotton Hybrid

Ankush B. Chougule¹, Sujeet S. Deshmukh^{2*}, Shantanu S. Dhawase¹, Priyanka K. Patil¹ and Sachin P. Jadhav¹

¹Department of Agricultural Meteorology, CoA, V.N.M.K.V. Parbhani

²Department of Agricultural Meteorology, CoA, Pune. M.P.K.V. Rahuri

*Corresponding Author Email : sujeetdeshmukh99@gmail.com

Abstract

The research trial was conducted during the *Kharif* season 2021-22 on the experimental farm of the Department of Agricultural Meteorology, AICRP on Agrometeorology, College of Agriculture, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani, to find out Impact of Different Planting Times on Thermal Heat Indices in *Bt.* Cotton Hybrid. This investigation employed a Split plot design with three replications and a total of 12 treatments. These treatments included four sowing dates (D1: 25 MW, D2: 26 MW, D3: 27 MW, and D4: 28 MW) and three *Bt.* cotton varieties (V1: Ajeet-155, V2: Ankur, and V3: Mallika) with a spacing of 120 cm x 45 cm. The study comprised 36 plots, each with a net area of approximately 5.4 x 2.4 m² and a gross area of 7.2 x 3.6 m². Cotton seeds were sown using the dibbling method. Given the dynamic water requirements of crops during various developmental stages and the impact of weather variables throughout their life cycle, this research is crucial for determining the Normalized Difference Vegetation Index (NDVI). The NDVI provides insights into the nature of crop growth stages, facilitating efficient irrigation scheduling and optimizing production and productivity in a given area.

The crop sown early, specifically on D1 (25 MW), exhibits the highest seed cotton yield, along with the tallest plant height, the greatest number of leaves per plant, branches per plant, and bolls per plant compared to other sowing dates. However, the seed cotton yield (Kg ha⁻¹) and various yield-contributing characteristics, including seed cotton yield (gm plant⁻¹), stalk yield (Kg ha⁻¹), biological yield (Kg ha⁻¹), and Harvest index (per cent), show a decline from D1 to D4. In this sequence, D1 (25 MW) is followed by D2 (26 MW), then D3 (27 MW), with D4 (28 MW) resulting in the lowest values. Among the different cultivars, Ajeet-155 demonstrates higher yields and superior yield-contributing characteristics compared to Ankur and Mallika, with Mallika recording the lowest values. The seed cotton yield decreases with delayed sowing dates beyond D1.

Key words : *Bt. cotton, Thermal Indices, Seed cotton yield, Growing degree days, Helio-thermal unit, Heat use efficiency, photo-thermal unit.*

Introduction

Cotton is one of the most important fiber and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. It provides the basic raw material (cotton fibre) to cotton textile industry. Cotton in India provides direct livelihood to 6 million farmers and about 40 -50 million people are employed in cotton trade and its processing. It belongs to the family 'Malvaceae', genus 'Gossypium' and native to tropical and sub-tropical region around the World. This genus has 50 species out of which only four are cultivated whereas the rest 46 species are wild crop. These 4 species include *Gossypium hirsutum*, *Gossypium barbadense*, *Gossypium herbaceum*, *Gossypium arboreum* (Anonymous, 2016).

In India cotton growing major states are Maharashtra, Gujarat, Telangana, Rajasthan, Karnataka, Haryana, Madhya Pradesh and Andhra Pradesh. Maharashtra has the largest area under cotton in the India. The area under cotton in Maharashtra was 4.29 million hectares with production 9.59 million bales each of 170 kg and productivity is 380

kg ha⁻¹ during 2020-21. In Maharashtra Vidharbha region contributes 30% of the crop. Marathwada is accounting of 16.88 lakh hectares area with a production of 35.26 lakh bales and productivity of 359 kg lint ha⁻¹ (Anonymous, 2012).

In Maharashtra, the production is about 95.575 lakh tonnes (170 Kg of each bale) having a maximum area under cultivation of 42.86 lakh hectares with a productivity of 379.9 kg ha⁻¹ (Anonymous, 2020c).

The growth, development and yield of the cotton crop are considerably affected by abiotic factors, *i.e.* air temperature, cloud cover, relative humidity, rainfall and radiation (Jadhav, 2014). The average optimum temperature requirements of cotton ranges between 25 to 35°C any fluctuation in this range may result into stunted growth of crop and finally lead to the reduction in yield (Waghmare *et al* 2016). At least 500 mm of water (rainfall/irrigation) is required to produce a cotton crop during the season in a constant and regular pattern (Doorenbos and Pruitt, 1984). The cotton is mostly grown on soils, which are black in colour and called as black cotton soil.

Materials and Methods

The experiment was carried out at the farm of AIRCPAM, Department of Agricultural Meteorology, College of Agriculture, Vasantrya Naik Marathwada Krishi Vidyapeeth, Parbhani, during the *Kharif* season 2021–22 on the experimental farm, Parbhani, which extends from 19° 16' N Latitude and 76° 47' E Longitude and from sea level to as high as 409 m elevation. This region is dominated by hot and dry summer, wet humidity with mild precipitation during monsoon season and cold winter. The experimental field topography was homogeneous and well-leveled. The weather data for the appropriate time of the experiment was recorded at Central Meteorological Observatory, AIRCPAM, Vasantrya Naik Marathwada Krishi Vidyapeeth, Parbhani.

The area of experiment was set out in the split plot design with three variation of replication and 12 treatment combination consisting of four sowing dates (D₁: 25th SMW (18-06-2021), D₂: 26th SMW (25-06-2021), D₃: 27th SMW (06-07-2021), D₄: 28th SMW (15-07-2021)) and three distinct *Bt.* cotton hybrid. (V₁ : Ajeet 155, V₂ : Ankur, V₃ : Mallika) with gross plot size 7.2m*3.6m and net plot size 5.4m*2.4m.

Computation of Thermal Indices

Growing Degree Days (GDD) : Growing Degree Days (GDD) or heat unit are commonly used in agriculture to estimate precisely the dates of phenological stages, crop maturity and measuring the interval between phenological stages. It can also be used to predict a crop's final yield at an early stage. Since the work on the heat-unit requirements of *Bt.* cotton is minimal, the analysis is being done in the same way as other crops.

GDD was computed by summing the daily mean temperature above base temperature (either 15.5 °C or 60 °C) and expressed in °C day. It was calculated using following formula. (Freeland *et al.* 2011).

$$GDD = \sum_{a}^{b} (T_{max} + T_{min}) / 2 - T_b$$

Where,

a = Date of starting of a phenophase, b = Date of end of the phenophase

T_{max} = Daily maximum temperature (°C)

T_{min} = Daily minimum temperature (°C)

T_b = Minimum threshold/ base temperature.

Helio-thermal units (HTU) : Helio-thermal units (HTU) for a day was calculated by multiplying GDD by the number of bright sunshine hours for that day and are expressed in °C days hours. The amount of HTU for a particular phenophase of interest was calculated using the following formula :

Where,

BSS = Bright Sunshine hours

Photo-thermal units (PTU) : One of the main factors that determine the duration of vegetative growth in the photosensitive crop is the length of day and night. PTU for a day was calculated by multiplying GDD by the maximum possible sunshine hours and are expressed in °C days hours. It was calculated using the following formula :

$$PTU (°C \text{ day hours}) = GDD \times N$$

Where,

N = Maximum possible sunshine hours or day length

Heat Use Efficiency (HUE) : Heat Use Efficiency represents the amount of seed cotton yield produced per unit of Growing Degree Days (GDD). It indicates the efficiency of crop to utilize the available heat energy. It is also represented by thermal time used efficiency (TTUE). It was calculated by using the following formula :

$$HUE = \frac{\text{seed cotton yield (kg / ha)}}{GDD}$$

Where,

GDD = cumulative Growing Degree Days.

Results and Discussion

In this chapter, the data obtained during the experiment was evaluated using suitable statistical techniques, and the findings are presented under the heading below.

Postharvest studies

These studies had collected after harvest picking of bolls of the crop to record the data which is relevant to yield attributing features like seed cotton yield (gm plant⁻¹), seed cotton yield (kg ha⁻¹), stalk yield (kg ha⁻¹), biological yield (kg ha⁻¹), and harvest index (per cent). This data was shown in Table-3.1.

Seed cotton yield plant⁻¹ (gm plant⁻¹)

The seed cotton yield recorded in gram per plant was presented in Table-3.1.

Effect of sowing dates : There were significant effects between different sowing dates and seed cotton yield in gram per plant, D₁ has recorded significantly higher seed cotton yield (gm plant⁻¹) which was 43.1 gm plant⁻¹, over rest of all sowing dates. Huang (2016) reported that the earlier sowing date produced higher yield and biomass because more heat resources were obtained for the earlier sowing date to prompt growth.

Effect of hybrids : Different hybrids have a significant impact on seed cotton yield (gm plant⁻¹), with V₁ (Ajeet-155) has recorded significantly higher seed cotton

Table-1 : Seed cotton yield (gm plant⁻¹), Seed cotton yield (kg ha⁻¹), Stalk yield (kg ha⁻¹), Biological yield, (kg ha⁻¹) Harvest index (%) of Cotton as influenced by different treatments.

Treatments	Seed cotton yield (gm plant ⁻¹)	Seed cotton yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Biological Yield (kg ha ⁻¹)	Harvest Index (%)
Date of Sowing					
D ₁ – 25 MW	43.1	709.8	3654.2	4364.0	16.9
D ₂ – 26 MW	33.8	574.3	3293.7	3868.0	14.8
D ₃ – 27 MW	31.2	530.1	3159.7	3689.8	14.3
D ₄ – 28 MW	26.9	476.0	2897.3	3383.7	14.3
S.E.m±	1.1	15.2	76.3	85.8	0.4
C.D. @ 5%	3.7	52.6	264.2	296.9	1.5
Hybrids					
V ₁ - AJEET 155	38.5	641.2	3386.3	4027.4	16.0
V ₂ - Ankur	33.9	575.3	3250.2	3825.5	15.0
V ₃ – Mallika	28.9	501.2	3117.3	3626.2	14.1
S.E.m±	0.7	13.2	57.0	66.2	0.4
C.D. @ 5%	2.2	39.6	171.0	198.4	1.4
Interaction (D × V)					
S.E.m±	1.4	26.4	114.0	132.4	1.0
C.D. @ 5%	NS	NS	NS	NS	NS
G.M.	33.8	572.6	3251.2	3823.8	15.1

Table-2 : Phenophase wise GDD required for different sowing dates of cotton during Kharif season 2021.

Date of Sowing	Phenophases								TOTAL	MEAN
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈		
D ₁ (25 th SMW)	121.4	613.5	302.7	437.8	249.3	1065.4	777.0	708.4	4275.3	534.4
D ₂ (26 th SMW)	121.9	555.4	440.6	441.3	976.7	357.4	675.3	481.7	4050.3	506.3
D ₃ (27 th SMW)	116.6	609.9	310.8	707.0	791.7	252.5	674.7	566.3	4029.5	503.7
D ₄ (28 th SMW)	118.9	621.1	304.5	406.7	221.0	405.8	1427.4	474.6	3979.9	497.5
MEAN	119.7	600.0	339.7	498.2	559.7	520.3	888.6	557.7	4083.8	510.5
P ₁	- Sowing to Emergence			P ₂	- Emergence to Seedling stage					
P ₃	- Seedling stage to Square Formation			P ₄	- Square Formation to Flowering					
P ₅	- Flowering to Boll Formation			P ₆	- Boll formation to Boll Bursting					
P ₇	- Boll Bursting to I st Picking			P ₈	- I st Picking to II nd Picking					

yield (gm plant⁻¹) which was 38.5 gm, over rest of all hybrids.

Interaction : The interaction between different planting dates and hybrids found non-significant effect on seed cotton yield in gram per plant.

Seed cotton yield (kg ha⁻¹)

Table-1, which is, presents the seed cotton yield measured in kg ha⁻¹.

Effect of sowing dates : Among different sowing dates, seed cotton yield in kg plant⁻¹ had statistically significant

effect between them, where the D₁ (25th SMW) has found significantly higher seed cotton yield (kg ha⁻¹) which was 709.8 kg ha⁻¹, over rest of all sowing dates. Falling of flower buds and young bolls or impair pollination by insect was due to heavy rainfall during flowering and boll opening, therefore yield was low as compare to normal season. Strong winds may also reduce the yield due to boll shedding (Cetin and Basbag, 2010). Decrease in yield had been mainly due to significant decrease in yield per plant, boll weight, and number of bolls harvested plant⁻¹ and growth parameters (Hallikeri *et al.* 2009). Bozbek *et al.* (2006) found that when the plant has less boll retention,

Table-3 : Phenophase wise Helio Thermal Unit required for different sowing dates of cotton during *Kharif* season 2021.

Date of Sowing	Phenophases								TOTAL	MEAN
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈		
D ₁ (25 th SMW)	756.7	3824.0	1886.9	2728.8	1553.8	6641.0	4843.3	4415.4	26649.9	3331.2
D ₂ (26 th SMW)	760.0	3461.8	2746.4	2751.0	6087.8	2227.8	4209.4	3002.6	25246.8	3155.8
D ₃ (27 th SMW)	726.8	3801.5	1937.2	4407.2	4935.2	1573.9	4205.2	3530.1	25117.2	3139.6
D ₄ (28 th SMW)	741.0	3871.7	1898.0	2534.8	1377.5	2529.4	8897.5	2958.1	24808.1	3101.0
MEAN	746.1	3739.7	2117.1	3105.5	3488.6	3243.0	5538.8	3476.6	25455.5	3181.9

Table-4 : Phenophase wise PTU required for different sowing dates of cotton during *Kharif* season 2021.

Date of Sowing	Phenophases								TOTAL	MEAN
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈		
D ₁ (25 th SMW)	1456.8	7361.6	3632.4	5253.4	2991.4	12784.2	9324.0	8500.2	51304.0	6413.0
D ₂ (26 th SMW)	1463.0	6664.4	5287.2	5296.0	11719.9	4288.8	8103.6	5780.5	48603.4	6075.4
D ₃ (27 th SMW)	1399.6	7318.3	3729.6	8484.5	9500.8	3030.0	8095.8	6795.9	48354.6	6044.3
D ₄ (28 th SMW)	1426.5	7453.5	3654.0	4879.9	2652.0	4869.6	17128.5	5694.8	47758.7	5969.8
MEAN	1436.5	7199.5	4075.8	5978.4	6716.0	6243.2	10663.0	6692.8	49005.2	6125.6

Table-5 : Heat Use Efficiency (HUE) for different sowing dates of cotton during *Kharif* season 2021.

Sr. No.	Particular	D ₁ (25 th SMW)	D ₂ (26 th SMW)	D ₃ (27 th SMW)	D ₄ (28 th SMW)
	Yield (Kg ha ⁻¹)	710.0	574.3	530.0	476.3
Phenophase		GDD (°C day)			
1	P ₁	121.4	121.9	116.6	118.9
2	P ₂	613.5	555.4	609.9	621.1
3	P ₃	302.7	440.6	310.8	304.5
4	P ₄	437.8	441.3	707.0	406.7
5	P ₅	249.3	976.7	791.7	221.0
6	P ₆	1065.4	357.4	252.5	405.8
7	P ₇	777.0	675.3	674.7	1427.4
8	P ₈	708.4	481.7	566.3	474.6
Accumulated GDD (°C day)		4275.3	4050.3	4029.5	3979.9
HUE (Kg ha ⁻¹ / °C day hour)		0.17	0.14	0.13	0.12

dry matter accumulations between flowering-boll retention had adverse effect on seed cotton yield. However, both number of bolls and boll weight plant⁻¹ contributed for the yield reduction (Hebbbar *et al.* 2002). Hallikeri *et al.* (2009) discussed the same finding that early sown crop produced significantly higher yield than late sowing. However, the yield attributing characters like Plant height, number of leaves, number of branches, and number of bolls that was higher in early sown crop resulted in higher seed cotton yield.

The yield in the previous years was greater than yield in the year 2021 on the same location, this might be due to the fact that the crop growth phenophase like the squaring and flowering stage does not meet its appropriate temperature requirement of 21–27 °C for vegetative growth and 27–32 °C during fruiting period

(Waghmare and Singh, 2017). The average temperature of *Kharif* 2021 for vegetative stages of early sown cotton crop was 27.4°C and late sown crop was 27.2 °C, respectively, whereas, that of fruiting period of early and late sown crop was 26.4 °C and 26.6 °C, respectively, which shows that the temperature exceeds the appropriate temperature requirement of the crop during vegetative growth but get reduced during fruiting period of the crop.

The average maximum temperature of early and late sown crop range was 31.1 °C and 32.3 °C, respectively, which shows that the data agreed with the results of Buttar, *et al.* (2012) who also reported that seed cotton yield decreases to half when temperature increase from 28 °C to 32 °C, especially, during sowing to flowering stage than the rest of phenol phases. Reddy *et al.* (1996)

also reported that young bolls shed or drop with temperature rise to -32.2°C . The result confirmed the findings of Cetin and Basbag (2010) that high temperature (30°C) reduces boll retention and final yield.

This year, the number of days taken for the crop to develop from boll formation to boll bursting (P_6) was good moisture in the soil and long duration due to heavy rainfall. Liakatas *et al.* (1998) discussed that rain lengthened cotton developmental stages, particularly when falling between sowing and anthesis or boll opening and harvest. Cetin and Basbag, (2010) stated that Climatic factors such as temperature, wind, rainfall and relative humidity significantly affect the boll production of cotton. Reduction in the yield due to boll shedding caused due to strong winds. Similarly, continuous rain during flowering and boll opening will impair the pollination and may thus reduce fiber quality. However, increasing amount of rainfall in early growing period of cotton can result in higher yield. Fruiting of cotton plant is determined and influenced by climatic conditions, cultivars, management practices and pests. In addition, the water requirement of cotton depends on length of the total growing period and climate.

Another reason of the low seed cotton yield was due to the infestation of Pink bollworm (*Pectinophora gossypiella*) which is one of the most dangerous pest of cotton during the boll formation of the crop. However, due to the infestation of Pest, the 3rd picking of cotton was not done for D_1 , D_2 , D_3 and D_4 . Santosh *et al.* (2009) reported that *Bt* cotton had 9.08 per cent mean green boll damage compared to 23.59 per cent for non-*Bt* cotton. Green boll damage had been recorded at 12.35 and 30.85 per cent in *Bt* and non-*Bt* cotton, respectively, during the peak boll growing period (up to December). During the peak boll development period, *Bt* cotton showed a 61.50 per cent lowering in boll damage compared to non-*Bt* cotton.

Effect of hybrids : Different hybrids had a significant effect on seed cotton yield (kg ha^{-1}) whereas among hybrid, V_1 (Ajeet-155) has recorded significantly higher seed cotton yield (kg ha^{-1}) which was of 641.2 kg ha^{-1} , over rest of all hybrids. Hebbar *et al.* (2002) also stated that delayed in sowing of hybrid Ajeet-155 significantly reduced the yield and yield attributing character due to low temperature during canopy development, surface area development, squaring and flowering. Waghmare *et al.* (2016) reported the same finding.

Interaction : The interaction between different sowing dates and hybrids had no significant effect on seed cotton yield (kg ha^{-1}).

Stalk yield (kg ha^{-1})

The stalk yield of the crop was recorded and presented in Table 3.1.

Effect of sowing dates : The differing sowing dates had a substantial impact on the amount of stalk produced. The early-sown crop, D_1 (25th SMW), has recorded significantly higher stalk yield, which was $3654.2 \text{ kg ha}^{-1}$, over rest of all sowing dates. The similar result was reported by Waghmare *et al.* (2016).

Effect of hybrids : Differences in hybrids have a considerable impact on stalk yield (kg ha^{-1}), with V_1 (Ajeet-155) has found significantly higher stalk yield (kg ha^{-1}), which was $3386.3 \text{ kg ha}^{-1}$, except V_2 .

Interaction : There is no significant interaction effect between different sowing dates and hybrids on stalk yield of cotton kg ha^{-1} .

Biological yield (kg ha^{-1})

The seed yield of cotton (kg ha^{-1}) and stalk yield of cotton (kg ha^{-1}), which are shown in Table-1, were used to calculate the biological yield of the crop.

Effect of sowing dates : The early sowing date, D_1 (25 MW), has recorded significantly higher biological yield of $4364.0 \text{ kg ha}^{-1}$, over rest of all sowing dates. The similar results were reported by Waghmare *et al.* (2016), who found that the 25 MW sowing produced the highest seed cotton yield ($907.62 \text{ kg ha}^{-1}$) compared to the 27 MW sowing ($677.36 \text{ kg ha}^{-1}$) which was comparable to earlier sowing in terms of all yield attributing characters.

Effect of hybrids : The biological yield kg ha^{-1} of the cotton varies significantly between three *Bt* cotton hybrids with V_1 has recorded significantly higher biological yield which was $4027.4 \text{ kg ha}^{-1}$ over rest of all hybrids.

Interaction : Different sowing dates and *Bt* cotton hybrids did not significantly affect the biological yield.

Harvest index (per cent)

This information, which is reported in Table 3.1, was computed using information on cotton seed yield and biological yield.

Effect of sowing dates : Different sowing dates have a significant impact on the harvest index of a crop. D_1 (25th SMW) has found significantly higher harvest index of 16.9%, over rest of all sowing dates. The same finding was reported by Waghmare *et al.* (2016), Dakhore and Kadam (2018).

Effect of hybrids : The harvest index of the crop varies significantly between the three *Bt* Cotton hybrids, with V_1 (Ajeet-155) has significantly higher harvest index which was 16.0%, highest over rest of all hybrids. The similar finding was reported by Dakhore and Kadam (2018).

Thermal Indices

Temperature plays a crucial role in crop development and

growth, particularly in determining the length of various phenophases and crop productivity. The formula provided by Major *et al.* (1975), Ramkuttu N. (2002), Sahu *et al.* (2007), Amrawat *et al.* (2013), and Sondarva *et al.* (2014) was used to estimate the thermal indices Growing Degree Days (GDD), Heliothermal Unit (HTU), Photo Thermal Unit (PTU), and Heat Use Efficiency (HUE) for various phenophases of Bt. cotton crop. Tables 3.2, 3.3, 3.4 and 3.5 gave the statistics.

Growing Degree Days (GDD) : Data on GDD during each phenophase were gathered at base temperature of 15.5 °C and presented on Table 3.2. The data showed that the average cumulative GDD of different sowing dates from each phenophase (*i.e.*, P₁ to P₈) of the Bt cotton crop was approximately 4083.8 °C day. The findings showed a significant relationship between sowing dates and Growing Degree Days of Bt. Cotton at each Phenophase, with the early-sown crop, D₁ (25th SMW), having the highest accumulated GDD of 4275.3 °C day compared to D₂ (26th SMW) 4050.3 °C, D₃ (27th SMW) which had the lowest accumulated GDD of 4029.5 °C day, and the late-sown crop, D₄ (28th SMW), having the lowest accumulated GDD of 3979.0 °C. The maximum mean GDD of 888.6 °C day was identified among the phenophase stages of various sowing dates, while the minimum mean GDD of 119.7 and 559.7 °C day was discovered during P₁(sowing to emergence stage) and P₅(Flowering to Boll formation), respectively. The effect of excessive rainfall, which prevents insect pollination of flowers, may be the cause of the GDD of P₅ increasing more than P₁. Early sown crops had the greater cumulative GDD than late-sown crops, according to Hebbar *et al.* (2002), Prakash *et al.* (2010), Kamble *et al.* (2018), Vora *et al.* (2018), waghmare and Singh (2017), Gaikwad (2019), and Shivani (2020).

