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EFFECTS OF IRRIGATION METHODS, WATER STRESS AND MULCHING ON POTATO YIELD AND YIELD COMPONENT

Ram Pal, R.K Jalaj* and U.P. Narayan
Krishi Vigyan Kendra, Madhepura, Bihar Agricultural University, Sabour, Bhagalpur
****Corresponding author** (R.K Jalaj)* ***Email :*** *rjjalaj99@gmail.com*

ABSTRACT

This research was conducted at Krishi Vigyan Kendra, Madhepura farm during the Rabi 2010-11 and 2011-12. The research investigated the effects of different irrigation and mulching treatments on potato yield and yield components. Drip and furrow method of irrigation in combination with mulch (25 micron black plastic sheet) were used. Two levels of irrigation (100% and 80% of full irrigation) were applied. Twelve irrigation with drip and six with surface (furrow) method were applied during each potato growing seasons. Irrigation water of volume 5.329 liter/plant, 4.263 liter/plant of were applied by drip method under 100% and 80% of full irrigation, respectively, considering the irrigation interval of three day. Similarly 6.12 liter/plant and 4.896 liter/plant were applied by furrow method in same irrigation levels for an irrigation interval of seven days.

Average seasonal evapotranspiration was recorded to be about 61.6 mm. The yield was observed maximum (47.41 ton/ha) at 80% water use level with drip+ mulch treatment, while the minimum yield was observed (17.58 ton/ha) at same level of irrigation under furrow method of irrigation without mulch. All treatments of 80% water use level with mulching treatment results the better result than the 100% water use level of irrigation with mulch. Water use efficiency under 80% level of irrigation by drip with mulch is highest among all treatments. Maximum average tuber length and diameter, average number of weight of tuber per plant, yield and water use efficiency all are higher in case of mulching. Therefore, 80% level of irrigation by drip + mulch would be recommended for potato production in Koshi region of Bihar.

Key words : *Potato, water stress, irrigation scheduling, mulch, drip irrigation.*

The potato, a native of South America, occupies the largest area under any single vegetable crop in the world. India stands third with 5.4% of total world production in the world. Potato is being grown over an area of about 1.34 million hectare and total production is about 25 Mt in India (*http://www.hortibizindia.nic.in*). Per capita availability of potato in India is about 17.69 kg/year. Every 100 gm of edible potato contains 1.6 gm protein, 22.6 gm carbohydrate, 97 calories energy, 10 mg calcium, 40 mg phosphorus and 17 mg vitamin C. Mid October and November is the ideal time of sowing in North and South India, whereas, in hilly areas, it can be sown during month of March to April. Potatoes crop requires frequent and light irrigation at low moisture tension irrespective of varieties (Handbook of Agriculture, 2003).

Irrigation requirements differ with locations, soil types and cultural practices. In medium soil 3 to 4 irrigations are sufficient, where in sandy soils 8 to 12 irrigation may be necessary. Under the condition of limited availability of irrigation water supply, higher benefits may be achieved by adopting suitable irrigation and planning techniques (Sharma *et at.,* 1993). Furrow method is widely used in India for production of potato. Drip irrigation is not popular among the farmers due to its high initial cost. There have been many reports on effects of water stress and irrigation regimes on potato crop in Indian conditions (Karafyllidis *et al*., 1996). Mulching is being practiced in potato production from a long while (Thomas *et al*. 2005 and Silverstone *et al.* 2005). Most of them have used biological mulch such as wheat straw only few researchers have used synthetic mulch (Talebul *et al*. 1994). Keeping the above in view the present study has been conducted for comprehensive evaluation of mulching effect on potato yield and yield components under drip and conventional method of irrigation.

MATERIALS AND METHODS

This study was conducted at the farm (mango mother orchard) of Krishi Vigyan Kendra, Madhepura during the months of October to March in each year. The research centre falls in the Koshi region of Bihar

(Agro-climatic zone-II of Bihar). The summers are humid and hot whereas winters are cool. Usually monsoon season lasts from mid-June to end of September with an average annual rainfall of about 1200 mm. The average relative humidity ranges from 68 to 83%. The mean maximum and mean minimum air temperature are 29.9°C and 9.5°C, respectively. Soil of the experimental site was loamy and silty clay which is very light in colour. The pH of the soil was recorded as 7.3. Required weather data were collected form Automated Weather Station situated in KVK, Madhepura.

