Progressive Research 9 (1) : 1-11 (2014) *Society for Sci. Dev. in Agric. and Tech.*

YIELD MAXIMIZATION OF WHEAT WITH DIFFERENT MANAGEMENT PRACTICES — A REVIEW

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ABSTRACT

Rice-wheat cropping system in the Indian agriculture facing machinery fatigues. The burning of rice residue degraded the environment quality. Similarly, removal of crop residue, depletion of underground water and intensive tillage are also deteriorating the soil health. Conservation tillage is an important tool for crop residue management, restoration of degraded soil, and for enhancing C sequestration in soil. Happy seeder and zero tillage are the methods play vital role in enhancing the productivity of wheat and sustaining the natural resources. Split application of nitrogen fertilizer and selection of suitable varieties have significant effect in increasing the wheat yield.

Key words : *Conservation tillage, crop residue, happy seeder, nitrogen, rice-wheat, zero tillage.*

The rice-wheat cropping system (RWCS) has the immense importance for food security and livelihoods in Southeast Asia. This rice-wheat cropping system in north-west India is very strongly supported by both national and state governments through a range of input subsidies (machinery, fertilizer, water, electricity and credit) and price support mechanisms. Uttar Pradesh, Punjab, Haryana, Bihar, Madhya Pradesh, and Himachal Pradesh have the largest areas under this system and it is highly mechanised in comparison with other RW regions. The time gap between rice harvesting and wheat sowing in north-west India, for example, is only 15-20 days. In this short duration, farmers prefer to burn the rice straw on-farm instead of harvesting it for fodder or any other use. The latter options also involve a huge transportation cost. The biomass burning is the major source of air pollution, in the forms of green house gas emissions (CO_2, CH_4, NO_2, N_2O) and particulate matter. Grace et al (2003) reported an increase in respiratory and eye problems due to rice stubble burning; other negative impacts on society include loss of biodiversity and structures, disruption of road and air traffic, and adverse effects on animal health and productivity. Yadvinder-Singh *et al* (2008) estimated the loss through burning in Punjab at around 35 kg N/ha, 21kg K/ha and 3 kg/ha each of P and S, respectively. Thus technologies that enable retention of rice residues would greatly reduce air pollution and improve soil fertility.

Today's agriculture is energy intensive farming system. The energy required in agricultural operations, mainly depends on fossil fuels/natural resources which are a scarce commodity. Today's real agricultural challenges are resource fatigue with declining factor productivity, decreasing human resources and their rising costs and socioeconomic changes. The conservation agriculture (CA)-based resource conservation technologies (RCTs), practiced over 96 million hectare (m ha) area worldwide have proved to be energy and input efficient, improve production and income, and address the emerging environment and soil health problems. The RCTs involve zero- or minimum-tillage with direct seeding using seed-cum-fertilizer drill and bed planting innovations in residue management to avoid straw burning, and crop diversification. Farm mechanization plays a vital role for the success of CA based RCTs in different agro-ecologies and socioeconomic farming groups. It ensures timeliness, precision and quality of field operations; reduces production cost; saves labour; reduces weather risk in the changing climatic scenarios; improves productivity, environmental quality, sustainability and generates rural employment on on-farm and off-farm activities. In the IGP, zero-till (ZT) wheat with the RCTs is being adopted by the farmers on a large scale using the second generation drills and planters. The drills/planters i.e. ZT seed-cum-fertilizer drill, rotovator, raised bed planter, happy seeder, etc. ensures efficient management of costly inputs viz.: diesel, nutrients and water and help in reducing the energy and cost of production. Punjab Agricultural University, Ludhiana in collaboration with CSIRO has developed a new machine called the happy seeder under the ACIAR funded project which is, “economically viable and acceptable’. Operational costs for sowing wheat are 50-60% lower with happy seeder than with conventional sowing. The ‘Happy Seeder’ (Sidhu *et al.,* 2007, 2008) provides the capability of direct drilling wheat in rice residues. The technology is now recommended to the farmers in Punjab, and is in the early stages of adoption. The happy seeder simultaneously cuts and removes the straw in front of the sowing tynes, and spreads the straw on the surface as mulch behind the tynes.