Helio Thermal unit (HTU) : The Heliothermal unit of the crop had been mainly dependent on the bright sunshine hours and GDD of the crop. Data was calculated for each phenophases of different sowing dates and showed in Table 3.3. Result showed that there is significant effect between different dates of sowing and Heliothermal unit of Bt. cotton where the maximum HTU for total crop life cycle was recorded during first date of sowing, D₁ (25th SMW) of 26649.9 °C day hrs⁻¹, followed by D₂ (26th SMW) with value of 25246.8 °C day hrs⁻¹, then comes the D₃ (27th SMW) of 25117.2 °C day hrs⁻¹ and the least HTU was recorded during D₄ (28th SMW) of 24808.1 °C day hrs⁻¹. The value of HTU of D₁ was bright sunshine hours. However, due to cloudy weather and less bright sunshine hours received during the growth period of the D₂ and D₃, there is less difference in their HTU values. Gaikwad (2018) reported that maximum HTU was recorded in D₃

(29th SMW) while the lower HTU were observed in D₁ (25th SMW) due to variation of temperature and Bright Sunshine hours during the crop growing season. According to data, the general mean value of total HTU of different date of sowing recorded during entire crop life period of Bt. cotton was 25455.5 °C day hrs⁻¹. Similar result was reported by Shivani (2020), Vora *et al.* (2018), Prakash *et al.* (2015) and waghmare and singh (2017).

Photo thermal unit (PTU) : The Photo Thermal Unit (PTU) data, which is reported in Table 3.4, was derived using GDD and the length of the day (13.5) to determine the heat energy utilized by crop during the day. Result revealed that the different sowing dates has a significant effect on photo thermal Unit of Bt. cotton at each phenophase where the early sown crop, D₁ (25th SMW) have the maximum total PTU of 51304.0 °C day hrs⁻¹ than D₂ (26th SMW) of 48603.4 °C day hrs⁻¹, D₃ (27th SMW) of 48354.6 °C day hrs⁻¹ with the least accumulated GDD by late sown crop D₄ (28th SMW) of 47758.7 °C day hrs⁻¹ which showed a decreasing trend from D₁ to D₄. The data was recorded in phenophase wise for different sowing date and observed that P₇ has the highest average PTU value of 10663.0 °C day hrs⁻¹, whereas, the lowest average value of PTU of 1436.5 °C day hrs⁻¹ and 4075.8 °C day hrs⁻¹ was found during P₁ (sowing to emergence stage) and P₃ (Seedling to square formation stage), respectively. However, the average accumulated PTU of different sowing dates for the total life cycle of crop was 49005.2 °C day hrs⁻¹. similar result reported by shivani (2020), Prakash *et al.* (2015), Vora *et al.* (2018) and waghmare and singh (2017).

Heat Use Efficiency (HUE) : Based on the seed cotton yield and accumulated GDD of a specific sowing date, the heat use efficiency of Bt. cotton was estimated, and it was found that D₁ (25th SMW) had the highest HUE with a value of 0.17, followed by D₂, D₃, and D₄ with values of 0.14, 0.13, and 0.12 kg seed cotton ha⁻¹degree days⁻¹, respectively, as shown in Table 3.5. This demonstrates how effectively the crop that was sowed on day 1 uses the heat energy that is available.

Conclusions

In the context of various sowing dates and their respective phenophase stages, the highest mean value of Growing Degree Days (GDD) was observed during P₆ (boll formation to boll bursting stage), while the minimum mean GDD values were recorded during P₁ (sowing to emergence stage) and P₅ (flowering to boll formation). These findings were consistent across Photo-Thermal Units (PTU), Heat Thermal Units (HTU), and Heat Use Efficiency (HUE). Specifically, the sowing on D₁ (25 MW) required the most accumulated GDD, PTU, HTU, and

HUE, followed by D2 (26 MW), D3 (27 MW), and D4 (28 MW) sowings.

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Forecasting the Phenology of Kharif Pearl Millet in Different Sowing Windows by Helio-Thermal Unit and Helio-Thermal Use Efficiency for Scarcity Zone of Maharashtra

Sujeet S. Deshmukh¹, Jaywant D. Jadhav², Ankush B. Chougule³, Vikas M. Londhe¹ and Vijay T. Jadhav¹

¹Department of Agricultural Meteorology, CoA, Pune. M.P.K.V. Rahuri

²Principal, ATS Solapur

³Vasantrao Naik Marathwada Krishi Vidyapeeth, CoA, Parbhani.

*Corresponding Author Email : sujeetdeshmukh99@gmail.com

Abstract

A field experiment conducted over two Kharif seasons (2021 and 2022) at the Zonal Agricultural Research Station in Solapur, Maharashtra, India, investigated the impact of Helio-thermal unit and helio-thermal use efficiency accumulation on different sowing times and pearl millet varieties. The study, positioned at approximately 17°41' N and 75°56' E, employed a split plot design with three sowing times S₁ (26th June – 01st July), S₂ (23rd July - 29th July), and S₃ (27th Aug – 02nd Sep.) as main plots and three pearl millet cultivars ICTP-8203, Mahyco hybrid, and Adishakti as sub-plots. Phenological stages and weather parameters were recorded, revealing a direct correlation between early sowing and increased HTU, dry matter production, and crop yield. Cultivar Adishakti exhibits the highest HTU and helio-thermal use efficiency when sown in early windows. Delayed sowing reduces HTU and HTUE accumulation, exposing crops to less warmth and disrupting critical growth stages.

Key words : Helio-thermal unit, helio-thermal use efficiency, cultivar, pearl millet, sowing windows.

Introduction

Pearl millet, constituting about two-thirds of India's millet production, is primarily cultivated in arid regions across states like Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, and Haryana (Anonymous 1996). This cereal crop is extensively grown under rainfed conditions in arid and semi-arid zones of Africa and southern Asia. In contrast, in other continents, it is cultivated intensively as a forage crop. Thriving in hot and dry climates, pearl millet adapts well to regions with precipitation levels ranging from 200 to 600 mm, making it suitable for areas where maize and sorghum may struggle. Due to its tropical nature, pearl millet is often compared to a "Camel" for its remarkable resilience to drought conditions. Even with limited rainfall, pearl millet typically demonstrates the ability to yield satisfactory harvests. Phenological behaviour and growth parameters such as leaf area development, biomass production, and seed yield can be effectively described using air temperature-based indices like helio-thermal unit (HTU) and helio-thermal use efficiency (HTUE). Modifying sowing dates leads to variations in the thermal conditions experienced by the crop during different growth stages.

Materials and Methods

A field experiment spanning two consecutive Kharif seasons in 2021 and 2022 was conducted at the Zonal Agricultural Research Station in Solapur, Maharashtra, India. The station is located at a latitude of approximately

17°41' N and a longitude of approximately 75°56' E. The experiment comprised three distinct sowing times denoted as S₁ (26th June – 01st July), S₂ (23rd July - 29th July), and S₃ (27th Aug – 02nd Sep.), treated as the main plots. Additionally, three pearl millet cultivars, namely ICTP-8203, Mahyco hybrid, and Adishakti were assigned as sub-plots. The experimental design employed a split plot arrangement with three replications. Various phenological stages, including sowing to emergence, 3-leaf stage, panicle initiation, flag leaf emergence, 50% flowering, soft dough stage, hard dough stage, and physiological maturity, were meticulously recorded. Meteorological data, encompassing weather parameters, were analysed based on observations from an agrometeorological observatory situated 60 meters away from the experimental farm.

Growing degree days GDD (°C day) : The growing degree days or heat units were calculated as per using base temperature of 10 °C.

$$GDD = [(T_{max} + T_{min}) / 2] - T_b$$

Where,

T_{max} = maximum temperature (°C)

T_{min} = minimum temperature (°C)

T_b = base or threshold temperature.

Helio-thermal units : The Helio-thermal unit is the product of GDD and the mean daily hours of bright

Table-1 : Cumulative Helio-thermal unit (HTU) as influenced by different sowing windows and varieties in *Kharif* pearl millet during 2021.

Treatments		Cumulative Helio-thermal unit unit (°C day ⁻¹ hrs ⁻¹)							
Sowing window	Varieties	Emer.	3 leaf	PI	Flag leaf	50 % flowering	Soft dough	Hard dough	Phy. Maturity
S1: 26 MW	V ₁ : ICTP-8203	739	1261	1632	3669	4175	5694	7171	8920
	V ₂ : Mahyco hybrid	745	1289	1674	4105	4518	5709	7351	9343
	V ₃ : Adishakti	752	1362	1746	4251	5059	6826	8871	10152
S2: 30 MW	V ₁ : ICTP-8203	569	952	1468	3563	4563	5412	6005	7918
	V ₂ : Mahyco hybrid	588	1133	2128	4081	5139	5926	7462	8403
	V ₃ : Adishakti	696	1216	2429	4297	5376	6112	7611	8962
S3: 35 MW	V ₁ : ICTP-8203	642	705	1941	4729	5829	7061	7251	7838
	V ₂ : Mahyco hybrid	670	821	2135	4896	6087	7383	8460	8968
	V ₃ : Adishakti	681	947	2317	5127	6448	7585	8557	9401

Whereas,

P1: Sowing to Emergence
P5: 50% flowering

P2: 3 Leaf
P6: Soft dough

P3: Panicle initiation
P7: Hard dough

P4: Flag leaf.
P8: Physiological maturity

Table-2 : Cumulative Helio-thermal unit (HTU) as influenced by different sowing windows and varieties in *Kharif* pearl millet during 2022.

Treatments		Cumulative Helio-thermal unit (°C day ⁻¹ hrs ⁻¹)							
Sowing window	Varieties	Emer.	3 leaf	PI	Flag leaf	50 % flowering	Soft dough	Hard dough	Phy. Maturity
S1: 26 MW	V ₁ : ICTP-8203	676	861	1392	3580	4432	5223	6583	8506
	V ₂ : Mahyco hybrid	681	884	1446	3838	4696	5558	6992	8765
	V ₃ : Adishakti	687	896	1446	4125	4880	6066	7239	8865
S2: 30 MW	V ₁ : ICTP-8203	795	1190	1942	4030	4305	6474	7719	7511
	V ₂ : Mahyco hybrid	810	1309	2242	4261	4753	6723	7821	8033
	V ₃ : Adishakti	819	1398	2437	4547	5290	6865	7946	10183
S3: 35 MW	V ₁ : ICTP-8203	656	772	1379	2605	3275	4467	5339	6061
	V ₂ : Mahyco hybrid	689	785	1565	2727	3406	4633	5721	6353
	V ₃ : Adishakti	712	798	1603	2833	3758	4804	5958	7128

Whereas,

P1: Sowing to Emergence
P5: 50% flowering

P2: 3 Leaf
P6: Soft dough

P3: Panicle initiation
P7: Hard dough

P4: Flag leaf.
P8: Physiological maturity

sunshine. The sum of HTU for each phenophase was worked out by using the following formula :

$$\text{Accumulated HTU} = [(T + T_b) / 2 - T_b] D$$

Where,

HTU = Helio thermal unit

T = mean daily temperature

T_b = Base temperature

T_s = Date of sowing or starting date of the phenophase of Interest

T_h = Date of harvesting or ending date of phenophase of Interest

D = Hours of bright sunshine

Helio thermal use efficiency : Helio thermal use efficiency was calculated by dividing the total dry matter

recorded at respective days by the accumulated helio thermal units.

It is expressed in expressed as g°C days⁻¹ hrs⁻¹.

Results and Discussion

Helio-thermal unit : The data on the cumulative helio-thermal units (degree day hrs.) of pearl millet as influenced by different sowing windows and varieties are presented in Table-1 and 2 and graphically depicted in Figure-1 and 2.

The mean cumulative helio-thermal units were increased with advancement in crop age and reached maximum at harvest 8878 during first year and 7934 during the second year of experimentation.

The cumulative helio-thermal units (HTU), representing the combined influence of solar radiation and temperature, displayed significant variation from the

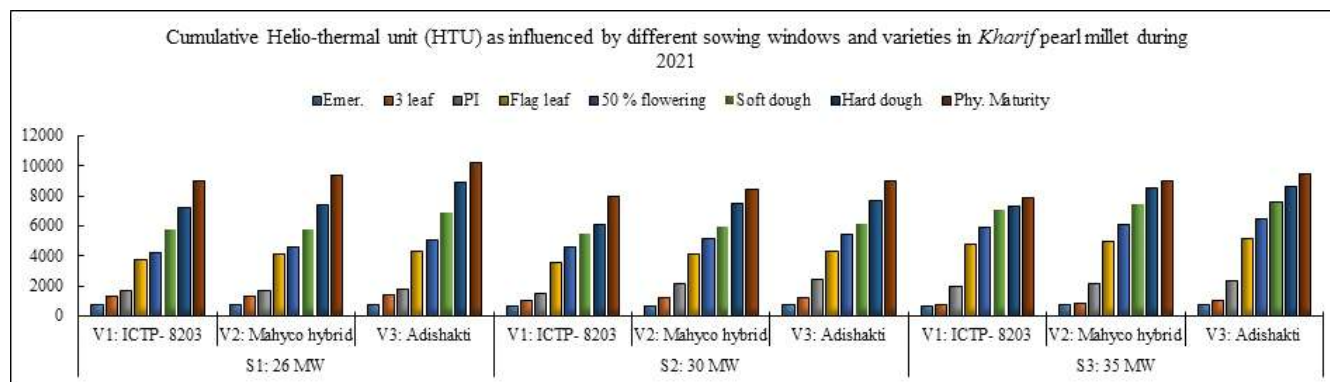


Fig.-1 : Cumulative Helio-thermal unit (HTU) as influenced by different sowing windows and varieties in Kharif pearl millet during 2021.

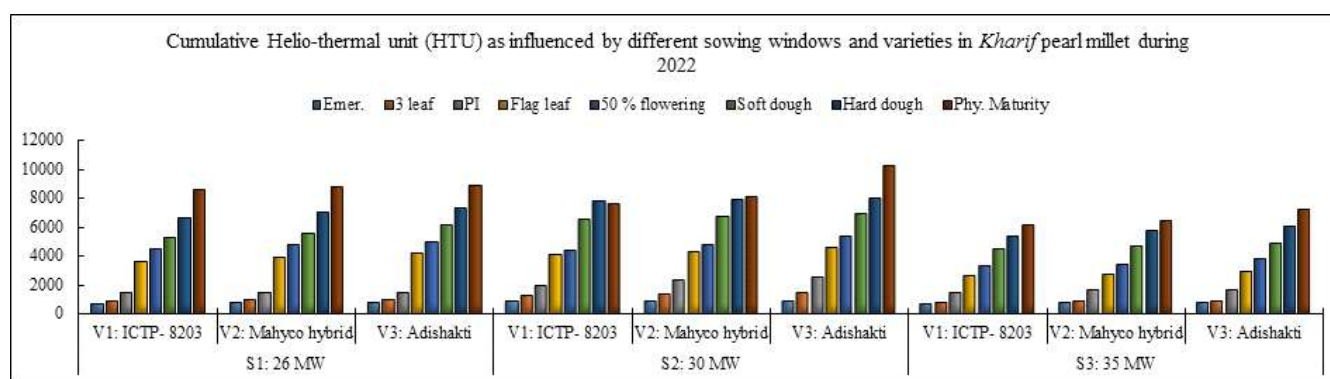


Fig.-2 : Cumulative Helio-thermal unit (HTU) as influenced by different sowing windows and varieties in Kharif pearl millet during 2022.

sowing phase to the physiological maturity of the crop. Diverse responses emerged among distinct pearl millet varieties concerning the accrual of HTU. Notably, the variety Adishakti exhibited elevated HTU values, with the highest levels observed during the 26 MW (S1) and 30 MW (S2) sowing windows, amounting to 10152 and 10183-degree day hours, respectively. Conversely, the variety ICTP-8203 demonstrated the lowest HTU values within the 35 MW (S3) sowing window, totalling 7838 and 6061-degree day hours. The Mahyco hybrid variety, alongside the 30 MW (S2) sowing window, registered intermediate helio-thermal units across both the experimental years of 2021 and 2022.

The delayed sowing can expedite crop maturity through warmer temperatures, shortening the window for HTU accumulation. The progressive accumulation of helio-thermal units (HTU) occurs across successive phenological stages spanning from sowing to harvesting. As the crop advances through subsequent phenological stages, a combination of solar radiation and increasing temperatures becomes influential, contributing to a rise in helio-thermal units. Notably, the lowest and highest accumulation of HTU were observed at the initiation of

sowing to physiological maturity, respectively. Similar findings were also reported by Anil Kumar *et al.* (2008).

Helio-thermal use efficiency (HTUE) : Helio-thermal use efficiency with grain and fodder yield as influenced by different sowing windows and varieties in Kharif pearl millet, is presented in Table 3-4 and graphically depicted in Fig. 3-4.

Considerable variations in helio-thermal use efficiency (HTUE) associated with grain yield were apparent across diverse sowing windows and pearl millet varieties. Elevated HTUE in conjunction with grain yield was notably observed within the 26 MW (S1) and 30 MW (S2) sowing windows for the Adishakti variety, manifesting as values of 0.168 and 0.150 g °C day⁻¹, respectively. In contrast, the lowest HTUE values emerged during the 30 MW (S2) and 35 MW (S3) sowing windows for the ICTP-8203 variety, registering values of 0.105 and 0.144 g°C day⁻¹. This pattern persisted consistently over the experimental years 2021 and 2022.

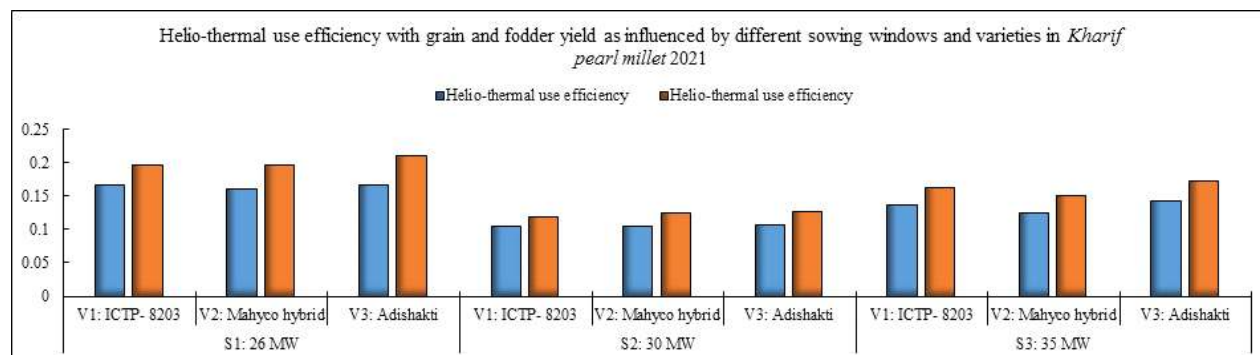
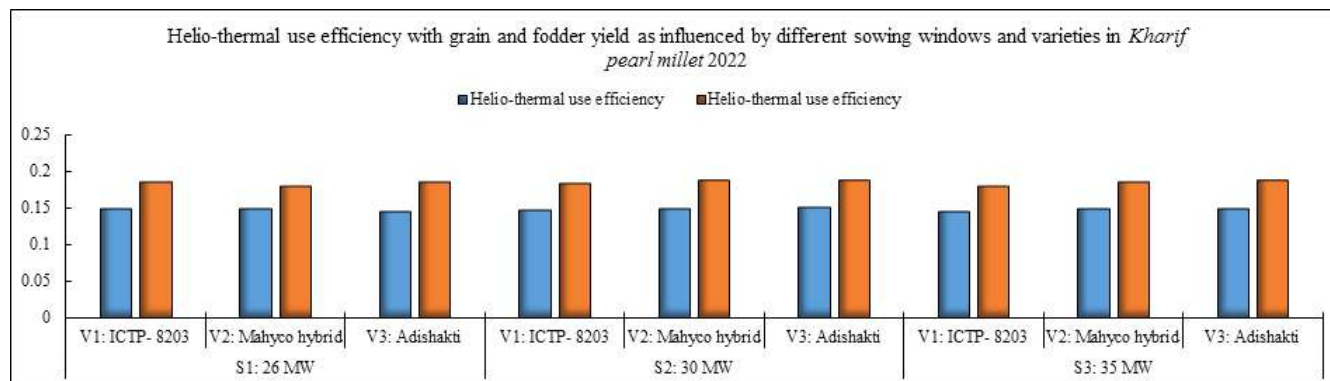
Parallel trends were observed concerning fodder yield, wherein the highest HTUE values occurred under the 26 MW (S1) and 30 MW (S2) sowing windows for the

Table-3. Helio-thermal use efficiency with grain and fodder yield as influenced by different sowing windows and varieties in Kharif pearl millet 2021.

Treatments Sowing window	Varieties	Helio-thermal use efficiency unit (g °C hrs ⁻¹)				
		Grain yield (Kg ha ⁻¹)	Fodder yield (Kg ha ⁻¹)	Cumulative Helio-thermal unit	Helio-thermal use efficiency (Grain yield)	Helio-thermal use efficiency (Fodder yield)
S1: 26 MW	V ₁ : ICTP-8203	1490.07	1759.93	8920	0.167	0.197
	V ₂ : Mahyco hybrid	1517.53	1836.83	9343	0.162	0.197
	V ₃ : Adishakti	1702.93	2142.4	10152	0.168	0.211
S2: 30 MW	V ₁ : ICTP-8203	830.87	951.03	7918	0.105	0.120
	V ₂ : Mahyco hybrid	878.93	1047.17	8403	0.106	0.125
	V ₃ : Adishakti	947.6	1139.87	8962	0.107	0.127
S3: 35 MW	V ₁ : ICTP-8203	1084.93	1287.5	7838	0.138	0.164
	V ₂ : Mahyco hybrid	1126.13	1366.47	8968	0.126	0.152
	V ₃ : Adishakti	1345.87	1630.83	9401	0.143	0.173

Table-4. Helio-thermal use efficiency with grain and fodder yield as influenced by different sowing windows and varieties in Kharif pearl millet 2022.