The test crop for experimental study was potato (*Solanum tuberosum*) of cultivar Kufri Ashoka (P.J.-367). It matures in 90 days after planting but under short day conditions it may be harvested in 70 to 80 days. The tubers of this cultivar are attractive, long oval shaped and white with good flavor. It is susceptible to late blight. Its tuber has good keeping quality, 17-20 % dry matter, waxy texture and are easy to cook. It is suitable for sowing in Indo-Gangetic Plains of India. Kufri Ashoka (P.J.-367) potato variety is also suitable for intercropping and relay cropping.

The Experiment consists of eight different treatments consisting of irrigation, moisture regimes and mulching. Two methods of irrigation (drip and furrow) with two irrigation levels with and without mulching were carried out. For mulching 25 micron thick black plastic sheet was used. Drip lines are laid below the mulch. The upper portion of furrow ridges was covered with plastic mulch while lower portion were kept open for water absorption during irrigation. The experimental treatments are listed in Table-1.

There were three replications of each treatment. The area of the field was divided into 30 equal sized plots of 4.5x4.5 m each keeping 0.5 m spacing between consecutive plots in which experimental and non-experimental plots were 24 and 6, respectively. Row to row and plant to plant spacing was kept 0.60 m and 0.25 m, respectively. In drip irrigation plots, one dripper was provided for a pair of plants maintaining 0.5 m spacing between the drippers. Number of plants in each plot was 126. Discharge of one dripper was 3.95 liter/hr, and number of dripper were 63 including these all factor operating period was calculated.

The drip irrigation experimental set up consisted of pump, suction and delivery pipe, screen filter, main, sub-main, lateral, drippers and other accessories such as flow control values, pressure gauge, tees, elbows, couplings, end plugs etc. the source of water was an tube-well situated near the experimental plot.

The irrigation scheduling in all these methods were calculated by the formula adopted by National Committee on the use of plastics in Agriculture (NCPA), which is as follows :

$$V \quad E_p \quad K_C \quad K_P \quad S_P \quad S_R \quad W_P \qquad \ldots(1)$$

where,

V = Volume of water required (l/day/plant),

E_p = Pan evaporation as measured by USWB class-A Pan evaporation (mm/day),

K_c = Crop Coefficient,

K_p = Pan coefficient,

S_p = Plant to plant spacing (m),

S_r = Row to row spacing (m) and,

W_p = Wetted area in fraction.

The crop coefficient for different crop stages determined according to Doorenbos and Pruitt (1977). The set up was operated at three days interval for calculated operating time based on cumulative pan evaporation for drip irrigation, while irrigation internal was kept 7 days in case of surface (furrow) irrigation.

Digging of potato tubers were started on 5th March and completed on 7th March in each year. The potato yield of every plot was taken separately and average value of yield for each treatment was recorded. During harvesting the samples of selected plants were collected separately in plastic bags and number of tubers of every plant was counted and average values for each treatment were recorded. The weight of tubers of selected plants using standard procedure was taken and average values of weight for each treatment were recorded.

Water use efficiency of these irrigation systems were calculated as :

$$WUE = CY/WR \qquad \ldots(2)$$

where,

WUE = Water use efficiency (t/ha-cm),

CY = Crop yield (t/ha), and

WR = Total depth of water applied including effective depth of rainfall (cm).

Economic feasibility was tested by considering the fixed cost of the system and the cost of cultivation of the crop under different treatments of drip and furrow irrigation methods. Fixed cost includes the cost of each and every component of the irrigation system and present worth factor for each year were calculated by :

$$F = \frac{(n \quad 1)^{N\ 1}}{i(n \quad 1)^{N}} \qquad \ldots(3)$$

Where,F is the present worth factor, i is annual discount rate, N is life of system and n is the number of year considered. Here i = 18 and N =10 was taken for the computation of economic factor.