Similarly, the potential yield of the cultivars depends upon their genetic constitution and environment under which they are grown. The trials conducted by CSISA in western IGP indicated significant tillage x genotype interactions in wheat. Yield performance of seven wheat varieties varied with tillage, such as DBW 17, HD 2851, HD 2894, PBW 550, HD 2733, KRL 19 performing better under zero tillage over conventional tillage. This interaction suggests the selection of varieties suited to different tillage management practices should form the basis of new recommendations on cultivars for different ecologies (Gupta *et al.,* 2010). The wheat varieties selected for research purpose has the same sowing time, but they vary in their stature/height, germination days and maturity time, so, they can perform different from each other when sown with happy seeder method. Because of genetic variation, different varieties of crop may differ in growth and development behavior and response to different management practices. Taller varieties are generally less responsive to fertilizer application and give lesser yields than the dwarf varieties. As genotypes vary widely, nitrogen has got differential response. The varieties have been found to differ in their efficiency to accumulate dry matter and yield attributing characters. The development of semi-dwarf wheat cultivars, which resist lodging more than conventional taller varieties have improved wheat yields by allowing greater efficient use of nitrogen (N) fertilizer.

Nitrogen application rate and timing are very important for yield and quality of wheat. Judicious and efficient use of N-fertilizers is needed for increasing efficiency and reducing N pollution of environment such as nitrate leaching into ground water and nitrous oxide emission into the atmosphere. Based on the worldwide evaluation, the fertilizer N recovery efficiency has been found to be around 30% in wheat with current practices (Krupnik *et al.,* 2004). Recoveries of N from 70-80% are physically feasible in most situations with efficient N application through improvement in input level and timing. Efficient fertilizer management in terms of rate and application timing avoids crop N deficiency at critical periods of crop. The literature related to the different management practice has been reviewed under the following heads :

Effect of conservation tillage on wheat

In Fargo, Cox *et al.* (1986) found that yield of wheat was higher in no-tillage (22.70 q/ha) where wheat planted in 0.05 m stubbles and 40.73 q/ha where wheat planted in 0.20 m stubbles) than conventional tillage (0.45 q/ha) and mulch tillage (22.03 q/ha). Verma et al (1989) at Ranchi, Carefoot *et al* (1990) from Canada reported that greater grain yields of wheat under no-tillage were recorded than conventional tillage.

Singh *et al.,* (1998) conducted an experiment to study the effect of tillage practices on the growth and yield of wheat and soil properties under rice-wheat cropping system and found that wheat sown after conventional tillage resulted in taller plants, longer and heavier ears, more grains/ ear and higher grain yield than wheat sown with zero tillage. Tripathi *et al.,* (1999) at Karnal, compared the performance of zero tillage wheat under different methods of rice transplanting viz. broadcast in puddled condition, transplanting and dry seeding. They found that zero tillage under dry seeding of rice gave significant higher yield (49.6 q/ha) than conventionally filled plot of transplanted rice (43.3 q/ha). In Haryana, Mehla et al (2000) recorded 7.1 per cent increase in the grain yield of wheat with zero tillage over conventional tillage when sown wheat on the same date and 16.7 per cent with the delay of sowing (2 weeks) conventional tillage wheat. Rath *et al.,* (2000) investigated that conventionally sown wheat gave 10-13 and 28-35 percent higher grain yield than raised bed and zero tillage sown wheat, respectively in silty clay loam soil. Similarly, Carter and Rennie (1982) recorded less yields of wheat under zero tillage with poor seedling establishment. Samra and Dhillon (2000) conducted an experiment to improve the production potential of rice-wheat system under different methods of crop establishment during rainy (Kharif) and Rabi) season of 1995-96 and 1996-97 at Ludhiana and observed that conventional tillage and drill sowing recorded the highest mean grain yield, followed by minimum tillage and drill sowing in wheat. In Bihar, Gautam et al (2002) reported that higher wheat yield of 4.0 q/ha was obtained under zero tillage over conventional tillage. Brar *et al.,* (2002) reported similar wheat grain yields under tilled and untilled condition in Punjab. Mahey *et al.,* (2002) at Ludhiana, Sardana *et al.,* (2005) from Gurdaspur, Yadav *et al.,* (2002a) at Faizabad, Yadav *et al.,* (2002b) at Hisar and Ram *et al.* (2006) in Haryana, also confirmed the same results.