Treatments Sowing window	Varieties	Helio-thermal use efficiency (g °C hrs ⁻¹)				
		Grain yield (Kg ha ⁻¹)	Fodder yield (Kg ha ⁻¹)	Cumulative Helio-thermal unit	Helio-thermal use efficiency (Grain yield)	Helio-thermal use efficiency (Fodder yield)
S1: 26 MW	V ₁ : ICTP-8203	1036.9	1297.8	7006	0.148	0.185
	V ₂ : Mahyco hybrid	1098.7	1373.33	8265	0.149	0.180
	V ₃ : Adishakti	1288.2	1615.73	8865	0.145	0.185
S2: 30 MW	V ₁ : ICTP-8203	1341.7	1675.47	8311	0.147	0.183
	V ₂ : Mahyco hybrid	1352.7	1685.77	9033	0.149	0.187
	V ₃ : Adishakti	1483.2	1854	9883	0.150	0.188
S3: 35 MW	V ₁ : ICTP-8203	892.7	1117.89	6061	0.144	0.179
	V ₂ : Mahyco hybrid	940.7	1174.89	6353	0.148	0.185
	V ₃ : Adishakti	1167.3	1461.23	7128	0.149	0.187

**Fig-3 : Helio-thermal use efficiency with grain and fodder yield as influenced by different sowing windows and varieties in Kharif pearl millet 2021.****Fig-4 Helio-thermal use efficiency with grain and fodder yield as influenced by different sowing windows and varieties in Kharif pearl millet 2022.**

Adishakti variety (0.211 and $0.188 \text{ g } ^\circ\text{C day}^{-1}$), while the lowest HTUE values were observed under the 30 MW (S₂) and 35 MW (S₃) sowing windows for the ICTP-8203 variety (0.120 and $0.179 \text{ g } ^\circ\text{C day}^{-1}$) during both years of investigation.

Fluctuations in helio-thermal use efficiency between distinct sowing windows and varieties of pearl millet are the result of the interplay between solar radiation availability, temperature conditions, plant physiology, and growth dynamics. Helio-thermal use efficiency (HTUE) refers to the efficiency with which crops convert solar radiation and temperature into growth or yield. The variation in HTUE at different times can be attributed to a combination of factors related to sunlight availability, temperature conditions, and plant physiological responses.

Conclusions

The results suggest that crops planted during early sowing windows, S₁ (26th June – 01st July), S₂ (23rd July - 29th July), demonstrated the highest accumulation of Helio-thermal units (HTU). This observed HTU accumulation exhibited a positive correlation with increased dry matter production and crop yield when compared to crops sown during the late sowing window, S₃ (27th Aug – 02nd Sep.). The precise estimation of HTU is of paramount importance for accurately predicting crop yield, as a direct and linear relationship is evident between crop yield and the accumulation of heat units.

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Internet-Based Rural Banking : A Study on Rural Clients

Ravindra Singh* and P.D. Turkhade

Krishi Vigyan Kendra, Kaneri, Kolhapur-II, Maharashtra

*Corresponding Author Email : ravindrasingh94125@gmail.com

Abstract

A study conducted in Kolhapur, Maharashtra, India, in 2022 investigated the adoption of digital banking in rural areas. Data was collected through interviews with 100 farmers selected through random sampling. The findings revealed that while traditional banking methods remained reliable for most respondents, digital banking was gaining popularity among younger individuals with smartphone access and internet facilities. Rural clients were using digital banking for balance checks and transaction histories but were cautious about online fund transfers and payments due to security concerns and a lack of training. India's Digital India initiative, led by Prime Minister Narendra Modi, aims to digitize the country's services. E-banking, a vital part of this initiative, offers convenience and efficiency. However, the transition from traditional to digital banking in rural India faces challenges. The study examined digital banking adoption across age groups, awareness levels, factors affecting adoption, and constraints faced by rural consumers. Results showed that younger individuals (18-35) were more likely to embrace digital banking, while those aged 36-50 hesitated. Education and income levels played significant roles, with self-employed individuals favoring cooperative banks. Constraints included poor internet connectivity, language barriers, trust issues, high smartphone costs, limited ATM access, and rural life's multitasking nature. Regression analysis indicated that convenience and security significantly influenced e-banking customer satisfaction, with convenience having a stronger impact. In summary, the study highlighted the growing popularity of digital banking among younger rural residents but identified numerous challenges, including security concerns, limited education and income, and infrastructure constraints. Addressing these challenges is crucial for the successful adoption of digital banking in rural India, aligning with the Digital India initiative's goals.

Key words : Digital banking, rural area, internet banking, adoption, constraints, satisfaction, internet connectivity, e-banking, digital India initiative

Introduction

The world of banking and financial services has undergone a significant transformation in the digital age, extending digital banking's reach far beyond urban areas and into remote corners of the globe. This global shift has put a spotlight on digital banking in rural regions, an area of great significance. The fusion of finance and technology, known as FinTech, has brought about a revolution in banking marked by convenience, efficiency, and accessibility. This transformation is no longer confined to cities; it has reached rural areas where traditional banking infrastructure was once scarce. The advent of digital banking in rural areas has the potential to reshape the financial landscape, bridging gaps and empowering underserved communities. Our study, conducted in rural India's heartland, particularly in Maharashtra, Kolhapur district in 2022, aims to investigate digital banking adoption among rural clients. Focusing on 100 randomly selected farmers, our research explores how rural clients engage with digital banking services and the challenges they encounter in this evolving financial landscape. India, like many other nations, is on a determined path toward digitization, driven by the visionary Digital India Program led by Prime Minister Narendra Modi. This program envisions a digitally

empowered society built on transparency, efficiency, and accessibility, with digital banking playing a central role. Digital banking promises convenience and efficiency for rural clients, who may be distant from traditional bank branches. It allows them to conduct financial transactions from their homes or fields, thanks to the proliferation of smartphones and improved internet connectivity. However, challenges persist, including a preference for traditional counter banking among farmers, apprehensions about online fraud, limited digital literacy, and varying adoption rates across age groups, education levels, and occupations. Our study also explores constraints faced by rural clients in their digital banking journey, such as poor internet connectivity, language barriers, security concerns, and smartphone costs. Rural life's multifaceted nature, where financial transactions intertwine with daily agricultural activities, adds complexity to the equation.

Through our research, we aim to shed light on the challenges, opportunities, and intricacies of digital banking in rural India. By understanding these dynamics, we can pave the way for more inclusive and effective financial services, empowering rural communities and contributing to India's vision of a digitally connected nation.

Objectives

To assess the adoption of digital banking across different age groups in rural areas.

To identify the factors influencing the usage of digital banking among rural customers.

To examine the constraints faced by rural consumers in the adoption of digital banking services.

Materials and Methods

The research was conducted by employing a comprehensive approach that encompassed both primary and secondary data collection methods. Secondary data, sourced from various published materials such as internet sources, articles, and newspapers, provided a foundational understanding of the subject. To conduct this study, a combination of non-probability and convenience sampling techniques was employed, ultimately gathering data from 100 respondents. The research aimed to discern the preferences of rural consumers towards digital banking. To ensure a representative sample, a random sampling method was utilized, randomly selecting 10 villages for data collection. The data collection process involved personal interviews with respondents, guided by structured schedules designed to align with the study's objectives. Furthermore, a multistage stratified sampling technique was adopted, enhancing the sample's diversity and representativeness. Data analysis was performed using standard statistical measures, including arithmetic mean values and percentages. In addition to primary data, secondary data played a crucial role in the study. The gathered secondary data was meticulously compared and cross-referenced with primary data findings to enhance the study's validity. The recorded responses from both data sources were tallied and converted into mean scores, systematically ranking the identified constraints. It's worth noting that equal emphasis was placed on both rural and urban areas during the research process. This balanced approach was taken to identify the factors contributing to the development of digital banking in rural regions, aligning with the insights shared by (Jyoti 2016). This methodological approach ensured a robust and comprehensive study, shedding light on rural consumers' preferences towards digital banking while considering the broader context of digital banking development.

Results and Discussion

Age : As the data depicted in Table-1 we looked at people of different ages, from 18 to 70 years old. We had respondents from various age groups, but most of them, around 53%, were between 18 and 35 years old. About 33% were in the 36-50 age range, while 44% fell into the

Table-1 : Age group of respondents.

Items	No. of Respondents
Age	
18-35	33
36-50	44
51-70	23
Total	100
Education	
Illiterate	01
Intermediate level	58
Graduate	25
Post Graduate	16
Total	100
Occupation	
Govt. employee	15
Private employee	29
Self-employed	35
Multitasking	21
Total	100
Annual Income	
Up to Rs. 1,00,000	45
Rs. 1,01,000 to 5,00,000	30
Rs. 5,01,000 to 10,00,000	16
Rs. 10,00,000 & above	09
Total	100
Bank accounts of the respondents	
Public Bank	27
Private Bank	9
idctIparCo-operative Bank	64
Total	100
Type of banking facilities	
Counter Banking	75
Use E-banking facilities	25
ATM	10
Mobile Banking (UPI payment)	10
Internet Banking	05
Total	100
Banking services used by the respondents	
Balance & Transaction History through app	79
Online Fund Transfer	7
Card to Card Fund Transfer	1
Online shopping	2
On line FD & Railway Ticket	1
UPI payments	10
Total	100
Security concern of the respondents	
Very much	10
Much	25
Not at all	65
Total	100
Satisfaction level of the respondents	
Very much	77
Little	23
Total	100
Disadvantage level of the respondents	
Overall difficulty of using online banking system	69
Lack of assistance	9
Security concern	15
Dependence on Internet service	07
Total	100

Table-2 : Constraints responsible for slow adoption of Digital Banking.

S. No.	Constraints	No. of Respondents	Rank order
1.	Poor speed of internet connectivity	89	I
2.	Language problem (English & Hindi)	87	II
3.	Lack of trust in digital banking	65	VI
4.	High cost of smart phones	77	IV
5.	Multitasking nature of farming community	47	VIII
6.	Low level of financial inclusion	58	VII
7.	Non of availability of ATM machines in rural area	82	III
8.	Limited working hours of ATM machines	71	V

Table-3 :

Parameters	Coefficients	Standard Error	t Stat	P-value
Intercept	0.724	0.323	2.250	0.024
Convenience Average	0.346	0.091	3.821	0.000
Security average	0.281	0.086	3.327	0.001

51-70 age group. Only 23% were older than 70. Our main interest was in understanding what younger people think about digital banking. Specifically, we wanted to know how young folks, between 18 and 50 years old, who use smartphones for things like entertainment, learning from the internet, taking pictures, and using different apps, feel about digital banking. Our research uncovered something interesting. More than half of the 18–50-year-olds who are tech-savvy and use smartphones extensively could potentially become future users of digital banking Sadamate and Sinha (1976). This means that young adults who are comfortable with smartphones might be the ones driving the adoption of digital banking in the future. we noticed that most of the respondents, which is about 58%, had completed their intermediate education. The second largest group, about 22% of the respondents, were graduates. Only a smaller group, around 10%, had completed their post-graduation studies. Surprisingly, a very small number, only 3%, were found to be illiterate. This pattern is similar to what other researchers like Sharma et al. (2006), Mishra and Sinha (1981) have also observed in their studies. They found similar trends in the education levels of respondents. Table also shows that people's occupation is crucial for their survival. It's important for individuals to be self-reliant. In rural areas, 35% of the respondents are self-employed, which means they work for themselves. About 34% of the respondents have jobs in the private sector, and only 10% are government employees, working for the government. However, 21% of the respondents have occupations that don't fall into these categories and are considered uncategorized. Investment and saving both are largely depends on individual's income. Not only in India but also in world income is an important aspect and peoples invest in savings with banks. As a result of the survey, it was found that in rural area 45% respondents having only Rs. 1 lakh annual income, 30% having in between Rs. 1to5

lakh, while 16% respondents were having in between 5-10 lakh and only 9% respondents having more than 10 lakh annual income. Table shows us something important about how interested and aware people are about the banking system. People have different options for saving and securing their money, like using a public bank, a private bank, or a cooperative bank. In our survey in rural areas, 37% of the respondents had accounts in public banks, 18% had accounts in private banks, A significant 45% of the respondents used cooperative banks, mainly because they were farmers. Many farmers use something called a "kisan credit card," and they are also part of societies. These societies make it easy for them to receive payments for things like sugarcane, and these payments go directly into cooperative banks. People like using cooperative banks because the staff is friendly, and these banks are often found in rural areas. The staff knows the people and how things work there. (Marenzi et al., 2016). When it comes to banking services today, every bank offers both online and offline options. During our survey, we discovered that around 75% of the people prefer using counter banking, which means going to the bank in person. They believe it's safer than doing banking on the internet or through e-banking. Out of these 75%, only 25% of farmers have accepted ATM cards, but they mainly keep it for emergencies and have never actually used them. Most farmers find ATM machines unsafe and have trouble understanding the instructions on the screen. Remembering the PIN (a secret code) for the ATM card is also a big challenge for them. Additionally, carrying cash from an ATM machine is risky in rural areas. We can see that digital banking users are mostly in the age group of 18-35, and they usually have an intermediate level of education Aladwani, A.M. (2001). This suggests that the real users of digital banking and payments are younger people. Middle-aged individuals, aged 36-50, have many reservations about using digital payments. They aren't

familiar with internet banking and don't know how to use mobile apps like BHIM, PAYTM, and PAY Phone. Only 25% of the respondents use digital banking or e-banking, but they tend to use only limited features, such as checking their account balance and withdrawing money from an ATM. They don't often use services like transferring money electronically Harris, L and L.J. Spence (2002). Respondents also highlighted some real problems in rural areas. For instance, not all villages have access to electricity. This causes issues because sometimes cash gets stuck in ATM machines, creating chaos. The behavior of banking staff in rural areas is also often seen as unhelpful. Out of the 25% of farmers who use digital banking, only 10% are familiar with UPI payments, and a mere 5% use internet banking, but only for things like booking tickets. Many villagers can't afford smartphones or laptops, and they lack the training needed to use accounts, conduct transactions on mobiles, and make online payments. It would help if there were ATM centers within a reasonable distance of at least 3 kilometers to make access easier. Morral (1995)

As far as banking services are concerned respondents were asked about the security of digital banking transactions, approximately 65% of them expressed concerns, stating that internet banking transactions are not safe. Around 25% of the respondents believed it might be a little safe but were uncertain about the level of security. They also discussed issues like leaks of one-time passwords (OTP) in online frauds. However, they admitted that digital transactions are faster. Only 10% of the respondents felt that digital banking is very safe. During the survey, it was observed that people lack awareness about the benefits of digital banking, and they have not received any training or assistance regarding how to use internet banking. They have learned about it from their friends and neighbors. (Balachandran and Balachandher K.G., 2000).

The information in tells us that banks offer various digital services to their users, which can be quite helpful for different transactions. About 79% of the respondents use digital banking primarily to check their account balance and transaction history through apps. Only 7% use it for online fund transfers, while a mere 1% use it for tasks like transferring money from one card to another or booking fixed deposits (FD) and railway tickets. Another 4% use digital banking for online shopping, and they mentioned that this feature was especially useful during the COVID-19 pandemic. Only 1% of the respondents felt that tasks like booking FDs and railway tickets were too complex for them and required special expertise, so they avoided them. However, 10% found UPI payments (a type of digital payment) easy and convenient, but they

preferred using QR code scanning over entering mobile numbers for transferring money.

Satisfaction level : The table illustrates that customer satisfaction is of utmost importance for any service. Based on this survey, 77% of the respondents in rural areas are highly satisfied with traditional counter banking services Chavan, J. (2013). However, only 23% expressed slight satisfaction with digital banking. They mentioned that counter banking is time-consuming, involves a lot of paperwork, often has long queues, requires additional transportation costs, and demands a significant amount of their time. These respondents also admitted that they have heard about other online banking options but are not very familiar with them. They prefer the traditional counter banking method over online transactions. They noted that banks do not organize training programs in rural areas to educate people on using smartphones and protecting themselves from online frauds P.V.N, 2016).

Regarding the pros and cons of digital banking, there are numerous benefits, but there are also many challenges in rural areas. In rural settings, 69% of the respondents face difficulties using digital banking primarily because they are not well-informed about it. Problems include the lack of nearby ATM machines, irregular cash availability in ATMs, and electricity issues. Additionally, 9% of respondents complained about the lack of assistance from banking staff, and 15% expressed concerns about the safety of digital banking due to issues like hacking and ATM card cloning. Only 7% mentioned problems with internet facilities, leading to difficulties in accessing cash from banks and ATMs. Table also reveals that 95% of respondents complained about the poor speed of internet connectivity, making it the primary constraint. Language issues were a concern for 87% of respondents, and 82% mentioned the non-availability of nearby ATM machines as the third constraint. High smartphone costs were problematic for 77% of respondents, and limited operating hours of ATM machines were a concern for 71%. Furthermore, 65% of respondents indicated a lack of trust in digital banking as the sixth constraint. Low levels of financial inclusion were noted by 58%, and the multitasking nature of farming communities was seen as a constraint by 47%. In summary, while digital banking offers several advantages, rural areas still face various challenges, including limited awareness, slow internet, language barriers, and issues with ATM accessibility and trust in digital banking. These factors contribute to the preference for traditional counter banking in rural communities.

The information in table number 2 shows that 95% of the respondents complained about the slow speed of internet connection. This issue was the most significant

problem they faced, making it the top constraint. Additionally, 87% of respondents mentioned language problems as another major concern, ranking it as the second constraint. About 82% of them expressed frustration over the lack of ATM machines nearby, making it the third constraint. High smartphone costs were an issue for 77% of respondents, ranking it fourth, while the limited operating hours of ATM machines were a concern for 71%, making it the fifth constraint. Furthermore, 65% of respondents cited a lack of trust in digital banking as the sixth constraint. About 58% of respondents mentioned low levels of financial inclusion as the seventh constraint, and 47% pointed out that the multitasking nature of farming communities posed the eighth constraint.

Regression coefficient analysis : In the regression analysis, we used p-values to determine whether the relationships in our model were statistically significant. These p-values help us understand if the variables we're studying are related to each other and how they're related mathematically. We set a significance level of 5 percent, and for each independent variable (convenience and security), we checked whether they had a meaningful relationship with the dependent variable (satisfaction level of E-Banking customers). Our sample results provided enough evidence to reject the null hypothesis for the entire population. When a variable's p-value is less than the significance level (0.05 in our case), it indicates that there's a statistically significant relationship between that variable and the response variable Dheenadhayalan, V. (2010). This means that changes in the independent variable are linked to changes in the dependent variable. In our analysis, both the dependent and independent variables had p-values of 0.000 and 0.001, which are smaller than the usual significance range of 0.05 at a 5 percent significance level. This shows that both convenience and security measurements are statistically significant, and they should be included in the regression model. Looking at the coefficients, we can see that convenience has the most significant impact, followed by security, on the satisfaction level of E-Banking customers. This means that changes in convenience have a stronger effect on customer satisfaction than changes in security. To sum it up, we rejected the null hypothesis (H01 and H02) for both security and convenience measurements, indicating that there is indeed a significant relationship between these measurements and the satisfaction level of E-Banking customers.

Conclusions

Bringing digital connectivity to India can help improve the lives of its people by fostering non-agricultural economic activities and granting access to education, healthcare, and financial services. However, it's essential to

understand that simply having access to Information and Communications Technology (ICT) won't automatically lead to the nation's overall development. To achieve holistic growth, we must focus on factors like literacy, basic infrastructure, the business environment, regulatory conditions, and more. The Digital India program is just the initial step in a digital transformation that, when properly implemented, will create new opportunities for citizens. Digital banking poses challenges in rural areas due to limited internet connectivity, ATM machines primarily using Hindi or English, and the multitasking demands on farming communities, where cash is still widely used for various transactions. High smartphone costs also hinder digital banking adoption. Many people lack awareness of internet banking procedures and how to register for these services with banks. Additionally, younger generations in rural areas may be technologically savvy but do not have bank accounts, while family heads with accounts may be hesitant to connect them to digital facilities. Low annual income is another barrier, as many individuals rely on cash transactions for essential purchases like seeds, pesticides, and fertilizers from local shops and cannot save enough to maintain bank accounts.

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Yield Performance and Popularization of Mustard Variety NRCHB 101 in Kolhapur District of Maharashtra

Ravindra Singh^{1*}, Pandurang A. Kale¹, Sunil Kumar¹ and Ashok Sharma²

¹ICAR-Shri Siddhagiri Krishi Vigyan Kendra, Kaneri, Kolhapur, Maharashtra

²ICAR- DMR, Sewar Bharatpur, Rajasthan

*Corresponding Author Email : ravindrasingh94125@gmail.com

Abstract

The present study was carried out at Shri Siddhagiri Krishi Vigyan Kendra, Kaneri, Tal: Karveer, Dist: Kolhapur, Maharashtra (MS) to know the yield gaps between improved package and practices (IP) under Front Line Demonstration (FLD) and farmer's practice (FP) of mustard crop during the year 2020-21 and 2021-22. The investigations were conducted in The FLDs were conducted in five selected talukas in Kolhapur District i.e. Chandgad, Gadhinglaj, Kagal, Karveer, and Hathkanagale of different farming situations. To show the demonstration on mustard NRCHB 101, field day on 24 Jan. 2022 was conducted. Package of practices along with market acceptability was discussed. Farmer shows their willingness to grow the crop at their field.

Key words : Indian mustard, NRCHB 101, extension gap, front line demonstration, technology gap.

Introduction

Among the nine edible oilseed crops in India, rapeseed mustard possesses a significant position. Rapeseed mustard group mainly consists of toria (*Brassica rapa*), raya (*Brassica juncea*) and gobhi sarson (*Brassica napus*). In India, it contributes nearly 80% of the total rabi oilseed production. Area under rapeseed mustard is 6.3 million ha with a production of 7.4 metric tonnes and productivity of 11.76 q/ha. (Directorate of Rapeseed Mustard Research, 2013). In terms of rapeseed mustard productivity, global ranking of India is 28th. There is variation in the production and productivity of rapeseed mustard in different states. Indian mustard is an important oilseed crop of Indian subcontinent contributing more than 80 per cent of the total rapeseed-mustard production in India (Meena et al., 2014). Mustard production in India stands in between 8-9 million tons with a significant growth in between 2000 and 2019. In India, major production regions of Mustard are Rajasthan, Haryana, Uttar Pradesh, and Madhya Pradesh while the major consumption (as raw pellets) regions are Rajasthan, Uttar Pradesh, Haryana, and Punjab. Being a major rabi (winter season) oilseed crop with advantage of soil moisture conserved during monsoon, it has greater potential to increase the availability of edible oil from domestic production. The highest productivity states are Haryana (2058 kg/ha), Gujarat (1745 kg/ha), Rajasthan (1720 kg/ha), Punjab (1523), U.P. (1483) and M.P. (1422) with overall national yield of 1499 kg/ha. (Directorate of Economics & Statistics, DAC&FW). In Maharashtra state, rapeseed mustard production scenario is not very encouraging despite its paramount importance for human beings and animals. The productivity of rapeseed mustard

in J&K is 6.98 q/ha. (Anonymous, 2013), which is far less than the national average. Adequate knowledge about different production recommendations of rapeseed mustard crop is must on the part of farmers to increase its productivity so that existing scenario of total oilseed production may be changed satisfactorily in general and rapeseed mustard in particular. Evidently this knowledge assessment requires an appropriate measurement tool such as a cognitive scale. (Raj kamal, 2001). Therefore a cognitive test to measure the knowledge of farmers about different production recommendations of rapeseed mustard crop was developed.