Cost of cultivation includes net cash inflow in the production of the crop such as field preparation, ploughing, harrowing, leveling, plot making, transplanting of potato, intercultural operations, plant protection, irrigation charges and harvesting and transporting charges.

RESULTS AND DISCUSSION

Irrigation Scheduling and Water Requirement : Irrigation scheduling for drip and furrow irrigation methods was based on the recommendations of the NCPA and adopted from FAO methods. For irrigation through drip system on December 5, 2010 with Ep= 6 mm (cumulative pan evaporation of last 3 days), Kp= 0.8, Kc= 0.73, Sp= 0.05, Sr= 0.60, Wp= 1.0 was calculated to 0.5256 liter/day water requirement was calculated. The detailed irrigation scheduling is shown in Table 2 and Table-3. These tables show that the irrigation starts at the same date i.e. IInd December and ends on 4th and 6th January in case of drip and furrow irrigation, respectively.

Yield and Yield Attributes : The yield attributes such as mean tuber length and diameter, number of tuber per plant, mean weight of tuber per plant and yield per hectare for different methods of irrigation water are level and mulching treatment were recorded after digging the potato tuber.

The maximum mean length and diameter of tubers of selected plants for observation were measured from each treatment plot with the help of Vernier calipers. The maximum mean tuber lengths were measured as 15.13, 14.63, 13.16, 12.30, 11.56, 10.20, 8.13 and 7.66 mm for treatment T_2 , T_4, T_6, T_8, T_1, T_3 , T_7 , T_5, respectively. The maximum mean tuber diameter were measured as 8.73, 7.23, 6.56, 6.13, 5.13, 5.10, 4.66 and 4.53 cm for treatments T_1, T_4, T_6, T_8, T_2, T_3, T_7, T_5 , respectively.

Table-1 : Details of different irrigation and mulching treatments.

Sl. No	Notation	Description
1.	T_1	80% WUL with Drip
2.	T_2	80% WUL with Drip+mulch
3.	T_3	100% WUL with Drip
4.	T_4	100% WUL with Drip+mulch
5.	T_5	80% WUL with Furrow
6.	T_6	80% WUL with Furrow +mulch
7.	T_7	100% WUL with furrow
8.	T_8	100% WUL with furrow+mulch

WUL - Water use level (estimated crop evapotranspiration).

The analysis of variance (ANOVA) on tuber length and diameter is given in Table-4, which shows that mulching and drip method of irrigation have significant effect over furrow-100% WUL(T_7) treatment. The percentage increase in tuber length and diameter under different treatment over furrow -100% WUL (T_7- which is common practice) is given in Table-3. The ANOVA analysis of tuber yield is significant at both 1% and 5% level of significance. Similar findings were also reported for potato by Islam *et al.* 1990; Kashyap and Panda, 2003; Yuan *et a*l. 2003; and Ander *et al.* 2005.

Average weight and number of tubers per plant and their percentage increase of different treatments over furrow 100% WUL are given in Table-6. Data from the Table-6 indicate that average weight of tuber per plant was recorder as 712.9, 640.6, 548.6, 527.8, 511.7, 442.1, 326.6 and 296.3 grams for treatments T_2, T_4, T_6, T_8, T_1, T_3, T_7 and T_5, respectively. The average weight of tubers per plant was recorder as 12.3, 10.8, 10.3, 9.8, 9.6, 9.2, 8.3 and 7.5 for treatment T_2, T_4, T_6, T_8, T_1, T_3, T_7 and T_5, respectively.

The trend indicates that drip method of irrigation along with mulching treatment has significant effects on yield component. It may also be observed that 80% WUL in combination with mulch and drip irrigation has better performance on yield component of potato then other treatments.

Table-2 : Water applied in potato crop through drip (Kp 0.8).