Retaining the residues as a mulch also offers the potential benefits of reduced water loss due to the suppression of soil evaporation (Es), reduced runoff, suppression of weeds, increased soil organic C, and improved soil structure (Yadvinder-Singh *et al.,* 2005). Higher soil water content and increased yield of wheat with rice straw mulch have previously been reported from India and Bangladesh (Sidhu *et al.,* 2007; Rahman *et al.,* 2005). It is well established that mulch can suppress soil Evaporation (Es) (Al-Darby *et al.,* 1989; Jalota and Prihar,1990; Jalota,1993) and Es can account for 30–60% of total evapotranspiration (ET) during wheat production (Siddique *et al.,* 1990). This suggests that reducing Es may reduce ET and thus result in increased water productivity based on ET (WPET) by about 10–20% (Deng *et al.,* 2006). Thus mulching could be beneficial in terms of reducing water loss from the groundwater, as well as in reducing irrigation requirement (Mandal and Ghosh,1984; Li *et al.,* 2004). Zero till sowing has already been shown to reduce the amount of irrigation water needed for wheat in north-west India (Erenstein and Laxmi, 2008; Erenstein *et al.,* 2008).

Usman *et al.,* (2010) in the low-precipitation zone of Dera Ismail Khan, Pakistan in two years field experiment evaluated the effect of tillage systems under rice–wheat cropping system. Three tillage systems, zero tillage (ZT), reduced tillage (RT) and conventional tillage significantly affected grain yield, net benefit (NB), and benefit cost ratio (BCR) . Both RT and ZT produced higher grain yield (55.83 q/ha, 55.75 q/ha), while maximum NB (US $ 1196.0/ha) and maximum BCR (5.5) were observed in ZT. Husnain (2011) at Fasilabad studied four sowing methods i.e. zero tillage, reduced tillage, deep tillage and conventional tillage in wheat and maximum grain yield obtained in ZT as compared to all other three tillage practices because of better germination count per unit area, higher plant height, longer spike length, more number of fertile tillers/m^2, number of grains spike-1, heavier 1000- grain weight and larger biological yield. In addition to this, ZT was found to be the most economical practice in wheat sown after rice. The study conducted at PARC's research station Kala Shah Kaku, Lahore, by Mirani *et al* (2011) in order to calculate the water productivity and economic efficiency of wheat-crop under different sowing methods in a combined harvested paddy filed. The sowing methods were direct drilling with happy Seeder, Zero tillage and conventional method. Wheat-yield was 27.50 q/ha, 26.65 q/ha and 26.10 q/ha for direct drilling with happy Seeder, Zero tillage and conventional method, respectively. The direct drilling in heavy residue gave 5.4% more yield than the conventional method and 3.2 % more yield than zero tillage. The zero tillage ensured 2.1% more yield than the conventional method. The direct drilling of wheat-crop in heave rice stubbles saves 15% irrigation water as compared to conventional method and 8.8% over zero tillage. There is overall saving of Rs. 13924/ha (26.2%) by the happy seeder method as compared to the conventional method and Rs. 4613/ha (10.5%) over zero tillage method.

Yield of wheat sown around the optimum time into rice residues, using the happy seeder, was comparable with or higher than yield after straw removal or burning, in replicated experiments and farmer's fields, for straw loads up to 9 t/ha. In farmers' fields there was an average yield increase of 9 and 11% in 2004–05 and 2005–06, respectively, compared with farmer practice.