Research Methodology

Frontline Demonstrations (CFLDs) were conducted by Krishi Vigyan Kendra, Kaneri, Kolhapur District, Maharashtra with the latest improved crop production technologies in Mustard during *rabi* seasons i.e. from 2021-22 to 2022-23. The FLDs were conducted in five selected talukas in Kolhapur District i.e. Chandgad, Gadhinglaj, Kagal, Karveer, and Hathkanagale of different farming situations. The beneficiaries were selected through Participatory Rural Appraisal (PRA) technique, baseline survey, later active meetings and group discussions. A total of 150 demonstrations were conducted in two consecutive *rabi* seasons i.e. from 2021-22 (50 No.) and 2022-23 (100 No.).

The percent yield comparison of improved practice with local check, district and state averages were calculated and also assessed the yield impact, impact of adoption and horizontal area spread. The technology gap, extension gap, technology index, and economic parameters were compared with farmers' practice.

Table-1 : Technology intervention and farmer practices under FLD on Improved variety of Mustard.

Particulars	Technological intervention	Existing practices
Variety	NRCHB 101	Local or other small grain, low yielding
Land preparation	Three ploughing and pudling	Three ploughing and pudling
Seed rate	4-5 kg/ha	5-6 kg/ha
Seed treatment	Trichoderma viride @ 4 g/kg of seeds	-
Transplanting	Manual	Manual
Fertilizer dose	80: 40: 30 Kg NPK/ha Based on soil test value	50:25:20 Kg NPK/ha
Plant protection	Need based IPM	Full

Table-2 : Performance of improved technology on pod yield, extension gap, technology gap and technology index in Mustard during rabi 2021-22 to 2022-23.

Year	No. of Demos	Variety		Mean Yield (Kg/ha)		Increase of yield over the control (%)	Extension Gap (Kg/ha)	Technology Gap (Kg/ha)	Technology Index (Kg/ha)
		Improved Practices	Farmers' Practices	Improved Practices	Farmers' Practices				
2021-22	50	NRCHB 101	Local	1183.83	982.77	20.45	201.06	252.67	17.58
2022-23	100	NRCHB 101	Local	1136.27	998.24	13.76	138.03	300.23	20.90
Mean	150	Average		1160.05	990.50	17.10	169.54	276.45	19.24

Table-3 : Impact of improved technologies on economics of Mustard during rabi 2021-22 to 2022-23.

Year	Gross Return (Rs./ha)		Cost of Cultivation (Rs./ha)		Net Return (Rs./ha)		B:C Ratio		Additional Net Monitory Return (Rs/ha)
	Improved Practices	Farmers' Practices	Improved Practices	Farmers' Practices	Improved Practices	Farmers' Practices	Improved Practices	Farmers' Practices	
2021-22	60375.67	50121.55	26715	28153	33660.67	21968.55	2.59	1.78	11691.45
2022-23	57486.24	53146.45	21459	37264	36027.25	15882.45	2.68	1.42	20144.80
Average	58930.95	51634.00	24087	32708.5	34843.96	18925.5	2.63	1.60	15918.12

$$\text{Impact yield} = \frac{\text{Yield of Improved practice} - \text{Yield of Farmer's practice}}{\text{Yield of Farmers' practice}} \times 100$$

Extension gap = Improved practice Yield – Farmers' practice Yield

Technology Gap= Potential Yield-Improved Yield

Technology Gap

$$= \frac{\text{Potential Yield} - \text{Improved Practice Yield}}{\text{Potential Yield}} \times 100$$

Results and Discussion

Adoption gap : The adoption gap is an important factor influencing productivity of Mustard. The yield gap analysis was evaluated through extension gap, technology gap and technology index. The extension gap was ranged from 138.03 to 201.06 kg/ha during the investigation period with an average of 169.54 kg/ha during two consecutive years (Table-1). Need arisen to educate the farmers on adoption of improved technologies as a wide gap between improved practice vs farmers' practice was observed. The technology gap varied from 252.67 to 300.23 kg/ha during the study period (Table 2). The technology gap was higher and reflecting on farmers' due to non-cooperation on demonstration of improved

technologies and poor extension activities. This might be attributed to different parameters, viz. soil fertility status, crop suitability, and variations among dates of sowing and weather parameters. Similar observations were reported by Kumbhare et al., (2014) and Nain et al., (2015) Strengthening of extension programs and location-specific on-farm research, encouragement and adoption of the improved package of practices lower the technology gap.

The technology index is dependent on the technology gap, and it is expressed in percentage (%). The higher value of technology index shows lower adoption of improved technologies by the farmers. The technology index of two years in demonstrations ranged from 17.58 to 20.90 per cent with an average of 19.24 per cent (Table 2). Timely and need based suggestions by KVK scientists, extension personnel, favorable climatic conditions and low incidence of pests and diseases favoured lower technology index. These findings were in conformity with Tiwari et al., (2017); Samui et al., (2000) in mustard, and Shekhawat et. al. (2012).

Economic Returns : The economics returns mainly depend on yield, variable cost, and fluctuations between minimum support price and market price. The values of input cost and labour wages varied from time to time. The higher average cost of cultivation (Rs. 24,087/ha), gross

returns (Rs. 58,930.95/ha) and net returns (Rs. 34843.96/ha) were recorded in improved practices with an average benefit-cost ratio of 2.63 when compared to farmers' practice (Rs. 32,708.5, 51634.00 and 18925.5/ha, respectively) with an average benefit-cost ratio of 1.6. These results were at par with Patil, et al., (2018) & Kumar et al., (2022) who reported the higher net returns and high benefit cost ratio in groundnut. Further, it was observed that on the average of two years, net returns of Rs. 15918.12/ha in improved practice were observed (Table 3). These results were in conformity with that of Chaudhary et al., (2018) & Kalita, et al., (2019); and Sangwan et.al., (2021) who observed higher benefit-cost ratio through improved technologies in Mustard.

Conclusions

The crop productivity and economic returns of mustard crop can be increased with the use of scientific production and protection technologies. The enhanced benefit cost ratio, explained the economic viability of the demonstrations and was convincing for the farmers to adopt the intervention. This study observed that FLD programmes were very effective in motivating and changing the attitude of other farmers to adopt improved cultivation practices and crop management. Moreover, more training and area under cultivation need to increase. The farmers through different educational and extension methods need to reduce the extension gap for better mustard production in the Kolhapur District.

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A Cross-Sectional Study of Climate-Smart Agriculture Adoption and Disaster Resilience among Smallholder Farmers in Rajasthan, India : A Survey-Based Approach

Shailendra Singh Shekhawat¹, Dinesh Acharya² and P. Bishnoi¹

¹Centre for Disaster Management Technology for Animals, Rajasthan University of Veterinary and Animal Sciences, Bikaner

²Livestock Feed Resource Management and Technology Centre, Rajasthan University of Veterinary & Animal Sciences, Bikaner

*Corresponding Author Email : shekhawatramsara@gmail.com

Abstract

This research paper investigates the adoption of Climate-Smart Agriculture (CSA) practices and their impact on disaster resilience among smallholder farmers in Rajasthan, India, employing a survey-based approach. With agriculture in India facing increasing challenges due to climate change, CSA has emerged as a critical strategy to enhance sustainability and resilience in this sector. The primary objectives of this study were to assess the demographic factors influencing CSA adoption, examine the relationship between CSA knowledge and practices, and analyze the impact of CSA adoption on disaster resilience. The research employed a stratified random sampling technique to collect data through online surveys and in-person questionnaires from a sample of 500 smallholder farmers in Rajasthan. The key findings of this study reveal that age, education, landholding size, and monthly income significantly influence CSA adoption and knowledge. Older and more educated farmers tend to have higher CSA knowledge, while larger landholders and higher-income individuals are more likely to adopt CSA practices. Moreover, our research indicates a positive correlation between CSA adoption and disaster resilience, with farmers practicing CSA exhibiting greater resilience to climate-related challenges. The implications of these findings underscore the importance of targeted education, support for small landholders, income enhancement initiatives, and inter-generational knowledge transfer. Policymakers and businesses can utilize these insights to develop more effective strategies to promote CSA adoption, enhance disaster resilience, and ensure the sustainability of agriculture in the face of climate change.

Key words : Climate-smart agriculture, disaster resilience, smallholder farmers, Rajasthan, India, demographic factors.

Introduction

Climate change poses significant challenges to agriculture, particularly for smallholder farmers in developing countries like India. Climate-Smart Agriculture (CSA) has emerged as a crucial approach to addressing these challenges. CSA aims to increase agricultural productivity sustainably, enhance resilience to climate change, and reduce or remove greenhouse gases where possible. In India, agriculture is not only a source of livelihood for millions but also a critical component of the economy. The advent of climate change has intensified issues like water scarcity, erratic weather patterns, and increased the occurrence of pests and diseases. This situation is especially acute in states like Rajasthan, where agriculture is predominantly rainfed and highly susceptible to climatic variations. Studies like Kakraliya et al. (2022) have emphasized the need for energy and economic efficiency in CSA practices in India.

CSA practices in India have evolved over time, incorporating traditional knowledge with modern technology. Efforts like those described by Khan et al. (2022) in promoting CSA through policies and schemes provide insights into the strategic overview of CSA implementation. In Rajasthan, the adoption of CSA

practices among smallholder farmers is varied and influenced by multiple factors, including socio-economic conditions, access to resources, and awareness levels. The work of Patra and Babu (2022) provides evidence from Nagaland State, India, showing the institutional and policy processes necessary for effective CSA implementation.

The significance of this study lies in its focus on the cross-sectional analysis of CSA adoption and disaster resilience among smallholder farmers in Rajasthan. It addresses a critical gap in understanding how these farmers, who are at the frontline of climate change impacts, are adapting to these changes through CSA practices. This study is pertinent, considering the increasing importance of sustainable agriculture practices in the face of global climate change. Globally, the adoption of CSA is seen as a key strategy for achieving food security under changing climate conditions. As Devi (2023) points out, smart agriculture is vital for climate change adaptation, emphasizing the need for innovative approaches in agriculture.

In conclusion, the adoption of Climate-Smart Agriculture practices is a critical pathway for enhancing the resilience of smallholder farmers to climate change, particularly in regions like Rajasthan, India. This study

seeks to contribute to the growing body of knowledge in this area, providing insights into the effectiveness and challenges of CSA in improving disaster resilience among these farmers. The findings from this study are expected to be beneficial not only for policymakers and agricultural practitioners in India but also for the global community committed to sustainable agricultural practices and food security.

Review of Scholarly Works

The study of Climate-Smart Agriculture (CSA) and its impact on smallholder farmers' resilience to climate change has generated extensive research, offering diverse perspectives and findings.

Mafwolo et al. (2023) conducted a study in Dodoma Region, focusing on smallholder farmers' resilience to climate change shocks. Using a mixed-method approach that combined surveys and focus group discussions, they examined the adaptive strategies employed by farmers in response to climate variability. The key findings highlighted that while farmers were aware of changing climate patterns, their adaptive capacities were limited due to socio-economic constraints and lack of access to climate-smart technologies. Teklu et al. (2023) explored the effectiveness of CSA innovations in enhancing climate resilience among farmers in the Blue Nile Highlands of Ethiopia. Their methodology included quantitative surveys and regression analysis to assess the impact of CSA practices on crop yield and income stability. The results indicated a positive correlation between the adoption of CSA practices and increased resilience to climate impacts, suggesting that CSA innovations can significantly contribute to sustainable agriculture in vulnerable regions.

Patel and Kumar (2023) discussed climate-resilient agriculture practices as the future of farming. Their research, which used a literature review methodology, emphasized the need for innovative agricultural strategies that could adapt to and mitigate climate change impacts. They found that practices such as diversified cropping, water-efficient irrigation, and improved soil management could significantly enhance farmers' resilience. In India, Victoria Devi (2022) analyzed farmers' resilience to climate change in the North Eastern Hill Region. Employing a case study approach with qualitative interviews, the study revealed that despite the high vulnerability to climate risks, farmers' adaptive capacities were enhanced through traditional knowledge and community-based adaptation strategies. However, there was a need for more structured support and access to climate-smart resources.

Awiti et al. (2022) investigated the cost structure of climate-smart crop diversification among smallholder farmers in Western Kenya. Their research employed econometric models to analyze the financial implications of adopting diversified crop systems. The study found that while initial costs were high, the long-term benefits in terms of resilience and income stability were significant, advocating for policy support in facilitating CSA adoption. Phiri et al. (2022) explored climate-smart cropping system solutions for smallholder farmers. Through field experiments and participatory approaches, they identified several CSA practices that could improve crop yield and sustainability. The study underscored the importance of integrating indigenous knowledge with scientific research to develop effective climate-smart solutions.

Devi (2023) emphasized the role of innovative agricultural practices in adapting to climate change in his work "Toward Smart Agriculture for Climate Change Adaptation." The study, primarily a theoretical exploration, argued for the integration of smart technologies in agriculture to enhance productivity and sustainability in the face of climatic challenges. Ravi Kumar et al. (2023) provided empirical evidence on the determinants of climate change adaptation strategies in South India. Using statistical analysis of survey data, their study identified key factors such as education, access to information, and institutional support that influenced the adoption of CSA practices. The findings suggested that targeted interventions are required to enhance the adaptive capacities of farmers in different socio-economic contexts.

Mahto et al. (2021) proposed Agrivoltaics as a climate-smart agriculture approach for Indian farmers. Their study, based on simulation models and cost-benefit analysis, demonstrated how integrating solar photovoltaics with farming could increase land productivity and provide renewable energy sources. This approach, they argued, could revolutionize agricultural practices in solar-rich countries like India. Khoza et al. (2021) presented a gender-sensitive adoption framework for CSA among smallholder farmers. Through qualitative research involving interviews and focus groups, the study highlighted the need for gender-responsive strategies in CSA adoption. It underscored the importance of considering the unique challenges and roles of women in agriculture to ensure effective and inclusive resilience-building.

These studies collectively deepen our understanding of CSA's role in enhancing smallholder farmers' resilience, offering insights into the varied methodologies,

challenges, and opportunities in implementing CSA practices globally and particularly in India.

Identification of Literature Gap

While the existing literature has provided valuable insights into the impact of Climate-Smart Agriculture (CSA) on smallholder farmers' resilience to climate change, there is a noticeable gap in research specifically addressing the cross-sectional analysis of CSA adoption and disaster resilience among smallholder farmers in Rajasthan, India. This gap is significant for several reasons.

Firstly, Rajasthan, with its arid and semi-arid climate, faces unique challenges in agriculture due to climate change. The state is characterized by rainfall variability, water scarcity, and extreme temperatures, making smallholder farmers particularly vulnerable to climate-related disasters. Understanding how CSA practices are being adopted and their impact on disaster resilience in this context is crucial, as it can provide region-specific insights that differ from those in other regions of India.

Secondly, while several studies have explored CSA adoption and its impact on resilience in different parts of India and globally, there is a need for research that focuses on the socio-economic and contextual factors influencing CSA adoption and its implications for disaster resilience among smallholder farmers in Rajasthan. The state's diverse agro-climatic zones and socio-economic conditions demand a localized and comprehensive analysis.

Thirdly, Rajasthan is a significant contributor to India's agricultural production, especially in crops like wheat, mustard, and pearl millet. Ensuring the resilience of smallholder farmers in the state is not only essential for their livelihoods but also for food security at the national level. Therefore, filling this literature gap is of paramount importance to inform policy decisions and interventions that can enhance the adaptive capacity of farmers in Rajasthan and, by extension, contribute to national food security and sustainable agriculture.

In summary, this research paper aims to address the literature gap by conducting a cross-sectional study in Rajasthan, India, to investigate the adoption of Climate-Smart Agriculture practices among smallholder farmers and its impact on disaster resilience. The significance of this research lies in its potential to provide region-specific insights, inform targeted interventions, and contribute to the broader discourse on CSA's role in building resilience among vulnerable farming communities in the face of climate change.

Research Methodology

Data Collection Source

Element	Description
Sample Size	500 smallholder farmers
Source of Data	Online Surveys and In-Person Questionnaires
Geographical Area	Rajasthan, India
Study Population	Smallholder farmers in Rajasthan
Sampling Technique	Stratified Random Sampling
Data Collection Time	July 2023 to September 2023
Data Collector	Trained survey enumerators
Data Collection Tool	Structured Questionnaire (See Appendix: Questionnaire)
Pilot Study	Conducted on a group of 30 individuals with similar demographics to pretest the questionnaire for clarity, reliability, and relevance. Necessary adjustments were made based on pilot study feedback.

Data Analysis Tools : The data collected through the survey will be analyzed using the following methods :

1. Frequency Count and Percentages : This analysis will be used to determine the frequency of responses to each question in the structured questionnaire. It will provide a comprehensive overview of smallholder farmers' preferences, perceptions, and practices related to Climate-Smart Agriculture (CSA) adoption and disaster resilience.

2. Cross-Tabulation Analysis : Cross-tabulation analysis will be employed to examine the relationships between different survey responses and demographic factors such as age, education level, landholding size, and income. This analysis will help identify any significant associations between demographic characteristics and CSA adoption or disaster resilience levels among the smallholder farmers in Rajasthan.

These analytical methods will allow us to gain valuable insights into the factors influencing CSA adoption and its impact on disaster resilience among smallholder farmers in Rajasthan, India. The data analysis will be conducted using statistical software to ensure accuracy and reliability in our findings.

Results and Analysis

Table-2 shows the results of the pilot testing of the questionnaire, indicating the Cronbach's alpha values for each variable, demonstrating that all measures were found reliable with Cronbach's alpha values exceeding 0.70.

Table-1 : Demographic Profile of the Sample.

Demographic Variable	Frequency (n)	Percentage (%)
Age Group (years)		
- 18-30	120	24%
- 31-45	180	36%
- 46-60	140	28%
- 61 and above	60	12%
Education Level		
- Primary	50	10%
- Secondary	120	24%
- Higher Secondary	180	36%
- Graduate and above	150	30%
Landholding Size (acres)		
- <1	90	18%
- 1-2	140	28%
- 2-5	180	36%
- >5	90	18%
Monthly Income (INR)		
- <5,000	60	12%
- 5,000-10,000	140	28%
- 10,000-20,000	160	32%
- >20,000	140	28%

Table-2 : Results of Pilot Testing of the Questionnaire/Instrument.

Variables	Cronbach's Alpha	No. of Items
CSA Knowledge	0.78	10
CSA Adoption Practices	0.84	12
Disaster Resilience	0.79	8

Table-3 : Relationship Between CSA Knowledge and Demographic Factors.

Demographic Variable	CSA Knowledge Low (%)	CSA Knowledge Moderate (%)	CSA Knowledge High (%)
Age Group (years)			
- 18-30	15%	40%	45%
- 31-45	10%	35%	55%
- 46-60	20%	45%	35%
- 61 and above	25%	40%	35%
Education Level			
- Primary	40%	30%	30%
- Secondary	25%	35%	40%
- Higher Secondary	20%	40%	40%

Table-3 illustrates the relationship between CSA Knowledge and demographic factors. It shows the distribution of respondents with low, moderate, and high CSA knowledge levels within different age groups and education levels.

Table-4 : Relationship Between CSA Adoption Practices and Landholding Size.

Landholding Size (acres)	CSA Adoption Low (%)	CSA Adoption Moderate (%)	CSA Adoption High (%)
<1	40%	30%	30%
1-2	25%	35%	40%
2-5	15%	40%	45%
>5	10%	30%	60%

Table-4 presents the relationship between CSA Adoption Practices and landholding size, demonstrating the distribution of respondents with low, moderate, and high CSA adoption practices among different landholding size categories.

Table-5 : Relationship Between Disaster Resilience and Monthly Income.

Monthly Income (INR)	Low Disaster Resilience (%)	Moderate Disaster Resilience (%)	High Disaster Resilience (%)
<5,000	35%	50%	15%
5,000-10,000	25%	45%	30%
10,000-20,000	15%	35%	50%
>20,000	10%	30%	60%

Table-5 displays the relationship between Disaster Resilience and monthly income, showing the distribution of respondents with low, moderate, and high levels of disaster resilience within different income brackets.

Table-6 : Relationship Between CSA Adoption Practices and Education Level.

Education Level	CSA Adoption Low (%)	CSA Adoption Moderate (%)	CSA Adoption High (%)
Primary	45%	30%	25%
Secondary	30%	40%	30%
Higher Secondary	20%	35%	45%
Graduate and above	10%	25%	65%

Table-6 reveals the relationship between CSA Adoption Practices and education level, showcasing the distribution of respondents with low, moderate, and high CSA adoption practices among different education levels.

Table-7 : Relationship Between CSA Knowledge and Landholding Size.

Landholding Size (acres)	CSA Knowledge Low (%)	CSA Knowledge Moderate (%)	CSA Knowledge High (%)
<1	30%	35%	35%
1-2	20%	40%	40%
2-5	15%	35%	50%
>5	10%	30%	60%

Table-8 outlines the relationship between CSA Knowledge and monthly income, showcasing the distribution of respondents with low, moderate, and high CSA knowledge levels within different income brackets.

Table-8 : Relationship Between CSA Knowledge and Monthly Income.

Monthly Income (INR)	CSA Knowledge Low (%)	CSA Knowledge Moderate (%)	CSA Knowledge High (%)
<5,000	35%	45%	20%
5,000-10,000	30%	40%	30%
10,000-20,000	20%	35%	45%
>20,000	10%	25%	65%

Table-9 demonstrates the relationship between Disaster Resilience and age groups, displaying the distribution of respondents with low, moderate, and high levels of disaster resilience within different age categories.

Table-9 : Relationship Between Disaster Resilience and Age Group.

Age Group (years)	Low Disaster Resilience (%)	Moderate Disaster Resilience (%)	High Disaster Resilience (%)
8-30	30%	40%	30%
31-45	20%	35%	45%
46-60	15%	30%	55%
61 and above	10%	20%	70%

These tables offer a comprehensive overview of the relationships between various survey responses and demographic factors, allowing for a deeper understanding of how these factors interplay in the context of Climate-Smart Agriculture (CSA) adoption, knowledge, and disaster resilience among smallholder farmers in Rajasthan, India.

Discussion

In this section, we will analyze and interpret the results obtained from our study on Climate-Smart Agriculture (CSA) adoption and disaster resilience among smallholder farmers in Rajasthan, India. We will also explore the implications of these results for policy, practice, and future research.

Demographic Profile and CSA Knowledge : Our study revealed that age and education levels have a significant influence on CSA knowledge. Older farmers tended to have higher levels of CSA knowledge, possibly due to their accumulated experience. Furthermore, those with higher education levels were more likely to possess better knowledge of CSA practices. This suggests that targeted educational programs and awareness campaigns may be effective in enhancing CSA knowledge among younger and less educated farmers.

CSA Adoption Practices and Landholding Size : The findings indicate a strong association between CSA adoption practices and landholding size. Farmers with larger landholdings were more inclined to adopt CSA

practices, possibly because they had the resources and capacity to implement these practices on a larger scale. Smaller landholders may benefit from support programs tailored to their specific needs to encourage CSA adoption.