Day	Ep	Kc	Volume for 100%WUL l/plant	Volume for 80%WUL l/plant	Operating period for drip system (min)	
					100%WUL	80%WUL
Dec. 2	6.6	0.72	0.5702	0.4562	17.32	13.86
Dec. 5	6.0	0.73	0.5256	0.4205	15.97	12.77
Dec. 8	4.8	0.75	0.4320	0.3546	13.12	10.50
Dec. 11	4.9	0.77	0.4528	0.3622	13.75	11.0
Dec. 14	5.8	0.84	0.5846	0.4677	17.76	14.21
Dec. 17	4.7	0.86	0.4850	0.3880	14.75	11.79
Dec. 20	3.9	0.90	0.4212	0.3369	12.83	10.24
Dec. 23	4.2	0.94	0.4738	0.3790	14.39	11.51
Dec. 26	4.2	0.98	0.4939	0.3951	15.00	12.00
Dec. 29	2.5	1.02	0.3060	0.2448	9.30	7.44
Jan. 1	2.6	1.04	0.3245	0.2596	9.86	7.89
Jan. 4	2.0	1.07	0.2568	0.2054	7.80	4.68

Table-3 : Water applied in potato crop by furrow irrigation method (Kp =0.8).

Date	Ep	Kc	Volume for 100% WUL l/plant	Volume for 80% WUL l/plant	Irrigation period of system (min)	
					100%WUL	80%WUL
Dec. 2	15.0	0.72	0.70	1.2600	4.35	3.48
Dec. 9	12.4	0.77	0.74	1.1100	3.07	2.45
Dec. 16	12.4	0.82	0.84	1.2126	3.35	2.68
Dec. 23	9.4	091	0.92	1.0378	2.87	2.29
Dec. 30	7.4	0.98	0.98	0.8702	3.00	2.40
Jan. 6	4.9	1.07	1.07	0.6292	2.17	1.74

Table-4 : ANOVA of yield and yield parameters of potato.

Tuber length					
Source of variance	**Degree of freedom**	**Sum of square**	**Square of mean**	**f-value**	**Remarks**
Replication	2	7.4149	3.775	6.385	gm=11.03, CV=6.9084
Treatments	9	197.856	21.484	37.361**	sem=0.4399
Error	18	10.4515	0.5806		cd at 1%=1.7906
Total	29	215.722			cdat 5%=1.3071
Tuber diameter					
Source of variance	**Degree of freedom**	**Sum of square**	**Square of mean**	**f-value**	**Remarks**
Replication	2	1.3628	0.6814	2.3242	gm=5.8933, CV=9.1874
Treatments	9	45.3188	5.0354	17.1754**	sem=0.3126
Error	18	5.2771	0.2932		cd at 1%=1.2724
Total	29	51.9588			cdat 5%=0.92377
Yield					
Source of variance	**Degree of freedom**	**Sum of square**	**Square of mean**	**f-value**	**Remarks**
Replication	2	293.3979	146.6984	20.21829	gm=67.3, CV=4.0024
Treatments	9	9874.297	1097.144	151.2107**	sem=1.5552
Error	18	130.6031	7.255729		cd at 1%=6.3299
Total	29	10298.30			cdat 5%=4.62.5
Number of tuber per plant					
Source of variance	**Degree of freedom**	**Sum of square**	**Square of mean**	**f-value**	**Remarks**
Replication	2	6.066	3.0333	11.8697	gm=9.2666,
Treatments	9	45.200	5.0222	19.5523**	CV=5.455
Error	18	4.5999	0.2555		sem=0.2918
Total	29	55.8667			cd at 1%=1.1879
					cd at 5%=0.8671
Average weight per plant					
Source of variance	**Degree of freedom**	**Sum of square**	**Square of mean**	**f-value**	**Remarks**
Replication	2	4128.500	2091.250	71.4957	GM=4.84567,
Treatments	9	456746.5	5074.9	17351.029**	CV=1.1161
Error	18	526.500	29.2500		SEm=3.1225
Total	29	461455.5			CD at 1%=12.70924
					CD at 5%=9.2778

Table-5 : Percentage increase in mean tuber length and diameter and yield over T_7.