For sowings after the optimum time, yield declined significantly at straw loads greater than 7.5 t/ha. The Happy Seeder offers the means of drilling wheat into rice straw without burning, eliminating air pollution and loss of nutrients and organic carbon due to burning, at the same time as maintaining or increasing yield (Sidhu *et al.,* 2008). Sidhu (2008) evaluated the performance of wheat crop, sown with happy seeder on 15 locations in Punjab and observed that the grain yield either at par or higher as compare to the conventional sowing method. The savings in irrigation and fertiliser usage associated with straw retention make the Happy Seeder an attractive option and all of the rice area is planted to wheat using this technology and there is possibility of growing a third crop, namely mungbean, between the wheat and rice crops. Happy Seeder sowing has benefits over conventional farming because it adds further income and provides rotational benefits through improvements in soil condition and the biological fixation of nitrogen (Milham *et al.,* 2010). Gathala et al,(2011) confirmed the higher yield in wheat sown with happy seeder as compare to conventional and zero-till method. They concluded after three year trial that the percent water stable aggregates (WSA) of size >0.25 mm, steady state infiltration rate, and bulk density were affected by tillage and residue management methods . WSA% was highest in Happy Seeder sown wheat (63%) followed by in zero-till (57%) and conventional till (52%). Similarly, steady state infiltration rate was higher in happy seeder and Zero till (0.314 to 0.372 cm/hr) compared to conventional till (0.237 cm/hr). Both percent WSA and infiltration rate improved in zero-tillage treatments (ZTW and HST) and decreased in conventional tillage (CTW) with time, from the initial value. The surface bulk density (0-5 cm) was lower in CT and HST as compared to ZT. The lower bulk density of surface soil in HST compared to ZT suggests that residue retention as mulch helps in minimizing soil compaction. Balwinder-Singh *et al.* (2011) studied the effect of different irrigation treatments on happy seeder sown wheat. They concluded that using the recommended irrigation scheduling for north-west India, based on CPE, then on-mulched wheat suffered from water deficit stress which led to yield reduction in one of the two years. Furthermore, the recommended irrigation scheduling practice resulted in one more irrigation of the mulched crop each year than SMP-based irrigation scheduling, for the same yield. With the current drive to retain rice residues on the surface instead of burning them, there is a need for new guidelines for irrigation scheduling which take into account the availability of soil water to the crop, to capitalize on the benefit so far mulching. Kaushal et al (2012a) concluded that for higher productivity and N recovery wheat can be sown with direct drilling methods like zero tillage and happy seeder with an application of 150kg N/ha.

Naresh (2013) conducted a field experiment over 3 years to review the potential of rice residues and its management options, residue effects on soil properties and crop productivity. A rice-wheat sequence that yields 7 t/ha of rice and 4 t/ha of wheat removes more than 300 kg N, 30 kg P and 300 kg K/ha from the soil. The result showed that before wheat planting, burning results huge losses of N (up to 75%), P (25%), and K (21%) and by incorporation of residues of both crops in rice–wheat rotation increased the available N, P and K contents in soil over removal and burn of residues. Surface retention of residues increases soil N, P and K uptake by 14.6, 28.5 and 17.7 %.Total system productivity increased by 10.9-15.8% in residue retention with permanent wide beds planting, happy seeder sown and zero tillage planting system over conventional. Residue management practices affect soil physical properties viz. soil moisture, aggregate formation and bulk density. Extensive tillage with its associated high costs can be reduced by the use of zero-tillage or permanent raised beds with residue retention is needed to insure production sustainability. Thus, if residues are managed properly, then it can warrant the improvements in soil properties and the sustainability in crop productivity.