Disaster Resilience and Monthly Income : A notable relationship emerged between disaster resilience and monthly income. Farmers with higher incomes displayed greater disaster resilience. This suggests that economic stability can enhance a farmer's ability to withstand climate-related challenges. To bolster disaster resilience among low-income farmers, income-generating initiatives and social safety nets may be necessary.

CSA Knowledge and Landholding Size / Monthly Income : Interestingly, CSA knowledge was associated with both landholding size and monthly income. Farmers with larger landholdings and higher incomes tended to have better CSA knowledge. This underscores the importance of making CSA information and training accessible to smaller landholders and those with limited resources to ensure equitable CSA adoption and disaster resilience.

Disaster Resilience and Age Group : Age was strongly linked to disaster resilience, with older farmers displaying higher levels of resilience. This may be attributed to their experience in dealing with climate variability over the years. Younger farmers might benefit from mentorship programs that transfer traditional knowledge and adaptive strategies from older generations.

Implications

1. Targeted Education and Awareness Campaigns : Policymakers and agricultural extension services should design education and awareness campaigns that cater to the specific needs of younger and less educated farmers. These programs should emphasize the benefits of CSA practices and provide practical guidance on their implementation.

2. Support for Small Landholders : To promote CSA adoption among small landholders, government and non-governmental organizations can offer financial incentives, technical assistance, and access to resources like improved seeds and climate-resilient technologies.

3. Income Enhancement Initiatives : Initiatives that improve farmers' income, such as market access, credit facilities, and income diversification opportunities, can help enhance their disaster resilience. This, in turn, can mitigate the adverse effects of climate-related shocks.

4. Inter-generational Knowledge Transfer : Encouraging mentorship and knowledge transfer programs between older and younger farmers can help

bridge the resilience gap among different age groups. It can also preserve valuable traditional knowledge.

5. Customized Interventions : Policymakers should recognize that a one-size-fits-all approach may not be effective in promoting CSA adoption and disaster resilience. Customized interventions based on demographic characteristics can yield more targeted and impactful results.

Our study provides valuable insights into the complex relationships between demographic factors, CSA knowledge, adoption practices, and disaster resilience among smallholder farmers in Rajasthan, India. By understanding these dynamics, policymakers and practitioners can formulate more effective strategies to promote CSA adoption and enhance disaster resilience, ultimately contributing to the sustainability of agriculture in the face of climate change. Future research should delve deeper into the causal mechanisms behind these relationships and explore the long-term impacts of CSA adoption on disaster resilience in different regions and contexts.

Conclusions

In conclusion, our study on Climate-Smart Agriculture (CSA) adoption and disaster resilience among smallholder farmers in Rajasthan, India, has yielded several key findings that contribute to our understanding of how demographic factors influence CSA practices and resilience. These findings align with and expand upon existing research in the literature.

Our study found that age and education levels play crucial roles in CSA knowledge, with older and more educated farmers displaying higher levels of awareness. These results corroborate previous studies highlighting the importance of education in promoting CSA practices. Moreover, our research showed that landholding size and income significantly influence CSA adoption practices and disaster resilience. Larger landholders and those with higher incomes were more likely to adopt CSA practices and exhibit greater resilience.

The implications of these findings are broad and have significant ramifications for businesses and policymakers. Firstly, targeted educational programs and awareness campaigns should be designed to bridge knowledge gaps among younger and less educated farmers, ensuring that CSA practices are accessible to all. Policymakers should also focus on supporting small landholders through financial incentives, technical assistance, and resource access, promoting equitable CSA adoption.

To enhance disaster resilience, income-enhancing

initiatives and safety nets are essential, especially for low-income farmers who are vulnerable to climate-related shocks. Businesses can play a role in providing market access and credit facilities to improve farmers' economic stability. Additionally, fostering inter-generational knowledge transfer through mentorship programs can help bridge the resilience gap among different age groups, preserving valuable traditional knowledge.

In summary, our study emphasizes the need for nuanced and targeted approaches to promote CSA adoption and enhance disaster resilience among smallholder farmers in Rajasthan, India. These findings underscore the importance of aligning policies and interventions with the specific demographic characteristics of the farming population. By addressing these needs, businesses and policymakers can contribute to the long-term sustainability of agriculture in the face of climate change, ultimately ensuring food security and livelihoods for millions of farmers in the region.

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Enhancing Disaster Preparedness and Response through Technology Integration in India

Shailendra Singh Shekhawat¹, Dinesh Acharya² and P. Bishnoi¹

¹Centre for Disaster Management Technology for Animals, Rajasthan University of Veterinary and Animal Sciences, Bikaner

²Livestock Feed Resource Management and Technology Centre, Rajasthan University of Veterinary & Animal Sciences, Bikaner

*Corresponding Author Email : shekhawatramsara@gmail.com

Abstract

This research paper investigates the integration of technology into disaster management in India with a focus on addressing regional disparities and enhancing community resilience. The primary research objectives were to identify the unique challenges and opportunities of technology integration in disaster management across different Indian regions and to provide recommendations for improving disaster preparedness and response. The research methodology employed a qualitative case study design, with data collected through field surveys and interviews conducted in Northern India, Coastal India, and Northeast India. Content analysis was used to analyze the collected data. Key findings include variations in disaster vulnerabilities, technology infrastructure availability, community awareness, and government investment across regions. Region-specific challenges such as the digital divide and infrastructure limitations were identified, along with success stories showcasing the potential of technology integration. Recommendations were provided to address these challenges and leverage opportunities for enhancing disaster resilience. The implications of this research highlight the importance of tailoring technology solutions to region-specific needs, adopting a community-centric approach, increasing government commitment to technology integration, and addressing common challenges. By embracing these findings, India can develop a more comprehensive and tailored approach to technology integration in disaster management, ultimately strengthening its resilience to disasters and reducing vulnerability.

Key words : Disaster management, technology integration, india, regional disparities, community resilience, government investment.

Introduction

The integration of technology into disaster preparedness and response in India marks a significant advancement in managing and mitigating the impacts of natural calamities. India, with its diverse geographical and climatic conditions, has long been vulnerable to a variety of disasters including floods, cyclones, earthquakes, and droughts. The management of these disasters has traditionally been reactive, focusing on relief and rehabilitation post-event. However, the last few decades have witnessed a paradigm shift towards a more proactive approach, emphasizing disaster preparedness and response, where technology plays a crucial role (Rao, 2020).

The scope of disaster management in India is broad, ranging from early warning systems to recovery and rehabilitation efforts post-disaster. The integration of Information and Communication Technology (ICT) has been a game changer, enhancing the efficiency and effectiveness of disaster management systems. Advanced technologies like Geographic Information Systems (GIS), remote sensing, and mobile applications are increasingly being employed to improve the resilience of communities to disasters (Sakurai & Shaw, 2021). The

use of technology in disaster management not only aids in efficient resource allocation and response but also in building sustainable mechanisms for risk reduction and community resilience.

Despite the progress, the application of technology in disaster management in India faces several challenges. The digital divide, infrastructural limitations, and a general lack of awareness among the population hinder the full realization of technology's potential in this domain. Addressing these issues requires a multi-dimensional approach, involving collaboration between the government, private sector, and civil society (2022).

The Indian government has made significant strides in incorporating technology into its disaster management framework. The establishment of the Indian Ocean Tsunami Warning System has been a notable achievement in reducing the vulnerability of coastal communities to tsunamis. Moreover, the creation of the National Disaster Management Authority (NDMA) and the integration of technology into its operational framework signify a commitment to a technology-driven disaster management system. These efforts are crucial in a country where the frequency and intensity of natural disasters are expected to increase due to climate change and other environmental factors.

The role of technology in enhancing disaster preparedness and response is multifaceted. It involves not just the development and deployment of technological tools but also the creation of a conducive environment for their effective utilization. This includes building robust infrastructure, ensuring widespread access to technology, and fostering a culture of innovation and adaptability. Moreover, it is imperative to tailor technological solutions to the specific needs and contexts of different regions and communities within India.

The significance of this research lies in its potential to contribute to ongoing efforts to enhance disaster preparedness and response in India through technology integration. By examining existing systems, identifying gaps, and proposing innovative solutions, this study aims to strengthen India's resilience to disasters and reduce the vulnerability of its population. The research also seeks to provide a comprehensive understanding of the current state of technology integration in disaster management in India, offering insights into best practices and lessons learned from both national and international experiences.

In conclusion, the integration of technology in disaster management in India presents both challenges and opportunities. As India continues to confront the reality of natural disasters, the effective utilization of technology becomes not just an option but a necessity. This paper seeks to explore this necessity, aiming to provide actionable insights and recommendations for enhancing disaster preparedness and response in India. Through a detailed analysis of the current landscape and potential pathways forward, the research will contribute to the development of a more resilient and responsive disaster management system in India, leveraging the power of technology to protect lives and livelihoods.

Literature Review

Review of Scholarly Works : The integration of technology in disaster management, particularly in the Indian context, has been extensively studied in recent years. This literature review examines relevant scholarly works that contribute significantly to understanding and advancing this field:

Srivastava (2009) focuses on the strategic use of technology for disaster management and poverty alleviation. Employing a qualitative approach, the study analyzes various technological interventions, particularly in satellite and communication technologies, and their impact on disaster preparedness and response. The key finding suggests that the effective use of technology not only enhances disaster response capabilities but also plays a significant role in poverty reduction by mitigating disaster risks.

Jha, Basu, & Basu (2016) examine policy changes in disaster management by studying responses to two major cyclones in India. Utilizing a comparative analysis method, the study reveals how policy and technological advancements post the 1999 Odisha cyclone led to significantly improved responses during the 2013 Phailin cyclone. The findings highlight the importance of policy evolution in strengthening disaster preparedness and response, underscoring the role of technology in effective policy implementation.

In Sharma's (2017) study, a comprehensive analysis of current technological applications in Indian disaster management is presented. The methodology involves reviewing existing literature and technology applications in various disaster scenarios. The study finds that while there is a significant uptake of technologies such as GIS, remote sensing, and early warning systems, there are gaps in implementation, especially in rural and remote areas.

Usman (2017) discusses an integrated approach to disaster risk management, emphasizing prediction, prevention, and preparedness. The study employs a case-study methodology, analyzing specific instances of disaster management in India. Key findings reveal that an integrated approach, bolstered by technological advancements, can significantly enhance disaster response efficiency and effectiveness.

Pal & Tarun (2018) focus on national-level disaster risk governance. Their research method involves an evaluative analysis of India's national disaster management framework. The study finds that rapid response capabilities have been substantially improved through technological integration, but challenges in coordination and resource allocation persist at the national level.

Sud (2018) explores the role of heavy machinery in disaster management. By reviewing case studies and current practices, the study highlights the critical role heavy machinery plays in rescue operations and recovery processes. The findings emphasize the need for better integration and management of such resources in disaster scenarios.

Rao (2020) offers an in-depth look at ICT infrastructure in Indian disaster management. Using a mixed-methods approach, combining both qualitative and quantitative data, the study underscores the transformative impact of ICT in enhancing disaster response and preparedness. A key finding is the need for continuous improvement and updating of ICT infrastructure to keep pace with technological advancements and changing disaster profiles.

Table-1 : Demographic Profile of the Sample.

Demographic Variable	Frequency (n)	Percentage (%)
Age Group (years)		
- 18-30	120	24%
- 31-45	180	36%
- 46-60	140	28%
- 61 and above	60	12%
Education Level		
- Primary	50	10%
- Secondary	120	24%
- Higher Secondary	180	36%
- Graduate and above	150	30%
Landholding Size (acres)		
- <1	90	18%
- 1-2	140	28%
- 2.5-5	180	36%
- >5	90	18%
Monthly Income (INR)		
- <5,000	60	12%
- 5,000-10,000	140	28%
- 10,000-20,000	160	32%
- >20,000	140	28%

Table-2 : Results of Pilot Testing of the Questionnaire/Instrument.

Variables	Cronbach's Alpha	No. of Items
CSA Knowledge	0.78	10
CSA Adoption Practices	0.84	12
Disaster Resilience	0.79	8

Table-3 : Relationship Between CSA Knowledge and Demographic Factors.

Demographic Variable	CSA Knowledge Low (%)	CSA Knowledge Moderate (%)	CSA Knowledge High (%)
Age Group (years)			
- 18-30	15%	40%	45%
- 31-45	10%	35%	55%
- 46-60	20%	45%	35%
- 61 and above	25%	40%	35%
Education Level			
- Primary	40%	30%	30%
- Secondary	25%	35%	40%
- Higher Secondary	20%	40%	40%

Lastly, the 2022 study (DOI) presents a vision of achieving disaster resilience through information technology. This conceptual analysis highlights how innovative IT solutions can revolutionize disaster management. The study underscores the potential of IT in

creating more resilient communities but also cautions about overreliance and the need for holistic disaster management strategies.

Collectively, these studies provide a comprehensive view of the evolution and current state of technology in disaster management in India. They highlight the progress made, identify challenges and gaps, and offer insights into potential future advancements in this vital field.

Identification of Literature Gap and Significance :

While the existing literature on technology integration in disaster management in India provides valuable insights into various aspects of the field, a notable gap persists in the area of comprehensive, region-specific technological solutions tailored to India's diverse geographical and demographic landscape. Most studies have explored the impact of technology at a broader national or policy level, focusing on the use of technology in disaster response, early warning systems, and policy frameworks. However, there is a lack of in-depth research that delves into the unique challenges faced by different regions within India and how technology can be specifically harnessed to address these challenges.

The significance of addressing this gap is twofold. Firstly, India's geographical diversity results in varying disaster profiles across different states and regions, each with its own set of vulnerabilities and infrastructural limitations. A one-size-fits-all approach to technology integration may not be effective in addressing the specific needs and vulnerabilities of these regions. Therefore, it is essential to conduct research that identifies region-specific challenges and proposes tailored technological solutions.

Secondly, by focusing on regional-specific technology integration, this study can contribute to a more decentralized and community-centric approach to disaster preparedness and response in India. This approach aligns with the principle of subsidiarity, which emphasizes decision-making and actions at the most local level possible. By addressing the technology needs of different regions, this research can empower local communities and authorities to take proactive measures in disaster management, reducing the dependency on centralized agencies and improving overall resilience.

In summary, the identified literature gap pertains to the absence of region-specific technological solutions in disaster management literature for India. This research aims to fill this gap by conducting an in-depth analysis of the technological needs and challenges of different regions within India, providing valuable insights into tailoring technology integration strategies to enhance

disaster preparedness and response at the regional level. This focus on region-specific solutions aligns with the broader objectives of the research paper, as it directly contributes to the goal of enhancing disaster preparedness and response through technology integration in India.

Research Methodology

In this section, we will outline the research design, the source of data, and the data analysis tool being used to gather insights and findings for this research paper.

Table-1 : Research Methodology

Aspect	Description
Research Design	Qualitative Case Study
Data Source	Field Surveys and Interviews
Data Collection Method	Primary Data Collection
Data Analysis Tool	Content Analysis

Research Design : Qualitative Case Study The research design employed for this study is a qualitative case study. This approach allows for an in-depth exploration of specific regions within India to understand the unique challenges they face in disaster management and the potential for technology integration. A case study design is well-suited for investigating real-world phenomena in their natural context and providing rich, context-specific insights.

Data Source : Field Surveys and Interviews Data for this research is primarily sourced through field surveys and interviews conducted in select regions across India. The choice of primary data collection methods is essential to capture real-time and region-specific information related to disaster management practices, technology integration, challenges, and opportunities. Field surveys involve on-site data collection through structured questionnaires and observations, while interviews with key stakeholders, including local authorities, disaster management officials, and community leaders, provide in-depth qualitative insights.

Data Analysis Tool : Content Analysis The data collected from field surveys and interviews will be subjected to content analysis. Content analysis is a systematic method of analyzing qualitative data to identify themes, patterns, and trends within the data. This analysis will involve categorizing and coding the textual data to extract key findings, emerging themes, and insights related to the region-specific challenges in disaster management and the role of technology integration. Content analysis allows for a rigorous examination of qualitative data, ensuring that the research findings are grounded in the data collected.

By employing a qualitative case study design, conducting field surveys and interviews, and applying

content analysis to the collected data, this research aims to provide a detailed and region-specific understanding of the challenges and opportunities associated with technology integration in disaster management in India. This approach aligns with the research objectives and will contribute valuable insights to address the identified literature gap and enhance disaster preparedness and response through technology integration in India.

Results and Analysis

In this section, we present the results of the research, which we have analyzed through data analysis tools. Below are tables that provide specific findings related to the challenges and opportunities of technology integration in disaster management in different Indian regions. Each table is followed by an explanatory paragraph.

Table-1 : Region-wise Disaster Vulnerabilities.

Region	Flood Vulnerability	Cyclone Vulnerability	Earthquake Vulnerability
Northern India	High	Low	Moderate
Coastal India	Moderate	High	Low
Northeast India	High	Moderate	Moderate

Explanation : Table-1 summarizes the disaster vulnerabilities of different regions in India, including Northern India, Coastal India, and Northeast India. These vulnerabilities are categorized into flood, cyclone, and earthquake vulnerabilities. The table provides an overview of the varying degrees of vulnerability across regions, which is crucial for understanding the specific challenges each region faces.

Table-2 : Technology Infrastructure Availability.

Region	Internet Access (%)	Mobile Coverage (%)	GIS Implementation (Yes/No)
Northern India	75%	90%	Yes
Coastal India	65%	85%	No
Northeast India	60%	80%	Yes

Explanation : Table-2 presents information on technology infrastructure availability in the selected regions. It includes data on internet access, mobile coverage, and the implementation of Geographic Information Systems (GIS). These factors influence the readiness of regions to integrate technology into disaster management.

Table-3 : Community Awareness and Preparedness.

Region	Community Awareness (High/Medium/Low)	Disaster Drills (Yes/No)	Early Warning Systems Usage (Yes/No)
Northern India	Medium	Yes	Yes
Coastal India	Low	No	No
Northeast India	High	Yes	Yes

Explanation : Table-3 assesses community awareness and preparedness in the studied regions. It categorizes

community awareness levels as high, medium, or low and provides information on the presence of disaster drills and the usage of early warning systems within the communities.

Table-4 : Government Investment in Technology.

Region	Funding Allocation for Technology (%)	Technology Training (Yes/No)
Northern India	20%	Yes
Coastal India	10%	No
Northeast India	30%	Yes

Explanation : Table-4 examines the government's investment in technology integration for disaster management. It includes data on the percentage of funding allocated for technology and whether technology training programs are provided to government personnel in the regions.

Table-5 : Technology Integration Challenges.

Region	Digital Divide (Yes/No)	Infrastructure Limitations (Yes/No)	Public Awareness (Yes/No)
Northern India	Yes	Yes	No
Coastal India	Yes	Yes	Yes
Northeast India	No	No	No

Explanation : Table-5 highlights the challenges faced in technology integration for disaster management. It identifies the presence of a digital divide, infrastructure limitations, and the level of public awareness as obstacles in the selected regions.

Table-6 : Success Stories of Technology Integration.

Region	Notable Technology Initiatives
Northern India	Mobile Apps for Flood Alerts
Coastal India	Satellite-Based Cyclone Tracking System
Northeast India	Community-Based GIS Mapping

Explanation : Table-6 showcases success stories of technology integration in disaster management from the selected regions. It highlights notable initiatives and technological solutions that have positively impacted disaster preparedness and response.

Table-7 : Recommendations for Technology Integration.

Region	Key Recommendations for Technology Integration
Northern India	Improve Public Awareness, Bridge Digital Divide
Coastal India	Invest in GIS Implementation, Enhance Mobile Connectivity
Northeast India	Strengthen Community-Based Preparedness, Expand Early Warning Systems

Explanation : Table-7 provides key recommendations for technology integration in disaster management based on the findings from the respective regions. These recommendations aim to address the specific challenges and leverage the opportunities identified in the research.

These tables present a comprehensive overview of the results obtained through data analysis tools, offering valuable insights into the challenges and opportunities of technology integration in disaster management across different regions in India. The subsequent discussion section will analyze and interpret these findings in greater detail.

Discussion

In this section, we will analyze and interpret the results presented in Section 4, specifically focusing on how these findings contribute to filling the literature gap identified in Section 2.2. We will also explore the implications and significance of these findings, providing a deeper understanding of technology integration in disaster management in various Indian regions.

The results presented in Section 4 shed light on the region-specific challenges and opportunities associated with technology integration in disaster management across Northern India, Coastal India, and Northeast India. By examining these regions individually, we have addressed the literature gap by providing a detailed understanding of the unique contexts and requirements of each region. Most existing literature tends to adopt a national or policy-level perspective, often overlooking the nuances present at the regional level. Our research rectifies this gap by delving into the specific needs and vulnerabilities of different regions, aligning with the title and methodology of this research paper.

Implications and Significance of Findings

1. Tailored Technology Solutions : The findings highlight the importance of tailoring technology solutions to the unique disaster profiles of each region. For instance, Northern India faces high flood vulnerability, necessitating the development of mobile apps for flood alerts. In contrast, Coastal India benefits from satellite-based cyclone tracking systems due to its high cyclone vulnerability. These tailored solutions are essential for effective disaster preparedness and response.

2. Community-Centric Approach : The research reveals that community awareness and preparedness levels vary significantly across regions. Northeast India exhibits high awareness and disaster drills, while Coastal India lags behind. These disparities underscore the need for a community-centric approach to technology integration, emphasizing community-based GIS mapping and early warning systems.

3. Government Investment : The allocation of government funding for technology integration varies, with Northeast India leading in this regard. These differences

suggest that increased government investment is associated with better technology integration. It is crucial for regions with lower investments, such as Coastal India, to enhance funding allocation to bridge the technology gap.

4. Challenges and Recommendations : The identification of common challenges, such as the digital divide and infrastructure limitations, highlights the need for addressing these barriers to technology adoption. The recommendations provided in Table 7 offer actionable steps for overcoming these challenges, such as improving public awareness and expanding early warning systems.

5. Success Stories : Recognizing successful technology initiatives in different regions underscores the potential for positive outcomes when technology is effectively integrated. These success stories serve as practical examples for other regions and highlight the importance of innovative approaches to disaster management.

6. Decentralized Disaster Management : The findings emphasize the significance of decentralized disaster management, where regions have the autonomy to adapt technology to their specific needs. This approach promotes resilience at the local level and reduces dependence on centralized agencies.

In conclusion, the results and analysis presented in this section not only contribute to filling the literature gap by providing region-specific insights but also offer practical implications and significance for disaster management in India. Tailored technology solutions, community engagement, government investment, addressing challenges, and learning from success stories are essential components of enhancing disaster preparedness and response through technology integration. This research aids in developing a more comprehensive and region-specific approach to technology integration, ultimately strengthening India's resilience to disasters and reducing the vulnerability of its population.

Conclusions

In this study, we have undertaken a comprehensive examination of technology integration in disaster management across different regions in India, addressing the unique challenges and opportunities presented by each. The main findings of this research can be summarized as follows:

Firstly, our investigation has illuminated the varying degrees of disaster vulnerabilities across regions. Northern India faces high flood vulnerability, Coastal India grapples with a high risk of cyclones, and Northeast India contends with multiple vulnerabilities, including

earthquakes. These regional disparities underscore the importance of tailored technology solutions that address specific disaster profiles.