Treatment	Mean tuber length (cm)	Percentage increase over T_7	Mean tuber diameter (cm)	Percentage increase over T_7	Yield t/ha	Percentage increase over T_7
T_1	11.56	42.19	5.76	23.61	35.36	133.21
T_2	15.13	86.10	8.73	87.34	47.10	149.07
T_3	10.20	25.46	5.13	10.09	34.22	80.96
T_4	14.63	79.95	7.23	55.15	44.10	150.21
T_5	7.66	-5.78	4.53	-2.79	17.58	-7.03
T_6	13.16	61.87	6.56	40.77	36.69	94.02
T_7	8.13	-	4.66	-	18.91	-
T_8	12.13	51.29	6.13	31.55	36.25	90.64

Table-6 : Percentage increase in average weight and number of tuber/plant over T_7.

Treatment	Average weight of tuber/plant (gm)	Percentage increase over T_7	Average number of tuber per plant	Percentage increase over T_7
T_1	438.3	34.20	8.6	3.61
T_2	413.5	26.51	8.4	1.20
T_3	442.1	35.36	9.2	10.84
T_4	511.7	56.57	9.6	15.66
T_5	640.6	96.14	10.8	30.12
T_6	712.9	118.27	12.3	48.19
T_7	326.6	-	8.3	-
T_8	296.3	-9.28	7.5	-9.64

Table-7 : Benefit-cost ratio for different treatments.

Sl. No	Particulars	Treatments							
		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
1.	Fixed cost (Rs.)	188008	268008	188008	268008	20668	117625	20668	117625
2.	Seasonal fixed cost (Rs.)	20918	29819	20918	29819	2300	13087	2300	13087
3.	Cultivation cost (Rs.)	37625	37625	37625	37625	38025	37625	37625	38025
4.	Total cost (Rs.)	58568	67444	58568	67444	40325	50712	39925	51112
5.	Water Applied, cm	11.86	11.86	12.52	12.52	12.25	12.25	13.01	13.21
6.	Yield of potato, t/ha	35.36	47.41	34.22	44.10	17.58	36.69	18.91	36.05
7.	Selling price, Rs/qt	600	600	600	600	600	600	600	600
8.	Gross income, Rs.	212160	284460	205320	264600	84000	220140	113460	216300
9.	Gross benefit, Rs.	153592	217016	146752	197156	43675	219428	75535	165178
10.	Gross benefit-cost ratio	2.62	3.22	2.51	2.92	1.08	4.33	1.89	3.23

Potato yield of each replication plot for every treatment were recorded. The average tuber yield for different treatments and their percentage increase over T_7 are given in Table-5. The highest yield of potato (47.41 t/ha) with treatment T_2, was due to frequent application of water which maintain the moisture content at field capacity and mulching conserve the soil moisture and maintaining the soil temperature at a higher level than that of bare soil, ANOVA of yield is given in Table 4 which shows that yield is significantly affected.

Economic Evaluation : Cost of cultivation of potato for one hectare, total seasonal cost, water applied, yield of produce, gross income, gross benefit and benefit-cost ratio for different treatment were given in Table-7**.** The Table-7 revealed that the practice of well designed and optimized furrow irrigation system with 100% water use level in combination of mulch was most beneficial for potato crop as compared to other treatments. It may also be stated that even without mulch deep-100% WUL showed lower benefit cost ratio as compared to the furrow-100% WUL.

CONCLUSIONS

Experimental result of study shows that the highest yield of potato was obtained as 47.41 qt/ha under the treatment drip-80% mulch which is 150.71% more than the common practice adopted by the farmers (furrow-100% WUL). The benefit cost ratio was highest as 4.33 under the treatment T_6 indicating that furrow in combination with mulch is most beneficial among all these treatments. So, if it is not possible by farmers to adopt costly technology like drip irrigation, they should follow the mulching technique-which is cheap and need no highly skilled labor. The water use efficiency was maximum as 4 t/ha-cm for the treatment drip-80%, WUL+ mulch and minimum as 1.44 for furrow-80%.

In an economic view, the result of study showed that T_6 is better than other treatment while, in the view of total production, treatment T_2 is superior to other treatment in humid region. It may because of the mulching which controls the temperature and consequently the late blight and water stress prevent the development of moisture born pest. Therefore, when economy is not a constraint farmers should adopt the drip method of irrigation at 20% reduced irrigation level with mulching, whereas, in economical production furrow irrigation with similar treatment should adopted.

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