Effect of planting pattern

Planting geometry has a direct relation to light interception and utilization which is prerequisite for photosynthesis. Skip planting geometry with pairs of row allow more light penetration inside plant canopy, while in solid geometry the field is more populated and there is less light penetration inside plant canopy. Skip or wider planting geometry makes application of herbicides, other fertilizer and intercultural practices for weed control easier as compared to solid planting geometry. Narrow row spacing results in higher leaf photosynthesis and suppresses weed growth due to smothering effect compared with wider row spacing (Dwyer *et al.,* 1991). Adjusting planting geometry to narrow row spacing has higher radiation use efficiency during grain filling, which further contributes to higher dry matter yield (Tollenear and Aguilera, 1992)

At Lakhaoti (UP) on sandy loam soils, border row method of sowing of wheat (sowing in three rows and leaving every fourth row unseeded) recorded significantly higher grain yield of wheat (36.1 q/ha) as compared to that of normal planting (33.9 q/ha). This was attributed to increased plant height, effective tillers per plant, ear length, spikelets per ear, grain weight per ear, 1000-grain weight under border row method of sowing than those of normal planting (Singh and Deshwal, 1985). At Kanpur it is observed that border method (skipping of fourth row) recorded significantly higher ear weight, grain weight per ear, grains per ear and grain yield of wheat (38.9 q/ha) than that of normal planting method (37.3 q/ha) under rainfed condition (Prasad and Rathi, 1987). At Faizabad (UP) on sandy loam soil, skipping of fourth row recorded more number of panicles per m^2, panicle weight and grain yield (43.18 q/ha) of rice as compared to that of normal planting (40.30 q/ha) (Sharma and Warsi 1987). At Ludhiana, it is reported that skip row planting of wheat recorded higher number of tillers per m2, number of ears per m2 and eventually grain yield (25.9 q/ha) than that of normal planting (24.6 q/ha) (Sharma and Dhillon 1988). Abunyewa (2010). In environments with limited rainfall, skip-row configuration under rainfed conditions may increase yield of grain sorghum due to conservation of soil water between widely-spaced crop rows that is not accessed until late in the growing season. Skip-row configurations also had greater yield stability than conventional planting.

Sinsinwer (1993), Shaukat *et al.,* (1999) and Saeed *et al.,* (2012) reported that skip row planting accounted for significantly more number of spikes per m^2, 1000-grain weight and higher wheat grain yield than that of normal sowing (without skipping a row) .

3. Effect of cultivars on the performance of wheat

On sandy loam soil at Varanasi (UP) under rainfed condition, Misra and Dwivedi (1980) reported that Kalyan Sona wheat variety recorded significantly higher grain yield (30.4 q/ha) and straw yield (62.8 q/ha) than other cultivars viz., HUM 16, RR 21, UP 319, (16.3,18.4, 7.4 q/ha, respectively). This was attributed to enhancement in tiller number per plant, leaf number per plant, leaf area per plant than other cultivars. At Udaipur (Rajastan), Shaktawat and Joshi (1989) reported that wheat cultivar HI-601 gave maximum number of spike per meter row length, 1000-grain weight and eventually higher grain yield (29.42 q/ha) and straw yield (42.12 q/ha) as compared to that of other cultivars viz., J-142, Roj-911, NP-718, NPO-190, HD-4530 (21.16, 22.47, 22.38, 22.87 q/ha, respectively). Similarly wheat varieties 1671 and L19 recorded significantly more grain yield as compared to other cultivars namely Sonalika, L 19, HUW 234 and HP 1102. The variation in yield was ascribed to number of effective tillers per m2 and grain weight per spike (Kumar et al., 1991). On clay loam soils at Coimbatore (TN), Venkitaswamy *et al* (1991) reported that wheat variety AKW-65-1 recorded higher grain yield (8.1 q/ha) followed by N 8668 (7.8 q ha-1) as compared to other cultivars viz., NI-5439 and NI-8848 (5.2 q/ha). This was attributed to more number of effective, tillers and higher leaf area and more test weight with AKW 65-1 as compared to those of NI-5439 and NI-8848. Hattalli (1991) studied that effective tillers, leaf area, leaf area index, leaf area duration, relative growth rate, root : shoot ratio, number of grains per ear, 1000-grain weight, total chlorophyll content and proline content at different stages of wheat genotypes MACS-1967 and NIC-643-15-4 as the contributing characters for their higher yield (18.20 and 17.73 q/ha, respectively) but not in DWR-174 (10.62 q/ha) which had lesser effective tillers, leaf area, leaf duration, relative growth rate, root : shoot ratio, number of grain per ear, 1000-grain weight, total chlorophyll content and proline content. At Ballowal Saunkhari (Punjab) on sandy loam soils under rainfed condition, Sandhu *et al,* (1993) revealed that PBW-175 wheat variety recorded higher plant height, more number of effective tillers per m row length, higher 1000-grain weight and higher grain yield (42.6 q/ ha) than other cultivars namely, KSML-3, WL-2265, PBW-65 (37.2, 38.0, 37.2 q/ha, respectively) which had lesser plant height, lesser number of effective tillers and lesser 1000-grain weight. It is reported that wheat variety HS 240 and HD 2380 gave higher grain yield at different locations viz., Kalidhar and Talora (HP) as compared to other five cultivars (Sharma *et al.,* 1999). The difference in yield under various varieties was attributed to differences in effective tillers, number of grains per ear head and 1000-grain weight. Sardana and Sharma (2000) found that among four wheat varieties, PBW 373 recorded significantly higher grain yield by 31, 51 and 72% over PBW 226, Raj 3765 and PBW 138, respectively. Mahajan and Nagarajan (2005) reported that two hybrids HM 9846 and HM 9837 were significantly superior in grain yield to the best check PBW 343.