Secondly, we have revealed significant differences in technology infrastructure availability among regions, including internet access, mobile coverage, and GIS implementation. These disparities influence the readiness of regions to integrate technology into disaster management, emphasizing the need for targeted infrastructure development.

Thirdly, our research highlights variations in community awareness and preparedness levels, with some regions exhibiting high levels of awareness and active disaster drills while others lag behind. This underscores the necessity of a community-centric approach to technology integration, where technology is used to empower and engage local communities in disaster preparedness and response.

Fourthly, government investment in technology integration varies, with some regions allocating more funding and providing technology training to their personnel. These differences emphasize the role of government commitment in driving technology integration efforts and improving disaster management capabilities.

Fifthly, we have identified common challenges, such as the digital divide, infrastructure limitations, and public awareness, which hinder technology adoption in disaster management. Addressing these barriers is essential to realizing the full potential of technology.

Lastly, our research has presented success stories of technology integration in disaster management from different regions, demonstrating the positive impact of innovative technological solutions and practices.

The broader implications of this research are significant. By filling the literature gap with region-specific insights, our findings contribute to the development of a more nuanced and tailored approach to technology integration in disaster management in India. This approach recognizes the diverse needs of different regions and aims to bridge the technology divide to improve disaster preparedness and response.

Moreover, our recommendations offer practical guidance for policymakers, disaster management authorities, and communities in enhancing their disaster resilience through technology integration. These recommendations underscore the importance of investing in infrastructure, improving community awareness, and fostering government commitment.

Ultimately, the research underscores the vital role of technology in disaster management and its potential to

protect lives and livelihoods in a disaster-prone country like India. As the frequency and intensity of disasters continue to rise due to climate change and other factors, technology integration becomes not just a necessity but a key driver of resilience and response effectiveness. By embracing region-specific solutions and addressing challenges, India can bolster its disaster management capabilities, reduce vulnerabilities, and better protect its population in times of crisis.

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Molecular Detection of *Phytophthora* Diseases in Crops

Aswathi M.S.* and N.V. Radhakrishnan

Department of Plant Pathology, College of Agriculture, Vellayani, Kerala Agricultural University

*Email : msaswathi95@gmail.com

Abstract

Diseases caused by *Phytophthora* spp. are of great economic importance due to their devastating effects (Rizzo *et al.*, 2005). Molecular methods are being widely used by researchers for the detection of *Phytophthora* diseases which enabled the accurate detection as well as the differentiation of closely related *Phytophthora* species (Arbefeville *et al.*, 2017). The polymerase chain reaction is a method for synthesising millions of copies of specific DNA sequences identified by two short oligonucleotides (primers) using a thermostable enzyme (Rahman *et al.*, 2013). The PCR method has been used for the detection of specific *Phytophthora* species that are infecting different spices and plantation crops (Lan *et al.*, 2013; Franco *et al.*, 2019). In nested PCR, two consecutive rounds of PCR occur in which a single pair of primer is used to amplify a large region of DNA, then this amplified sequence of DNA acts as a target for the second round by using two internal primers. It is used to achieve a high degree of specificity and sensitivity in detection (Li *et al.*, 2014b). Multiplex PCR uses the several pairs of primers in the same reaction that allowing the simultaneous detection of different targeted sequences of DNA. Different fragments that are specific to target *Phytophthora* species were simultaneously amplified, and detected on the basis of their molecular sizes on the agarose gels (Bi *et al.*, 2018). The real time PCR, an improved form of conventional PCR in which the DNA can be quantified along with the amplification (Rahman *et al.*, 2013). In Fluorescence *in situ* hybridization, a fluorescent probe is used that binds only those part of the chromosome with which it shows a greater degree of homology or complementation. Li *et al.* (2014a) detected *P. cinnamomi* in infected plant tissues using fluorescent *in situ* hybridization without damage to plant or pathogen cell integrity. Loop mediated isothermal amplification amplifies the targeted nucleic acid under the isothermal conditions with high specificity. Because of the improved sensitivity and specificity, this technique can be used for the early detection of *Phytophthora* (Verma *et al.*, 2019; Maizatul-Suriza *et al.*, 2024). Recombinase Polymerase Amplification - Lateral Flow Dipstick (RPA-LFD) is an emerging isothermal nucleic acid amplification technique for detecting plant pathogens. A strand displacing DNA polymerase amplifies the template which can be visualized by LFD assay. Presence of *P. hibernalis* in orange fruits was detected by Dai *et al.* (2019) using this RPA-LFD assay.

Introduction

Phytophthora species are a very diverse collection of plant pathogenic organisms that damage hundreds of plant species globally, including decorative plants, forest trees, and vegetable and fruit crops. (Erwin and Ribeiro, 1996; Rizzo *et al.*, 2005). Many diseases they cause are of great economic importance due to their devastating effects. Accurate identification of the *Phytophthora* species affecting crops is a key factor for adopting eco-friendly and effective control strategies. Traditionally, the pathogen has been isolated on selective media, morphological characters have been examined under a microscope, and physiological traits have occasionally been used to identify and detect certain *Phytophthora* species. However, the absence of trustworthy morphological markers and the significant morphological flexibility that some taxa exhibit could result in incorrect identification. Researchers from a wide range of fields have been using molecular approaches with increasing willingness in recent years. Additionally, they are frequently used in the identification of *Phytophthora* illnesses, the identification of novel *Phytophthora* species, and the characterization of pathogen populations. When molecular markers are used,

the identification of fungi is actually more accurate than when the species is determined only by morphology (Arbefeville *et al.*, 2017) and the technique may be used by personnel without specific taxonomic expertise.

Since there aren't many effective control methods for *Phytophthora* illnesses, it's important to have a solid understanding of the pathogen's biology. Excellent management practices will be developed with a complete understanding of the disease's host range, modes of survival and propagation, and the impact of environmental factors. Preventing a *Phytophthora* illness from beginning is the best course of action. When choosing and preparing land for planting, care should be taken right away. Options that can be used include clean stock, crop rotation, water regulation, use of organic amendments, sanitation, biocontrol, pesticides, and host resistance.

Conventional detection methods

Traditional techniques for identifying *Phytophthora* include examining diseased material under a microscope, baiting with plant materials, and isolating the pathogens using general or specific agar media from infected plant tissues, water, and soil. It is extremely difficult to visually detect

Phytophthora indications on sick plant parts, and the number of host-pathogen combinations in which airborne spores are apparent as a downy mass of sporulation is restricted (Cooke *et al.*, 2007). The isolation of *Phytophthora* from soil and host tissues using host-specific baiting is far more significant. This technique, which was widely used as the sole successful way to isolate *Phytophthora* before the development of selective media, is based on the use of extremely susceptible hosts that become quickly infected by a *Phytophthora* species. The most widely used techniques for identifying *Phytophthora* are the use of culture media containing antibiotics to isolate the pathogen from damaged plant tissue and the creation of asexual structures based on the examination of morphological characteristics such as colony appearance by skilled scientists. A light microscope can be used to track the presence of even the smallest structures in samples that have been isolated on sufficient agar media. The goal of inducing spore formation is to expose traits that have taxonomic significance. The morphology of the spores will then be examined under a microscope. The presence of hyphal swellings, chlamydospores, and structures connected to oospore production are also recorded. This approach takes a lot of time, and it can only assess fully grown colonies. Sometimes, in order for colonies to produce spores, they must meet specific requirements, which can interfere with laboratory workflow (Frac *et al.*, 2015).

Generally, conventional techniques rely on morphological and cultural standards, necessitating the development of specialized microbiological knowledge over many years. These techniques take days or weeks to finish, and the results are not always definitive when distinguishing between closely related organisms. Additionally, in presymptomatic infections, conventional approaches might not be sensitive enough to identify the pathogen. (Erwin and Ribeiro, 1996). Moreover, perceptions of the *Phytophthora* morphology are very individualized and contingent upon personal experience. The human aspect may result in erroneous pathogen identification, which would lead to misdirected plant protection efforts. A reliable identification based solely on the morphology of the colonies is extremely difficult, if not impossible, due to the lack of carrier specificity and symptom changes between plant populations at different latitudes.

Molecular detection

The majority of modern methods for *Phytophthora* species identification, diagnosis, and research as well as other plant pathogens have shifted toward those that take use of variations in nucleic acid sequences among species.

Hybridization probes were a common component of nucleic acid-based diagnostics prior to the development of the polymerase chain reaction (PCR), and they are still employed as a PCR substitute for the identification of plant infections, including *Phytophthora* species. Several scientists have used this method for the detection of *Phytophthora* spp. (Goodwin *et al.*, 1990; Judelson and Messenger-Routh, 1996). However, PCR-based techniques have recently superseded hybridization because of their increased sensitivity, ease of use, and speed, as well as the ability to use far simpler methods to extract the nucleic acid samples for detection. (Cooke *et al.*, 2007). When there are no outward symptoms, nucleic acid-based techniques can identify closely similar species and find the minute quantity pathogen.

By carefully crafting oligonucleotide primers, great degrees of specificity in molecular detection can be reached. The cyclic amplification technique enhances the high sensitivity achieved by carefully selecting the reaction conditions. It was combined with the creation of bioinformatics software and algorithms intended especially for the analysis and manipulation of massive volumes of DNA sequence data, creating a strong foundation. In order to determine the evolutionary links between various species, this allowed researchers to analyze or compare a wide variety of DNA sequences.

Target DNA regions for diagnostic assays

Selecting a suitable target DNA region is an essential first step in molecular detection. A suitable target gene should not contain intraspecific variation that would compromise the detection of all strains, but it should be sufficiently varied to allow the distinguishing of closely related species. While various assays may need differentiating lineages of a single species, others may require a highly conserved target region in order to facilitate the construction of generic primers that amplify target DNA from a collection of species (Fajarningsih, 2016). An ideal target gene should have the following general characteristics: it should be simple to amplify, sequence, and ideally have several copies to facilitate the creation of sensitive detection techniques.

Internal Transcribed Spacer (ITS) regions: The nuclear ribosomal DNA (rDNA) array's ITS sections are the most often sequenced for *Phytophthora* and have been extensively used in phylogenetic analysis and the creation of diagnostic assays (Kroon *et al.*, 2004; Silvar *et al.*, 2005; Bienapfl *et al.*, 2011). The ITS sections provide good targets since their sequences are both conserved and varied, they exist in numerous copies, and they are highly stable. They may also be easily amplified and sequenced using universal primers without any prior sequence knowledge. Because of the areas of high

interspecific and low intraspecific variability they possess, which are beneficial for designing primers specific to a given species (Fajarningsih, 2016; Shamim *et al.*, 2017).

Intergenic spacer (IGS) region: As an alternative to the ITS sections, the intergenic (IGS1 and IGS2) regions of rDNA appear to have a lot of promise. They are multicopy (up to 200 copies per haploid genome), similar to the ITS sections, but they are also quite long (4000–5000 bp), which gives ample scope for primer creation. But the IGS regions haven't been used much as targets to create unique molecular markers. This is mostly because it's hard to amplify up a large fragment (4000–5000 bp) and there aren't any reliable universal primers (Pecchia *et al.*, 2019).

Random DNA fragments: Using PCR-based methods like random amplified polymorphic DNA (RAPD), random amplification of genomic areas is another strategy for identifying certain target sequences. Several *Phytophthora* species-specific sequence characteristic amplified region (SCAR) primers have been designed using randomly amplified PCR fragments as targets (Hussain *et al.*, 2015). This approach is particularly useful when closely related species or specific strains need to be identified.

Alternative genomic regions: The ras-related protein (Ypt1) gene is a particularly attractive target gene for phylogenetic studies and for the creation of particular molecular detection techniques (loos *et al.*, 2006). A molecular toolbox for the identification and detection of 15 distinct *Phytophthora* species was developed using the non-coding sections of the Ypt1 gene, which demonstrated enough variance to distinguish *Phytophthora* species that are almost identical in ITS sequence (Schena *et al.*, 2006). The Ypt1 gene showed high sensitivity and specificity to various detection methods (Khan *et al.*, 2017). Without intra-specific variability, the Ypt1 gene has enough variation to include both coding (exons) and non-coding (UTRs and introns) regions that are ideal for the development of molecular markers for almost all *Phytophthora* species. *P. pluvialis* was detected with high specificity and sensitivity from both artificially inoculated and naturally infected samples of red needle cast disease of *P. radiata* by targeting the Ypt1 gene (McDougal *et al.*, 2021). *Phytophthora* species identification also uses the elicitor genes as target regions.

Mitochondrial DNA (mtDNA): The complete mtDNA sequencing of *P. infestans* has led to the utilization of this cytoplasmic genome as a valuable tool for *Phytophthora* phylogenetic study and species determination. It has been demonstrated by the sequencing of mtDNA coding areas from numerous *Phytophthora* species that genes like Cox2 and Cox1 are suitable for extensive phylogenetic

analysis within the *Phytophthora* genus (Martin and Tooley, 2003; Kulik *et al.*, 2020). Mitochondrial spacer between *atp9* and *nad9* can also be used as a target region for molecular detection. The extremely high AT/GC ratio of mitochondrial DNA is a common drawback. The AT/GC ratio in certain intergenic areas can readily approach 80–90%, which makes the creation of efficient primers quite difficult. In addition, compared to genomic DNA, mitochondrial DNA is typically harder to amplify and needs a larger concentration of MgCl₂.

Simple sequence repeats (SSRs) marker: For taxonomy and diversity study, simple sequence repeats (SSRs), also referred to as microsatellites, offer a potent tool. Studies on the diversity of fungi have also widely employed this marker. Short DNA pieces known as microsatellites include tandem repeating patterns consisting of one to six nucleotides. Among the several markers now in use, the SSR marker offers codominant nature and excellent resolution. It is especially suitable to differentiate closely related genotypes using these microsatellite sequence variants. The genetic diversity of *Phytophthora* within species is studied using these markers (Shamim *et al.*, 2017).

Molecular detection of *Phytophthora*

A variety of molecular techniques have been used for species and subspecies-level identification ranging from the technologically complex to simpler procedures requiring less technical skill or sophisticated equipment.

Polymerase chain reaction (PCR)

The polymerase chain reaction (PCR) is a technique that uses a thermostable enzyme (Taq DNA polymerase) and repeated cycles of denaturation, polymerization, and elongation at different temperatures to synthesize (amplify) millions of copies of particular DNA sequences identified by two short oligonucleotides (primers) (Ward *et al.*, 2004; Rahman *et al.*, 2013). The whole process is repeated many times, so that after 30–35 cycles (approximately 2 hours) millions of copies of the sequence have been produced. Due to primer specificity, the presence of a particular organism can be determined by amplifying a segment of the right size. Basically, the processes are quite straightforward: a PCR machine that is designed to alternate between the necessary temperatures needs to be used to combine a few ingredients (DNA, buffer, oligonucleotide primers, dNTPs, and DNA polymerase) and then incubate the mixture. Selectivity at either narrow or broad taxonomic levels is feasible, depending on the primer design, making it possible to identify a single pathogen at the genus, species, or strain level. The presence of the amplified DNA is usually checked by agarose gel electrophoresis,

but alternative detection formats include colorimetric or fluorometric assays. Many scientists have utilised this technique for the detection of *Phytophthora* in plants (Coelho *et al.*, 1997; Winton and Hansen, 2001; Martin *et al.*, 2004; Causin *et al.*, 2005; Iloos *et al.*, 2005; Hughes *et al.*, 2006). Lan *et al.* (2013) detected the presence of *P. capsici* in infected tissues of black pepper using the primer targeting the Ypt gene. Similarly, Franco *et al.*, 2019 also detected *P. palmivora* from infected cocoa pods.

Mathew *et al.* (2020) have done the species-specific detection of *Phytophthora* using the primers for species-specific microsatellites. Using the primers for species-specific microsatellites, DNA from three species *P. nicotianae*, *P. capsici*, and *P. palmivora* was screened in order to verify the uniqueness of the species-specific microsatellites found and their value in identifying the *Phytophthora* species. Upon screening the genomes of *P. nicotianae*, *P. capsici*, and *P. palmivora* using the primers for microsatellite (GGTAT)19 and (AACGAG)8 from *P. nicotianae*, only *P. nicotianae* produced markers at 193 and 139 bp, respectively. Similarly, when the primer combination for the microsatellite (CGAGTT)5 from *P. capsici* was screened in *P. nicotianae*, *P. palmivora* and *P. capsici* genomes, marker at 157 bp was generated only in *P. capsici*.

Nested PCR

High levels of sensitivity and specificity are attained by nested PCR. This approach consists of two rounds: the first uses a single pair of primers to amplify a sizable section of DNA, and the second uses two internal primers to target the amplified DNA sequence. Because two cycles of amplification need to be carried out in separate tubes with this sort of PCR, there is a significant possibility of contamination. (Rahman *et al.*, 2013). Li *et al.* (2014b) detected the presence of *P. nicotianae* in the infected tobacco tissues and soil using nested PCR. In conventional PCR, the primer pair (Yph1F/ Yph2R) could detect 10 pg purified DNA per 25- μ l reaction volume. In nested PCR, a second round of amplification using 1 μ l Yph1F-/Yph2R-amplified product from the first round as the template and the primers YhF/YhR was capable of increasing the sensitivity of the assay at least 100-fold, to 100 fg per 25- μ l reaction volume.

Multiplex PCR

Multiplex PCR allows for the simultaneous detection of various targeted DNA sequences by using multiple pairs of primers in a single reaction (Bi *et al.*, 2018). The method has so much importance in plant pathology when plants get infected with more than one pathogen. A variety of fragments unique to the target *Phytophthora* species were amplified concurrently and identified on the agarose gels

based on their molecular sizes. A multiplex PCR method for the simultaneous detection of *P. cactorum*, *P. cinnamomi* and *P. lateralis* was established by Bi *et al.* (2018) and the three pathogens were detected in artificially and naturally infested soils, indicating that these markers can be used in the diagnosis of *Phytophthora* diseases. The results showed that the target pathogens could be detected from diseased plants by a combination of the specific primers.

Real-time PCR

Conventional PCR methods give only amplification of targeted DNA that is not enough for rapid disease diagnosis. In last few years, a new technique, Real-time PCR has been introduced. This technique is an improved form of conventional PCR in which the DNA can be quantified along with the amplification (Rahman *et al.*, 2013). Sequence-specific fluorescence-labeled probes like the Taq Manprobe or fluorescent dyes like SYBR Green I have made it feasible to monitor the reactions during the amplification stages. Fluorescent signal is produced when the fluorescent dye intercalates to DNA. As the amount of targeted DNA rises following each amplification cycle, this signal also increases.

Huang *et al.* (2010) developed a real-time polymerase chain reaction (PCR) detection approach for *P. nicotianae* that is quick, specific, and sensitive. They employed primers that target the internal transcribed spacer (ITS) sections of *Phytophthora* spp. rDNA genes. The primers and probe were particularly developed to amplify DNA from *P. nicotianae* based on the nucleotide sequences of ITS2 of 15 different species of *Phytophthora*. The detection limit of *P. nicotianae* pure cultures, using a series of 10-fold DNA dilutions, was 10 pg μ l⁻¹ for conventional PCR; 0.12 fg μ l⁻¹ for SYBR Green I PCR and 1.2 fg μ l⁻¹ for TaqMan PCR. Realtime PCR was 104–105 times more sensitive than conventional PCR. The quick and easy processes made it possible to handle a large number of samples quickly while optimizing the yield and quality of DNA recovered from soil. To get DNA appropriate for PCR, direct extractions of DNA from soil were employed. It was possible to identify *P. nicotianae* in soil with a sensitivity of 1.0 pg μ l⁻¹ by combining this process with the real-time PCR method.

Fluorescence in situ hybridization (FISH)

Fluorescence in situ hybridization (FISH) was developed in response to the limitations of radio-labeled probe-based hybridization. FISH is a fast method for characterizing microorganisms, including fungus. FISH offers increased speed, safety, and resolution. It also cleared the path for the development of simultaneous detection of numerous targets and quantitative phylogenetic analysis (Tsui *et al.*,

2011). Furthermore, analyzing the geographical organization of fungal colonies is crucial. Using this cytogenetic method, particular DNA sequences on chromosomes can be found. A fluorescent probe that exclusively binds to chromosomal regions that exhibit higher levels of complementation or homology is utilized in FISH. Enzymatic fluorophore modification of the probe base is incorporated throughout the probe length to create fluorescent probes. Cells must be actively dividing in order for microorganisms to be identified using conventional methods. However, FISH is a very flexible approach because it may be applied to non-dividing cells as well. Li *et al.* (2014a) reported that by employing fluorescent in situ hybridization (FISH) and a species-specific fluorescently labelled DNA probe, *P. cinnamomi* can be directly identified and observed without compromising the integrity of plant or pathogen cells or necessitating subculturing. Bellgard *et al.* (2016) employed this technique to visualise the clear differentiation of the intracellular and intercellular structures of *Phytophthora agathidicida* in *Agathis australis*.

Loop mediated isothermal amplification (LAMP)

An effective and cutting-edge nucleic acid amplification technique called LAMP is being explored as a PCR substitute. It has a high selectivity and amplifies the desired nucleic acid in an isothermal environment. For DNA amplification, LAMP only needs a single temperature rather than a thermal cycler to create temperature fluctuations (Nagamine *et al.*, 2002; Tsui *et al.* 2011). It is therefore predicated on auto-cycling DNA strand displacement amplification. Utilizing Bst DNA polymerase and a set of four primers two inner and two outer this method can identify a total of six distinct sequences on the targeted DNA. The outside primers are F3 and B3, while the two inner primers are known as forward inner primer (FIP) and backward inner primer (BIP) (Fakruddin, 2011). Each BIP and FIP is made up of two unique sequences corresponding to the targeted DNA's sense and anti-sense strands. The LAMP reaction is initiated with one of the inner primers, while the other is utilized for self-priming. The LAMP reaction is run for one hour at 65°C in a heat block or water bath. Subsequently, both electrophoresis and the dye SYBR Green 1 are used to detect the amplification product. The target sequence is repeated numerous times in the final result, displaying a structure like a cauliflower with numerous loops.

Verma *et al.* (2019) developed a fluorescent based loop-mediated isothermal amplification (LAMP) assay for a simple, sensitive and visual detection of *P. infestans* from tubers targeting a novel internal transcribed spacer 1 (ITS-1) region of ribosomal DNA. With the newly created LAMP primers, they were able to detect DNA down to 1 pg

µl-1, whereas the lowest amount detectable with traditional PCR was 0.1 ng µl-1. The low-cost laboratory LAMP test may prove to be an advantageous instrument for the timely identification of *P. infestans*. As a result of the LAMP assay's strong performance in terms of sensitivity, reproducibility, target specificity, dependability, and visibility, *P. infestans* can be detected in potato tubers and leaves that are infected. Hieno *et al.* (2019) also reported the high sensitivity, specificity and stability in detection of *P. nicotianae* using rapid DNA extraction and LAMP assay methods. The detection of *P. palmivora* using real-time loop mediated isothermal amplification was possible within 30 minutes of incubation (Maizatul-Suriza *et al.*, 2024).

Recombinase Polymerase Amplification - Lateral Flow Dipstick (RPA-LFD)

A new isothermal nucleic acid amplification method for identifying plant pathogens is called recombinase polymerase amplification (RPA). The target region of the DNA template is amplified exponentially by the mixture of RPA enzymes. This was achieved via a phage-derived recombinase called UvsX, which forms a nucleoprotein filament by aggregating with two oligonucleotide primers and searching for a single homologous target sequence in the DNA template. The filament is bound by a protein that binds to single strands of DNA. After that, a strand that moves DNA polymerase amplifies the template (Dai *et al.*, 2019). RPA has several advantages compared to conventional PCR-based methods and LAMP assays. This method does not require thermal cyclers because it amplifies DNA at consistent, low temperatures (the ideal range is 37–42° C). While the LAMP technique takes four to six primers to synthesis varying sizes of DNA amplicons, each RPA assay simply needs two oligonucleotide primers. Dipsticks for lateral flow allow real-time visualization of the RPA amplicons (LFDs). The RPA-LFD test was utilized by Dai *et al.* (2019) to identify *P. hibernalis* in orange fruits. The method is a rapid, simple, and accurate sensitive visual detection method of *P. cactorum* (Lu *et al.*, 2021) and *P. cinnamomi* (Chen *et al.*, 2022).

Conclusions

Phytophthora diseases pose a hazard to commercially important plants, resulting in substantial financial losses on a global scale. Enhancing comprehension of pathogenicity variables and promptly and accurately identifying *Phytophthora* to the species or strain level are essential prerequisites for disease monitoring and the creation of innovative disease management tactics. Detection, identification, and tracking of *Phytophthora* species by molecular approaches have shown to be valuable instruments in addressing this dilemma. They

have made it possible to swiftly characterize novel species and to develop and apply targeted DNA-based assays for precisely identifying the origin of illnesses and locating pathogens in soil, water, and plant material. Additionally, timely identification of the resistance levels in *Phytophthora* populations in a field will assist growers in making informed decisions regarding resistance management plans to prevent plant illnesses.

Future thrust

Even with current technical advancements, field kits remain necessary for the quick and precise on-site detection of *Phytophthora*. Additionally, automation and miniaturization through the use of “lab-on-a-chip” and array-based technologies to boost sample throughput are soon to come. Methods for the accurate and timely identification of *Phytophthora* that will cut down on the amount of time or specialist equipment needed to process a sample.

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Opportunities and Challenges of Entrepreneurship for Agri-Graduates in India

Sampriti Guha*, Debabrata Basu and Swadhin Priyadarsinee

Department of Agricultural Extension, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal

**Corresponding Author Email : sampriticrj111@gmail.com*

Abstract

The transformation of traditional agriculture into agribusiness is crucial for revitalizing the agricultural sector in India, making it a more attractive and profitable venture. Agripreneurship has the potential to drive social and economic development, including employment generation, income growth, poverty reduction, and improvements in nutrition, health, and overall food security. This paper aims to delve into the fundamental concepts of agripreneurship, the critical need for agripreneurship development in India, the areas of entrepreneurship development in agriculture. Additionally, it will highlight the initiatives and process taken to foster agripreneurship ecosystem development in the agricultural universities.

Introduction

Indian economy is primarily agrarian. During independence, more than half of the national income came up from agriculture, with more than 70 percent of total population being dependent on agriculture (Pandey, 2013). Agriculture and allied sectors are contemplated to be the pillars of Indian economy because they are considered as predominant sources of raw materials for industries and even generate a huge demand for many industrial products specifically fertilizers, pesticides, agriculture tools and different consumer goods (Bairwa et al., 2014a). In light of evolving socio-economic, political, environmental, and cultural dimensions, the need for farmers and nations to adapt to changing economic environments has become increasingly critical. It is also worth noting that the emergence of the free market economies globally has resulted in the development of a new spirit of enterprise "Agripreneurship" and the increased individual need for responsibility for running their own businesses (Alex, 2011). Agripreneurship is the profitable amalgamation of agriculture and entrepreneurship, transforming farms into sustainable agribusinesses. The term is often used in the context of education and the formation of small agricultural enterprises. Dollinger (2003) defines entrepreneurship in agriculture as the creation of innovative economic organizations with the aim of growth and gain, amidst conditions of risk and uncertainty in the agricultural sector. Meanwhile, Gray (2002) describes an entrepreneur as an individual who manages a business with the intent to expand and possesses the leadership and managerial skills necessary to achieve those goals. Given the challenges of rural unemployment, poverty, and sluggish agricultural growth, fostering entrepreneurship in agriculture becomes imperative to enhance productivity and profitability. The Agripreneurship program is

necessary to develop entrepreneurs and management workforce to cater agricultural industry across the world (Bairwa et al., 2014b). Agripreneurship is greatly influenced mainly by the economic situation, education and culture (Singh, 2013).

Key Terminologies associated with Agripreneurship Development :

- 1. Agripreneurs:** Agripreneurs, also known as entrepreneurs, exhibit proactive, curious, determined, and visionary qualities. They possess strong management and organizational skills, working hard with honesty and integrity. Agripreneurs undertake a range of activities in the agricultural sector to drive entrepreneurial initiatives.
- 2. Agripreneurship:** Agripreneurship represents the profitable integration of agriculture and entrepreneurship. It involves transforming traditional farming practices into agribusiness ventures, thereby maximizing the economic potential of agriculture and its allied sectors.
- 3. Agriclincs:** These are envisaged to provide expert advice and services to farmers on technology, cropping practices, protection from pests and diseases, market trends, prices of various crops in the markets and also clinical services for animal health which would enhance productivity of crops/animals and increased income to farmers (Global Agrisystem, 2010).
- 4. Agribusiness Centres:** Agribusiness centers serve as hubs that offer farm equipment for hire, input sales, and various services. These centres will provide a package of input facilities; consultancy and other services with the aim of strengthening transfer of technology and extension services and also provide self-employment opportunities to technically trained persons (Chandra shekara, 2003).

Need for Agri-entrepreneurship : Since the implementation of the New Economic Reforms in the 1990s, which included liberalization, privatization, and

globalization (LPG) policies, as well as membership in the World Trade Organization (WTO), there has been an expectation that rural areas would grow at a rate similar to urban areas. Performance of agriculture during first phase of economic reforms till 1998 remained driving force for this notion among all the spheres of academia, administration and government (Singh, 2013). However, the subsequent years witnessed a different trajectory, with agriculture's performance failing to meet expectations. The growing wasteland, depletion of natural resources, rural youth migration to urban areas, negative perceptions of farming among the children of farmers, and advancements in agricultural technologies have necessitated a redesign of agricultural activities. Introducing entrepreneurship into the agricultural field holds the potential to yield numerous economic benefits, including increased productivity, the creation of new businesses and jobs, innovative products and services, rural development, and wealth creation.

Redefining Agriculture through Entrepreneurship : Traditionally, agriculture was viewed solely as land cultivation and crop harvesting. However, the difficulties caused by increasing wastelands, resource depletion, migration, and technological advancements have entailed a re-evaluation of agricultural operations. The incorporation of entrepreneurship principles in agriculture can turn up to bring about a span of positive results, like increased productivity, establishment of new business enterprises, job creation, innovation, and rural development. By encompassing scientific agriculture and adequate agri-management systems, farmers can beat some major issues like late monsoons, droughts, crop debts, spurious seeds, and fertilizer deficits. Implementing entrepreneurial and managerial skills in agriculture can provoke and legitimise traditional farmers, equipping them with the essential tools to deal with challenges and transform into successful agripreneurs.

Addressing the Challenges: The introduction of entrepreneurial skills in agriculture can help mitigate countless challenges faced by farmers. By creating agripreneurs, the following issues can be effectively addressed:

1. Reducing the burden on agriculture: Agripreneurs can embrace modern farming practices, employ advanced technologies, and make use of effective management systems, thus reducing the burdens of traditional agriculture.

2. Generating employment opportunities for rural youth: Agripreneurship proscribes plethora of opportunities for rural youth to get enrolled in agricultural ventures, designing employment opportunities and ensuing the tide of migration to urban areas.

3. Increasing national income: Agripreneurs can subsidise higher agricultural incomes through enhanced productivity, value addition, and market-oriented ventures, thus boosting overall income of the country.

4. Supporting industrial development in rural areas: Agripreneurs can commute the advancement of agro-processing industries, resulting to rural industrialization and uplifting economic growth.

5. Alleviating pressure on urban cities: By developing viable agribusiness ideas in rural areas, agripreneurs can decrease the migration of rural population to urban cities for the sake of employment, hence alleviating the stress on urban infrastructure.

Agriculture Education System in India : The purview of agricultural education is vast, encircling numerous disciplines like Agriculture, Veterinary Science, Forestry, Fisheries, Horticulture, Home Sciences, Agricultural Engineering, Food Science & Technology, and Dairy Technology. The Indian Council of Agricultural Research (ICAR) serves as the regulatory body, functioning similar like the University Grants Commission (UGC) for the agricultural university system. The Government grants financial assistance to these institutions for the raising the standards of agricultural education and research. The Indian agricultural education system, with 64 SAUs, 3 CAUs and 4 Deemed Universities is considered as one of the world's largest system imparting knowledge in this sector. Annually, these institutes enrol about 15,000 students at undergraduate level in almost 11 disciplines, 7,000 at Post-graduate level and 1700 at Doctoral level (Rathore *et.al*, 2019). Beside this, there are many private universities, affiliated or non-affiliated to SAUs which also enrolls many students annually. Furthermore, many general universities also offer agricultural education programs either independently or through affiliated colleges, further contributing to the growing number of agricultural graduates each year. The agricultural education system in India plays a pivotal role in equipping students with the necessary knowledge, skills, and practical experience required to address the diverse challenges faced by the agricultural sector. These institutions emphasize a multidisciplinary approach, blending theoretical education with hands-on training, research, and extension services. Agriculture, once viewed primarily as a traditional occupation, is now emerging as a preferred career choice in India. This shift in perception is driven by several factors that highlight the potential and opportunities available in the agricultural sector.

Gap between the Agri-graduates and employment in agriculture field : One reason for graduates'

unemployment and joblessness is by all accounts absence of versatility between graduates' capacities and abilities required by work and profitable units (Shahbazi and Alibeigi, 2007). Absence of business enterprise abilities among the agricultural understudies and graduates is another explanation behind unemployment in emerging nations (Sabouhi, 2000). Zamani (2001) says that poor down to earth capacities of agrarian graduates, insignificance of college subjects and educational module with work showcase needs, administrative impediments about giving chances of work to Agri-graduates are a portion of the explanation for the crumbling nature of present instruction. It is ending up progressively troublesome for farming graduates to discover work in the private area or act naturally utilised (Movahedi *et al.*, 2011). Agripreneurship does not present a happy scene. For example, in 2015 out of \$6 billion invested in an overall tech start-up, the agriculture sector managed to attract less than 1% investment. However, in 2016, a sum of \$3.23b was invested in agriculture sector worldwide, out of which 53 Indian agri-tech start-ups managed to raise \$313m. One would like to believe 'slow and steady wins...', but regional/ state-wise inequality in attraction investment remained a challenge even in 2019. (Mukhopadhyay *et al.*, 2020)

The increasing number of agricultural graduates in India presents a significant challenge in terms of providing sufficient job opportunities for them in the real market. The gap between the number of graduates and available jobs is a pressing concern. According to estimates from IAMR (2001), 43% of graduates and 23% of postgraduates face employment challenges in the country. As a result, many graduates are turning to entrepreneurship as a reliable option for their livelihood. India, with its large population, holds immense potential for entrepreneurial activity. Entrepreneurship education can prove to be a valuable

means to harness the untapped human resources and propagate a culture of job creators rather than job seekers. It is important for colleges and educational institutions to foster entrepreneurial attitude among students, reassuring them to challenge the status quo and take risks. The Government of India is also actively promoting entrepreneurial education, granting technical and financial support to individuals from diverse backgrounds. This assistance aims to boost entrepreneurship as a workable career option and enable the formulation of new enterprises. The increasing number of agricultural graduates in India entails a focus on entrepreneurship as a means to bridge the gap between supply and demand in the job market. By fostering entrepreneurship education and granting fundamental support, the country can tap into its vast human potential and create a generation of job creators.

Areas of Entrepreneurship development in Agriculture : Recent studies show that agricultural entrepreneurship is not only wishful thinking or a new hype: it has a profound impact on business growth and survival (Lans *et al.* 2011: Verhees *et al.* 2011). According to the Chairperson of NASSCOM, MR. Reddy, "Start-ups now employ over 80,000 people and some 72% of the founders are less than 35 years old, making India home to the youngest entrepreneurs in the world." India abounds in its resources, like it has world's largest dairy herd, ranks 3rd amongst the egg producers of the world, globally 6th largest producer of poultry meat. Animal husbandry comprises ¼th of total agricultural output, making a large portion of the farming sector to depend on it. These numbers are quite satisfactory to uplift and exhibit the critical need of Agripreneurship development in India.

The following are the areas of entrepreneurship development in agriculture sector :

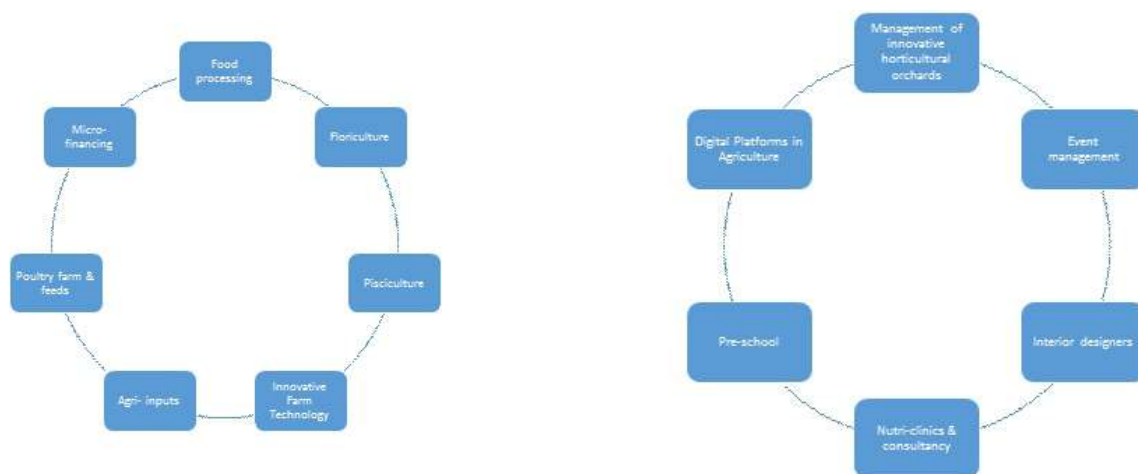


Fig. : Areas of Entrepreneurship Development in Agriculture.

Cultivating an Agripreneurship Ecosystem to empower State Agricultural Universities :

In today's changing agricultural landscape, boosting entrepreneurship and innovation has become vital for sustainable growth and development. State Agricultural Universities (SAUs) play a crucial role in driving agricultural research, education, and extension services. By building a potent agripreneurship ecosystem within these institutions, we can allow students, researchers, and farmers to grab entrepreneurship to solve complex agricultural challenges and infuse rural economic development. SAUs are goldmines of knowledge, resources, and talent serving as centres of excellence, contributing specialized courses in agriculture, horticulture, veterinary sciences, and other related disciplines. By harnessing the untapped potential of these institutions and ascending their expertise, we can breed an essence of innovation and entrepreneurship among students and faculty.

Building an Agripreneurship Ecosystem :

1. Curriculum Enhancement: SAUs need to analyse and amend their curricula to insert courses that boost entrepreneurship, business management, and technology commercialization.

The UG curriculum of the 5th Dean Committee has taken the initiative to look into the capacity building of the agricultural graduates by unveiling the core concept of entrepreneurship and involving them in taking on entrepreneurial risk during their academic course work and during the RAWE & AIA program as well as during the ELP courses. It includes the following courses that will help students acquire the necessary skills, knowledge, and mindset to start and manage their own agribusinesses :

Comprehension & Communication Skills in English
 English for special purpose
 Agricultural Marketing, Trading and Prices
 Communication skills and Personality Development
 Entrepreneurship studies and Business Communication
 Rural Agricultural Work Experience (RAWE) & Agro Industrial Attachment (AIA)

Uplifting the syllabus of agri-graduates to include a potent Information Technology (IT) component is important. It is compulsory to tutor agri-graduates about the significance of introducing IT into agriculture, like digital marketing for business promotion. This integration can be accomplished through the following measures:

Introducing IT in Agriculture: Design courses which will introduce the basics of IT and its relevance

in the agricultural sector. This must include topics such as data management, precision farming technologies, and agricultural software applications.

Digital Marketing for Agribusiness: Introduce specific courses which highlights the role of digital marketing in promoting agricultural products and services. This must encompass strategies for efficient online presence, social media marketing, search engine optimization, and e-commerce platforms.

AgTech and Farm Management Systems: Include modules on agricultural technologies (AgTech) and farm management systems that allow IT solutions. This consists of training on using farm management software, remote sensing technologies, and automated monitoring systems for increased productivity and efficiency.

Data Analytics and Decision-making: Offer training on data analytics to excerpt meaningful perception from agricultural data. Educate students about how to analyse data for decision-making, like optimizing crop yields, managing resources, and determining market trends.

Geographic Information Systems (GIS) and Mapping: Incorporate GIS concepts and mapping tools to allow agri-graduates to employ spatial data for farm planning, land management, and precision agriculture. Highlight the concern of GIS in advancing resource allocation and developing sustainability.

2. Incubation Centers: India has endorsed symbolic growth in the agricultural sector, driving to the formulation of numerous agri incubation centers all over the country. These centers aid to foster innovation, entrepreneurship, and technological advancements in agriculture. Installing dedicated agripreneurship incubation centers within SAUs is a crucial step. These centers must provide a supportive ecosystem for aspiring entrepreneurs to access mentorship, business development services, infrastructure, and funding opportunities.

A list of few prominent Incubation centres have been included here :

ICRISAT Agri-Business Incubator, Hyderabad: Located at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) campus in Hyderabad. This provides support to agri-based startups by delivering mentors, networking, and infrastructure facilities.

NAARM Agri-Business Incubator, Hyderabad: The National Academy of

Agricultural Research Management (NAARM) functions as an agri-business incubator which aims to promote agricultural entrepreneurship and technology-driven startups.

Agri-Business Incubation (ABI) Program, Indian Council of Agricultural Research (ICAR): ICAR engages numerous agri-business incubators across India to assist innovative agri-startups. They are associated with agricultural research institutions and grant resources, mentorship, and technical assistance.

Indigram Labs Foundation, New Delhi: This is also an incubation centre which offer assistance to startups working in agriculture, food processing, and rural development areas. It provides mentoring, funding, and access to industry networks.

Technology Business Incubator (TBI), Indian Agricultural Research Institute (IARI), New Delhi: TBI-IARI provides support to agri-based startups by granting infrastructure facilities, technical expertise, business development assistance, and access to funding opportunities.

TBI Agri-Business Incubator, Coimbatore: TBI Agri-Business Incubator is located in Coimbatore, Tamil Nadu. This focuses on uplifting technology-driven agri-startups by mentoring, networking, and market linkages.

ICAR-NAARM Technology Business Incubator (TBI), Hyderabad: Agri-business incubator associated with the ICAR-National Academy of Agricultural Research Management (NAARM), Hyderabad. The incubator helps startups in the agriculture and allied sectors.

RKVY-RAAFTAR: This is a flagship scheme of Ministry of Agriculture and Farmers' Welfare (MoA&FW), Government of India. This is a flagship scheme of Ministry of Agriculture and Farmers' Welfare (MoA&FW), Government of India. Under the RKVY-RAAFTAR scheme, financial assistance is provided to states and Union Territories for implementing various agricultural projects and activities. These may include the establishment of agri-infrastructure, technology dissemination, capacity building, market linkages, farm mechanization, soil health management, organic farming, and promoting agri-entrepreneurship.

By nurturing startups and facilitating collaboration between academia, industry, and government, these incubation centers can foster innovation and accelerate the commercialization of agricultural technologies.

3. Industry-Academia Collaboration: SAUs should actively engage with the agricultural industry to identify real-world challenges and opportunities. Collaborative research projects, technology transfer initiatives, and joint ventures can bridge the gap between academia and industry, ensuring that research outcomes are aligned with market needs. This collaboration also provides students with exposure to industry practices and enhances their entrepreneurial acumen. Foster partnerships with IT professionals and organizations to facilitate knowledge transfer and practical experience. Arrange guest lectures, workshops, and internships to expose agri-graduates to real-world applications of IT in agriculture.

4. Networking and Mentorship: SAUs should organize networking events, workshops, and seminars that bring together aspiring agripreneurs, industry experts, successful entrepreneurs, and investors. These platforms facilitate knowledge sharing, skilldevelopment, and networking opportunities, enabling aspiring agripreneurs to learn from experienced professionals and establish valuable connections. The Agri-Clinic/Agribusiness scheme of MANAGE, Hyderabad should merge with SAUs, and connections with EDI (Entrepreneurship Development Institute of India), Ahmedabad, and ICAR's Agribusiness Incubators should be established to promote the concept of entrepreneurship among the budding agri-graduates. The Placement Cells of the Universities should shoulder the responsibility of unveiling the Agripreneurship core and indulging the graduates into entrepreneurial ventures and providing assistance for few years.

5. Funding and Financial Support: Access to capital is critical for transforming innovative ideas into successful agribusiness ventures. SAUs should collaborate with government agencies, financial institutions, venture capitalists, and philanthropic organizations to create funding mechanisms specifically tailored for agripreneurs. This may include seed funding, grants, low-interest loans, and crowd-funding platforms to provide financial support at various stages of venture development. By facilitating connections with banks, AC/ABCs, and incubation centres enhance the chances of trainees/incubates securing the necessary finance for their agricultural ventures. This collaborative approach streamlines the process and increases the likelihood of success in obtaining financial support, enabling trainees/incubates to pursue their entrepreneurial aspirations in the agriculture sector.

6. Policy Support: The Government of India aims to encourage innovation, entrepreneurship, and the export of agricultural products. These efforts support the growth and development of the agricultural sector, while also

providing opportunities for aspiring entrepreneurs in the rural areas of India.

The GOI has implemented the Agriculture Entrepreneurship Promotion Scheme (AEPS) with the aim of supporting rural agriculture entrepreneurs in the country. Launched in 2018, this scheme aims to foster innovation and entrepreneurship in the agricultural sector.

Additionally, the ICAR-NAARM Technology Business Incubator (TBI) has introduced the AGRI-UDAAN program, which assists innovative startups in the agricultural value chain, thereby promoting advancements in agriculture.

To cultivate a culture of innovation and entrepreneurship, the GOI has established the Atal Innovation Mission (AIM). This initiative serves as a platform to promote world-class startup businesses, innovation hubs, and technology-driven self-employment activities.