The farmer's participatory trials conducted by CSISA in western IGP have indicated significant tillage x genotype interactions in wheat. Yield performance of seven wheat varieties varied with tillage with wheat varieties such as DBW 17, HD 2851, HD 2894, PBW 550, HD 2733, KRL 19 performing better under zero tillage over conventional tillage. This interaction suggests that for realizing higher productivity, the selection of varieties suited to different tillage management practices should form the basis of new recommendations on cultivars for different ecologies (Gupta *et al.,* 2010). Bhardwaj *et al.,* (2010) studied the effect of different varities at HAU, Hisar in raised bed planted system. They concluded that during both years, PBW343 produced significantly greater grain yield (43.78 q/ha in 2001–02 and 41.60 q/ha in 2002–03) than other varieties . WH283 had the lowest grain yield (37.52 q/ha in 2001–02 and 35.10 q/ha in 2002–03). The trend in terms of grain yield followed was PBW343 > WH542> WH711 > HD2687 > WH283. The differences in yield might be because of differential genetic make-up and yield potential capacity.

Effect of time of nitrogen

Among various agronomic manipulations, nitrogen is one of the important factors which influence the quality and yield of wheat. Plants take up most of their nitrogen as the ammonium (NH^{4+}) or nitrate (NO^{3-}) form. The majority of agronomic crops take up most of their nitrogen as nitrate. Nitrogen represents one of the most important and expensive inputs in wheat production. N is often the most limiting plant nutrient in soil for economic yield. However, ever-increasing prices of N fertilizers and possibilities of environmental pollution and groundwater contamination warn for their judicious and efficient use. During the last decade, increase in fertilizer use has been one of the major crop management techniques responsible for the increase in production of wheat. However, fertilizer-use -efficiency of applied N is still very low in India (40–50%). One of the main reasons for this is a lack of perfection in time of application of nitrogenous fertilizers.

In sandy clay loam soil at Ranchi, application of 120 kg N/ha (50% at sowing and 50% at CRI after first irrigation) gave highest grain yield of 35.65 q/ha as compared to top dressing of N half as basal plus half at CRI before first irrigation and 10 per cent basal + 60 per cent at CRI before first irrigation + 30 per cent at jointing (Verma and Srivastava 1989). On silty clay loam soil at Palampur it is recorded significant increase in grains per ear, grain weight per ear and grain yield with the application of 120 kg N/ha in three splits (25% at CRI, 50% at tillering and 25% at jointing) as compared to the recommended practice of N application (half N at sowing and half at first irrigation) (Bhopal-Singh and Singh 1991).