The Self-Employment and Talent Utilization (SETU) component of AIM focuses on promoting entrepreneurship through self-employment and harnessing talent.

The "Innovation Promotion" component provides a platform for generating innovative ideas.

APEDA (Agricultural and Processed Food Products Export Development Authority), which operates under the Ministry of Commerce and Industry, GOI, plays a vital role in promoting the export of agricultural products. It serves as the apex body responsible for facilitating the export promotion of agricultural goods.

In order to provide a supportive environment for aspiring and established women entrepreneurs nationwide, NITI Aayog has launched the Women Entrepreneurship Platform (WEP). SIDBI and NITI Aayog have teamed up to support this programme.

The Start-up Village Entrepreneurship Programme (SVEP) helps entrepreneurs launch and grow their agriculture-based enterprises while promoting entrepreneurship in rural communities.

The Deendayal Antyodaya Yojana-National Rural Livelihood Mission supports rural entrepreneurs, including those working in agribusiness, in order to combat poverty and advance sustainable livelihoods in rural areas.

SAUs should advocate for supportive policies and regulatory frameworks that foster entrepreneurship in the agricultural sector. This includes tax incentives, simplified procedures for business registration, intellectual property

protection, and the establishment of agricultural innovation zones. By engaging with policymakers, SAUs can influence the creation of an enabling environment for agripreneurs to thrive.

7. Alumni Engagement: The documentation of success stories of agri-graduates turned entrepreneurs also reveal that there has been somewhat institutional support to reinforce their success. SAUs should leverage their alumni network, which often includes successful entrepreneurs and industry leaders, to support and mentor current students. Alumni can contribute through guest lectures, mentorship programs, internship opportunities, and investment in promising ventures. Their knowledge, experience, and networks can be invaluable in nurturing the next generation of agripreneurs.

Conclusions

Agripreneurship is vital for developing agriculture into a more profitable and promising venture. Efficient management of basic agricultural elements like soil, seed, water, and market demands is essential to harness the potential of entrepreneurship in agriculture. Individuals having a risk-taking mindset and a hunger for updated knowledge in the agrarian sector can shine as agripreneurs. Agriculture has the power to contribute to nation's income, providing direct employment and income to a large share of population. Agripreneurship is not only an opportunity but also a prerequisite for raising production and profitability in agriculture and allied sectors. Fostering an agripreneurship ecosystem in SAUs can aid addressing the challenge of attracting youth to the agrarian sector. SAUs can collaborate with industries, establish entrepreneurship cells, provide funding opportunities, develop curricula, and organize networking events to develop a professional agripreneurship ecosystem. This can lead to the creation of innovative agribusinesses, which can contribute to the growth of the agriculture sector and the overall economy. This will foster in fulfilling our PM's dream of 'Atmanirbhar Bharat', ensuring 'Job Creators' rather than 'Job Seekers'.

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Review Article on Important Antioxidants Present in Onion (*Allium cepa* L.) Lost as Peel Off

Sharad Bisen*, Dharna Bisen and Roshanlal Raut

¹Department of Horticulture, Raja Bhoj College of Agriculture, Balaghat, JNKVV, Jabalpur, M.P.

²Department of Entomology, Raja Bhoj College of Agriculture, Balaghat, JNKVV, Jabalpur, M.P.

³JNKVV-Krishi Vigyan Kendra, Badgaon, M.P.

*Email : bisencharad@gmail.com

Abstract

In India onion is a king of vegetables as everyone loves to eat onion in raw or cooked form. But, onion processing waste is usually thrown away. The waste is an excellent source of bioactive compounds and is rich in phytochemicals. However, with the growing interest in sustainable resource use and circular economy to reduce adverse environmental impacts, food processing wastes such as onion peel can be extracted and used as inputs in the development or reformulation of nutritional supplements and pharmacological drugs. This review highlights the major bioactive constituents, especially total phenolics, total flavonoid, quercetin and its derivatives present in onion peel and their therapeutic applications as cardioprotective, neuroprotective, antiobesity, antidiabetic, anticancer and antimicrobial agents. The present review highlights that onion peel is one of the important agricultural by-products that is rich in bioactive compounds and can be used as a health-promoting ingredient especially in pharmacological and biomedical fields. Thus, with the increasing burden of lifestyle disorders/non-communicable diseases, finding a suitable natural alternative for their treatment is one of the main interests of scientists, and onion skin and its extract can be used as a primary ingredient.

Key words : Onion peel/waste, bioactives, biofunctionalities, phytochemicals.

Introduction

Now a days increasing cases of heart diseases, heart attack, diabetes, obesity, various cancers etc. are alarming as they can be fatal in young ones around the world. Onion (*Allium cepa*) is the most common ingredient in Indian households and is also one of the most commonly grown and consumed vegetables worldwide. Total world onion production is 94.23 million tonnes (MT), with China (22.91 MT), India (20.42 MT), Egypt (4.12 MT), USA (3.33 MT) and Iran (2.33 MT) are the top five countries contributing to this total production. However, onion processing in the home kitchen or at an industrial level generates a large amount of waste, which includes its inedible viz. top and bottom, outer skins and husks, and two outer layers [12]. Among all producers, European countries alone were reported to be able to produce almost 0.7 MT of onion waste per year [21]. In addition, the waste can harm the environment when disposed of incorrectly, as it is not suitable for the preparation of fodder due to the strong onion aroma, nor can it be used as a fertilizer [4]. Therefore, onion wastes are underutilized even after being a rich source of bioactive compounds such as flavonols, flavonoids and phenolics. Evaluation of onion waste and its extracts in the field of biomedicine and pharmacy can thus be a suitable solution to reduce environmental damage and provide an economic and

low-cost substitute for the production of therapeutic supplements or plant-based medicines. For example, various researchers reported that onion peel extract capsules help in weight loss [11, 18, 23 and 35]. Also researchers highlighted that a capsule composed of onion peel extract promote the heart health activity and support for better circulation.

However, the presence of all these bioactive compounds gives onion skin its various therapeutic benefits in the prevention of cancer, obesity, diabetes, neurodegenerative disorders, cardiovascular disorders, microbial damage and erectile dysfunction [27, 29]. Thus, onion skins in the form of powders or extracts can be used in various industries as a therapeutic and pharmaceutical agent.

Various by-products obtained from various sources have been recently reviewed for their bioactive substances and biomedical activities [9, 10, 26, 27, 28, 29, 30, 31, 52]. This review is a primary attempt to summarize under one roof a detailed and comprehensive compilation of data on onion peel, its bioactive compounds and biological activities. This review can put light on chemical characterization and more knowledge of all bioactive compounds or all the activities of onion skin is necessary for best use and development of optimal and effective system of waste resource recovery or management or recycle.

Sr. No.	Substance	Quantity	Reference
1.	protein	(8.3–15.6% dm (dry matter)	[4]
2.	ash	(4.4–8.6% dm)	
3.	total fiber	(169–750 mg/g dm)	
4.	minerals potassium	(11.1–15.9 mg/g)	
5.	calcium	(1.8–16.5 mg/g)	
6.	magnesium	(0.6–1.5 mg/g)	
7.	iron	(0 .0196–0.8889 mg/g)	
8.	zinc	(0.0162–0.0538 mg/g/g) g)	
9.	manganese	(0.0065–0.0288 ìg/g)	
10.	selenium	(0.00003–0 .00093 g/g)	
11.	total phenolics	(9.4–52.7 mg gallic acid equivalent (GAE)/g dm)	
12.	flavonoids	(7.0–43.1 mg equivalent (quercetin equivalent QE)/g dm)	
13.	flavonols	(6.19–27 mg/g dm)	
Other study also highlighonion skin had a good amount of but was lower in and.			
14.	carbohydrates	(88.56%)	[19]
15.	protein	(0.88%)	
16.	ash	(0.39%)	
17.	crude fiber	(0.15%)	
When similar study were done on onion powder it showed following result			
18.	protein	(2.58-3.06%)	[44], [56]
19.	crude fat	(0.71-0.77%)	
20.	ash	(5.50-5.93 %)	
21.	total fiber	(7.78–62.09%)	
22.	soluble fiber content	(7.38%)	
23.	insoluble fiber	(54.71%)	
Study on outer scales of onion shows:			
24.	crude protein	2.64%	[42]
25.	crude fiber	26.84%	
26.	crude fat	15.13%	
27.	ash	8.06%	
28.	moisture	8.02%	
29.	carbohydrate	66.12%	
Study of Fatty acids			
30.	lauric acid	(0.94%)	[3] [42]
31.	myristic acid	(1.28%)	
32.	palmitic acid	(9.80%)	
33.	stearic acid	(8.81%)	
34.	oleic acid	(17.57%)	
35.	linoleic acid	(52.87%)	
36.	linolenic acid	(2.88%)	
37.	arachidic acid	(0.59%)	
38.	behenic acid	(1.23%)	
39.	erucic acid	(0.63 %)	
40.	lignoceric acid	(0.54%)	

The bioactive substances present in onion skins

In our regular households when we prepare meals twice a lot of waste is generated in significant quantities during industrial processing and these wastes are rich in bioactive compounds/phytochemicals [5, 12]. Some researchers have studied and highlighted the presence of phenolics [1, 5, 19, 56], flavonoids [1, 4, 56], flavanols [4], anthocyanins [2, 4, 44], tannins [47], vanillic acid and ferulic acid [7].

As compared to edible onion/pulp, the highest concentrations of phenolic substances and flavonoids were observed in onion peel [1], [42]. The richness in bioactive compounds, onion wastes can emerge as vital ingredients in herbal therapeutic medicine and pharmaceutical formulations and reuse of these peel can create a revolution in pharmaceutical industry.

The biological activities observed in onion peel:

Changing dietary patterns worldwide, with increased consumption of processed foods, lack of exercise, sedentary lifestyles and exposure to polluted environments, have resulted in an increasing incidence of disorders such as obesity, cardiovascular disorders, diabetes, neurodegenerative disorders and cancer, with oxidative stress being one of the main causative agents of these diseases [44,51,58]. Research has shown that bioactive compounds/phytonutrients of plant origin can play a protective role in preventing damage caused by excessive free radical generation and oxidative stress [43,50,58]. Extensive research on onion peels/wastes and their extracts shows that they are a rich source of phyto-constituents with various therapeutic potentials and pharmacological activities. In this section, detailed studies which highlights the properties of onion skin extracts such as anticancer, antimicrobial, weight management, nerve treatment, cardiac activity, treatment of diabetes and in treatment of infertility in male properties. Understanding these biological activities can pave the way for further research and potential use of onion waste in biomedical fields and the pharmaceutical industry.

Role in cancer treatment : The heavy use of insecticide and pesticides in agriculture sector and excessive use of preservatives in food processing industries causes cancer and the increasing incidence of cancer cases has attracted the attention of researchers to formulate new herbal medicines with minimal side effects to solve or alleviate the problem which is predominant globally.. For studying the metabolism of xenobiotics in the human body, HepG2 cells are the most suitable because they can help measure the uptake, metabolism, distribution and effect of bioactive compounds in human cells. Thus, in an in vitro cell culture study, different onion peel extracts

(ethanolic, methanolic and aqueous) at different concentrations (1–100 g/ml) were indicated to reduce intracellular oxidative stress induced by AAPH (2,2'-azobis (2-methylpropionamidine) dihydrochloride) in HepG2 cells (human liver cancer cell line) due to the permeability of phenolic and flavonoid compounds (mainly quercetin 4'-glucoside quercetin, epicatechin and morin) from onion peel extract into cells. [21].

Human colorectal adenocarcinoma (HT-29) cells treated with onion peel extracts (50, 100 and 250? g/ml, 24?h incubation) showed a dose-dependent reduced survival capacity. Cell viability decreased and reached a maximum after 24?h at 250? g/mL because the normal nuclear structure was lost, cells detached or floated in the medium. Treatment with onion peel extract also decreased the expression of heme oxygenase-1 (HO-1) and glutathione S-transferase (GST) detoxification genes, i.e. GSTM1, GSTT1, GSTP1 and interleukin (IL)-?8. Antioxidant, cytotoxic and anti-inflammatory effects of onion peel extract of onion skins are associated with quercetin, which helps in inhibiting the formation of reactive oxygen species (ROS) and preventing cell damage by oxidative damage [24]. Nile et al. [47] also claimed that spiraeoside (IC₅₀: 4.8? M) and quercetin (IC₅₀: 6.3? M) extracted from red onion solid waste (ROSW) had cytotoxic effects against HeLa cancer cells (cervical cancer cell line). Fredotovi  et al. [14] reported that the antiproliferative activity of onion peel extract (from *Allium cornutum* and *A. cepa*) on cancer cell lines, viz. HeLa, HCT116 (human colon cancer cell line) and U2OS (human osteosarcoma cell line) was not only due to the abundant flavonols (quercetin 3,4'-diglucoside and quercetin 4'-monoglucoside), but also due to the synergistic effect of other phytochemicals in peel. Onion peel extract (ethyl acetate) inhibited *S. typhimurium* strain TA-102 in a dose-dependent manner (200? g: 10.72%, 400? g: 20.59%, 600? g: 32.77%, 800? g: 4.07% and 53.07% %) where tobacco was used as a mutagen. This antimutagenic activity of the onion peel extract was due to the presence of phytochemicals in the ethyl acetate fractions and their ability to scavenge ROS [59]. Choe et al. [11] reported the anticancer effect of onion peel extracts against breast cancer. Cancer cells exhibit uncontrolled cell proliferation along with defects in apoptosis mechanisms. Natural extracts generally target cell proliferation by stopping cell division or inducing the apoptotic machinery in cancer cells.

Onion peel off act as a antimicrobial activity : If we keep the onion chopped and open for long time in air, we can observe the fouo and pungent smell due to the microbial activity occurring in it. The quercetin from onion skins acts as an antimicrobial agent by disrupting energy

metabolism and cytoplasmic membrane functions and inhibiting nucleic acid biosynthesis. Another study also demonstrated the bactericidal effects of onion peel extract, viz. SWE: 110°C at a concentration of 0.6 mg/ml against *Bacillus cereus* and SWE (160°C) had a bacteriostatic effect at a concentration of 1 mg/ml due to the presence of antimicrobial components such as quercetin and oxidation products quercetin in onion peel extract. These compounds exhibited antioxidant capacity by disrupting the cell wall, causing cell lysis, and facilitating the entry of antimicrobial compounds into the cell upon leakage of cell contents. Thus, cell death ultimately occurs by reaction with bacterial DNA [27]. The antimicrobial effect of onion peel extract (OPE) showed that the yellow variety was more effective than the red variety; however, two strains of *Staphylococcus aureus* were strongly inhibited by both varieties. The study also showed that pure flavanols, i.e., quercetin 3,4'-diglucoside (MIC: >300, MBC: >300) and quercetin 4'-monoglucoside (MIC: >200, MBC: >200) had lower antimicrobial properties than the OPE of yellow and red varieties, suggesting that other phytochemicals present in the onion skin also contribute to the antimicrobial effect [13, 14]. Dried onion peel extract (aqueous) was used to synthesize gold nanoparticles (OP-AuNP) and its biological potential was investigated and showed strong synergistic antibacterial and anti-candidal activity and strong proteasome inhibitory ability [49]. The reason for the effective antimicrobial activities of the nanoparticles may be their smaller size, which may have helped them gain easy entry into the bacterial cell, further causing cell death. Furthermore, the authors reported that the interactions of nanoparticles against target microorganisms can be attributed to the high surface-to-volume ratio allowing for many functional ligands and multivalency on the particle surface. The study also demonstrated the use of onion skin for the synthesis of silver nanoparticles and these particles were tested for antimicrobial activity against *Salmonella typhimurium* (gram-negative) and *Staphylococcus aureus* (gram-positive) [53]. Good results were obtained against both bacteria with an inhibition zone of 9 mm and 8 mm, respectively. Thus, various studies have shown that gold and silver nanoparticles from food waste such as onion skin can be used in areas such as biomedicine (for antibacterial drugs, dressing materials, etc.), cosmetics (antiaging, sunscreens and waters), food industry the antimicrobial coatings, packaging and medical and pharmaceutical industries [49].

Role in weight loss activity : One of the rapid growing metabolic disorder in present day is obesity which is prevalent in all age groups due to a sedentary lifestyle. It may also attract other co- morbidities such as diabetes,

hypertension, hyperlipidemia, and hypercholesterolemia. However, a proactive lifestyle, consumption of whole foods and a plant-based diet rich in polyphenols have shown a positive activity in weight management [39, 41]. However, further research is needed to determine the benefits of antioxidants in weight management.

The high-fat diet onion peel extract increased adiponectin mRNA levels from adipose tissue, especially from mesenteric fat, and thus had a beneficial effect on the regulation of obesity-induced inflammation and related pathologies [27]. The randomized, double-blind, placebo-controlled trial study shows in obese healthy women administered quercetin-rich onion peel extract (OPE) capsules (100 mg/day, 50 mg twice daily) for 12 weeks showed that WHR (hip waist) ratio) was significantly reduced compared to baseline values after consumption of OPE capsules [23]. Also another study showed that consumption of OPE in the form of soft red capsules (100 mg quercetin/d, 50 mg quercetin twice daily; n=36) for 12 weeks significantly reduced body mass index (BMI) from 26.8 to 26.4 kg/m² and body weight from 70.8 to 69.7 kg in the OPE group, while in the control group BMI increased (from 26.4 to 27.8 kg/m²) and body weight (from 69.3 to 70.1 kg) [12]. Also researchers confirmed reductions in body weight, waist circumference, hip circumference, thigh circumference and skin fold thickness, and percent body fat after supplementation with quercetin-rich OPE capsules (100 mg quercetin) for 12 weeks [36]. However, researchers reported that supplementation with OPE soft capsules for 12 weeks significantly reduced the percentage of body fat in both the placebo and OPE groups, but showed no significant difference between the groups [24].

The neuroprotective activity showed by onion peel-off

: Old age people suffering from many neurological disorders such as neurodegenerative Alzheimer's disease and Parkinson's disease are common that are prevalent in older age group and the elderly. These problems affect millions of people worldwide; therefore, there is a need to explore new treatments to improve these conditions. Researchers claimed that onion peel ethanol extract (OHE) had a neuroprotective role, as OHE also increased GSH levels (control group: 25.04 μmol/g protein; OHE group: 33.56 μmol/g protein) in the brain, increasing the total antioxidant capacity compared to control. [16, 22]. Onion solid waste (OSW) extracts have the potential to inhibit AChE and BuChE. Thus, the AChE and BuChE inhibitory effect showing its utility in the management and control of Alzheimer's disease [46]. Author also reported that OPE (10–50 μg) can effectively improve cognitive function through its potential to inhibit AChE and its antioxidant activities by inhibiting lipid peroxidation [42].

Role in heart health activity : Sudden increase in the rate of heart attack incidents in young population attracts the scientist to find out some good medicinal sources for its treatment. Increased cholesterol is mainly responsible for heart attack. Consumption of OPE can thus be beneficial for patients with cardiovascular disease due to the presence of quercetin it help to increase the endothelial activity which help in cholesterol level maintenance [11].

Studies on Sprague-Dawley rats showed that when the rats were supplemented with quercetin-rich OPE at different doses (2?mg and 10?mg) for 6 weeks reported that blood triglyceride and glucose levels decreased significantly. However, there was no effect on cholesterol [34, 35, 37]. After 12 weeks of supplementation with onion peel extract (100?mg/kg body weight; 200?mg/kg body weight) together with a high-fat diet in a mouse model, a hypocholesterolemic effect was demonstrated [20]. Lee et al. [38] studied OPE supplementation led to a decrease in blood LDL cholesterol and an increase in high-density lipoprotein cholesterol, and ultimately to the management of heart disease.

Role in glucose level maintenance : Some researchers reported that ethyl alcohol extracts of onion skin had quercetin, which act as a inhibitory against sucrose, -glucosidase, maltase, amylase [29]. Thus, quercetin and other bioactive compounds that have potential glucose-lowering effects through inhibition of -glucosidase. Some studies also reported that, the onion skin extract had higher α -amylase inhibition than the quercetin standard, suggesting that other substances in the onion skin may also have a synergistic effect contributing to -amylase inhibition along with quercetin [18]. Nile et al. [47] also confirmed that extracts (methanol, ethanol, distilled water, diethyl ether, ethyl acetate and n-butanol) had enzymatic inhibitory effects [48]. Accordingly, Nile et al. [48] also suggested that onion solid waste (OSW) extracts had a dose-dependent inhibitory effect on -amylase and -glucosidase, and the inhibitory effect was higher than that of acarbose (used as a standard drug).

Role in male infertility treatment : Erectile dysfunction and infertility are common problems in men. Recent studies suggest that erectile dysfunction is not only associated with sexual activity, but also helps detect systemic endothelial dysfunction, which may aid in the early detection of men at risk for cardiovascular disease. [62]. Therefore, it is important to identify and treat these problems. Che et al. [9] showed that quercetin-rich OPE improved sperm motility and viability OPE had positive

effects on human male fertility. Thus, the overall free availability of onion trimmings, and the therapeutic potential for various diseases due to the presence of abundant phytochemicals, has made onion skins/trimmings a popular choice in various herbal medicine formulations. It has the potential to become a economical, functional and natural ingredient in the pharmaceutical industry [55].

Conclusions

The outermost layer of onion exhibited the highest antioxidant activity, with a clear decreasing trend toward the innermost layer observed for all types of onion samples. Our studies shows that carbohydrate content (glucose, fructose, sucrose) have large variations that had a significant impact on the flavor (sweetness and spiciness) and suitability of these onions for further processing. Also it showed that the distribution of antioxidant activity in the outermost layers of the onion bulb was highest. This fact should be brought to the attention of consumers that in order to know the benefits of these important health-promoting phytochemicals found in the outer layer of onion bulbs. Waste in the form of onion skins, upper, lower and outer layers are disposed of as waste despite various studies confirming bioactive components, it has been confirmed that onion skins are a concentrated source of bioactive substances and therefore have many therapeutic benefits. Biochemical compounds, especially phytochemicals, and total flavonoids, total polyphenols, quercetin and its derivatives in onion skin enable applications in biomedical and pharmaceutical fields. In this review, we found through in vitro and in vivo studies that onion skin extract has antibacterial, neuroprotective properties and has been shown to reduce cancer (cervical, breast and liver cancer cells), hyperglycemia, and hypercholesterolemia. It has been emphasized that it plays a protective role against, weight loss and male infertility or dysfunction. This overview will serve as a database of information that can form the basis for further comprehensive research on onion waste utilization. There is scope for preliminary studies to fully understand the mechanisms behind these protective functions, which could allow onion waste and its extracts to be used as promising active ingredients in pharmaceuticals and drug development. The exact molecular mechanisms underlying such effects are not fully understood yet, but the presence of bioactive compounds such as quercetin in *A. cepa* is responsible for most of the pharmacological activities. As there are currently no studies available so the biotrans-formation and role of bioactive compounds in onion skins in the large intestine and their direct effects on the gut need to be investigated and reported.

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