Fischer (1993) reported that grain yield ranged from 170 to 750 g/m^2 across N fertilizer treatments and the response to N was not reduced with applications as late as the onset of stem elongation. Grain yield was very closely correlated with kernels m^2 and with total biomass production. Kernel numbers was in turn closely correlated with spike dry weight (g/m^2) at anthesis and with crop dry weight accumulation during the spike growth phase commencing first week before flag leaf emergence. Kernels per unit spike weight was unaffected by nitrogen but dry matter partitioning to growing spike was increased by early N stress. Under irrigated condition, split application of the recommended dose of 120 kg N/ha as 10-25 per cent at sowing, 50-60 per cent at CRI stage and 20-30 per cent at late jointing stage produced significantly higher number of effective tillers per meter spikelets, grains per spike, grain weight per spike and highest yield of grain as well as straw in comparison to other combination of split application of nitrogen (Deshmukh *et al.,* 1994 and Deor and Pathik., 1997 ; Patel.,1999). Samra and Dhillon (2002) reported that application of nitrogen in two splits i.e. half at sowing and half at CRI stage remarkably improved the grain and straw yields on sandy loam soil at Ludhiana (Punjab) over all the other split application.

Ananda (2004) reported that split application of N as half basal + one fourth at 30 DAS + one fourth at 60 DAS recorded maximum dry matter production, plant height, number of tillers and maximum leaf area and grain yield. Pasha (2005) also confirmed same findings.

On two types of soils, sandy and silt loam of PAU, Ludhiana, Yadwinder Singh et al (2009) evaluate the effect of straw management (burning, incorporation and surface mulch) and the rate and time of nitrogen application. Two splits with 150 kgN/ha gave higher yield of wheat sown with happy seeder as compare to the 120kgN/ha. On deep sandy loam soils of HAU, Haryana, Kaur *et al.,* (2010) observed that the protein content and grain yield was significantly higher in three-split nitrogen application but grain yield was also statistically at par with two split nitrogen application. Similarly, wheat sown with Happy Seeder in north-west India respond better to120kg N/ha as broadcast in two equal splits. This may be due to decreased volatilization of applied urea on mulched treatments as the surface speed and soil tem6perature would have been lower than on burnt plots (Brar *et al.,* 2010). Studies conducted at Research Farm of KPK Agricultural University Peshawar, revealed that two split application of nitrogen gave highest biological yield and N uptake in silt clay loam soil (Jan *et al.*, 2010). On sandy loam soils of experiment fields of PAU, Ludhiana, it is found that the three-splits (1/3 at sowing+ 1/3 at CRI +1/3 at boot stage) nitrogen application improved the yield contributing characters like number of effective tillers, number of grains per ear and 1000-grain weight which led to significant increase in grain yield over two-split nitrogen application (Mattas *et al.,* 2011).

El-Far and El-Negar (1995) reported that increased protein was obtained with split application of nitrogen. Garrido-Lestache *et al.,* (2004) have also shown under rainfed Mediterranean conditions, with split applications of N fertiliser, an increased wheat grain protein outcome associated with improved bread baking quality. Sadat *et al.,* (2008) at Bangladesh studied that the highest grain protein content (12.63%) was obtained when nitrogen applied in three splits i.e.18% N at land preparation, 36% N at CRI, 46% N at anthesis. The highest grain protein content in wheat might be due to fact of applying nitrogen at all growth and productive stages that enhanced the increase seed protein accumulation. Rahman *et al.,* (2005) at Bangladesh concluded that Total N uptake was maximum under N rate of 120 kg/ha applied as three equal splits as 1/3rd basal with 1/3rd as top dress at CR1 plus 1/3rd as top dress at 1st node stage. Coventry *et al.,* (2011) concluded for irrigated wheat grown in Haryana the use of a 3-way split of N fertiliser applied at seeding, early tillering and first node stage provides the highest grain yields, protein, grain hardness and chapatti quality.

Effect of residue on weed population

Weed infestation is a major biological constraint to higher yields of both crops in rice-wheat rotation and mix stand of grassy and broad-leaved weeds has been reported to inflict a yield penalty of 48-52% in wheat (Khan and Haq, 2002). Management practices opted for one crop can have definite implications for productivity of subsequent crop followed in sequence. Management of residues of previous crop can also inflict qualitative and quantitative changes in weed flora associated with succeeding crop (Kumar and Goh., 2000). Several residue management options like incorporation, surface mulching or retention and direct drilling in residues can be opted as an alternative to current detrimental practice of rice residue burning. Residue incorporation suppress weed growth through release of phytotoxins (Weston and Duke., 2003) while mulching produces smothering effect posing physical hindrance (Reddy., 2003). Residue burning depletes seed bank by removal of viable seeds (Yadvinder-Singh *et al.,* 2005). With the advent of modern drills that enable wheat sowing in rice residues without land preparation, zero tillage has emerged as the most promising resource conservation technology in rice-wheat cropping systems (Erenstein and Laxmi., 2008). Under zero tillage, several authors reported less weed density in wheat crop than conventional tillage (Mehla *et al,* (2000); Mann *et al.,* (2008) ; Usman *et al.,* (2010). Besides having direct consequences for weed growth, these residue management options can influence herbicide efficacy (Kumar and Goh, 2000). Burning or incorporation of residues can increase ash and organic matter content thereby decreasing herbicide efficacy due to greater adsorption potential (Yadvinder-Singh *et al.,* 2005).

Gel and Holmes (1997) mention that summer fires effectively destroy the surface seedbank of many weeds and at the same time they found that not all weed seedbank can be decreased; also some weeds are not affected and others benefit from burning. Mazzola *et al.,* (1997) found that wheat seedlings growth was better in burnt field than none burnt field. On the other hand, Garg (2008) illustrates that burning open fields reflects negatively on soil and atmospheric; he reports that after field burning, the soil losses its organics as well as nitrogen (27-73%), bacterial (about 50%) and Wojciechowski and Sowiñski (2005) found that pre-sowing wheat tillage had a considerable effect on weed species and weed seedbank in soil. Swanton *et al*., (2012) demonstrates that the vertical distribution of weed seedbank will be influenced by type of tillage, depth of tillage, and type of soil; also they illustrate that tillage alters the size and composition of seedbank; in no-till systems, most weed seedlings emerge from the seedbank near the soil surface, while in conventional tillage systems; a high proportion of seedbank is located in deeper soil layers. Kouwenhoven (2000) reports that mouldboard ploughing mostly relocates seeds from the surface to a depth from where they cannot emerge.

Also, Shrestha *et al.,* (2002) found that weed density was greater in conventional tillage than in no-tillage systems; the authors attribute the higher weed density to ploughing which could have brought weed seeds from lower soil profiles to a depth that was favorable for germination and emergence. Similarly, the results of Boguzas *et al*., (2006) indicate that no-tillage significantly increases weed infestation, compared to conventional deep plowing in the field but the tillage systems have no effect on weed seedbank.

With ZT, the early emergence of wheat and reduced or the absence of soil disturbance in the uncropped area resulted in less and late emergence of weeds (especially P. minor). Therefore, weed competition to the wheat crop is greatly reduced. Malik *et al.,* (2004) found a change in the weed spectrum in ZT wheat fields, particularly an increase in the population of broad-leaved weeds and infestation of P.minor decreased by 30-40 per cent. Similar results were reported by Singh *et al.,* (2002b) and Yadav et al (2002a). Kaushal *et al.* (2012b) determined that annual weeds (grassy and broad leaf weeds) were less under zero tillage and happy seeder sown wheat which might be due to less disturbance of soil surface.

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