Tillage System, Crop Residues and Nitrogen to Improve the Productivity of Direct Seeded Rice and Transplanted Rice

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ABSTRACT

Rice is grown by different techniques for higher productivity with judicious use of inputs and natural resources. Transplanting of paddy seedlings is common method of crop establishment in the irrigated rice systems of Asia but transplanting is labour intensive (30 persons/ha/day). The preparation of land for transplanting paddy (puddling) consumes about 20-40 % of the total water required for growing of crop and subsequently poses difficulties in seed bed preparation for succeeding wheat crop in rotation. It also promotes the formation of hard pan which effects rooting depth of next crop. So, in this paper discussed the different methods of establishment of rice, sowing of rice in the crop residue of wheat with different tillage systems and use of nitrogen for higher productivity of rice.

Key words: Methods of establishment, Transplanting, Seedlings, Water, Labour, Puddling**.**

INTRODUCTION

Rice is one of the most important cereal crops and provides food security and livelihood for millions of people across the globe. It is the main staple food crop of India, covering an area of about 43.97 mha with the total production and productivity of 104.32 mt and 2.37 t/ha of rice, respectively during 2011-2012 (Anonymous 2013a). In Punjab, rice was grown on an area of 28.18 lakh ha with the total production and productivity of 105.42 lakh t and 3.74 t/ha, respectively during 2011-2012 (Anonymous 2013b). To meet the future demand, world rice production must increase by more than 60 per cent in the next 30 years (IRRI 1989), which is possible only if soil, water resources and inputs are used more efficiently.

In the recent years, the rural labour had migrated towards the industrial sector, which had led to the non-availability of labour for transplanting of rice at the appropriate time. It results in delayed transplantation of rice as per the schedule, thereby resulting in yield reductions. This method also results in drudgery among women workers (Budhar and Tamilselvan, 2001). Transplanting of paddy seedlings is common method of crop establishment in the irrigated rice systems of Asia but transplanting is labour intensive (30 persons/ha/day). The preparation of land for transplanting paddy (puddling) consumes about 20-40 % of the total water required for growing of crop and subsequently poses difficulties in seed bed preparation for succeeding wheat crop in rotation. It also promotes the formation of hard pan which effects rooting depth of next crop (Bhuiyan *et al* 1995).

Zero tillage or reduce tillage establishment is used widely for many crops around the world and this technology has potential to allow saving in time, energy, water and labour during rice establishment (Piggin *et al* 2002). It has therefore growing significance due to receding water table (Humphyreys *et al* 2004), rising costs of labour for transplantation of paddy (Singh *et al* 2005) and adverse effects of puddling on the soil health (Timsina and Connor 2001).

Rice is predominantly grown as puddled transplanted crop in Punjab. The farmers in Punjab transplant rice from 10 June when the daily evaporation rate is very high (8-10 mm/day). The underground water is being over exploited by excessive pumping to meet the water requirement of transplanted rice. As a consequence, it has been causing a sharp decline in ground water table. Therefore, need has been felt to develop technically viable and economically feasible alternate techniques for growing rice in this region. The preliminary research conducted at Punjab Agricultural University (PAU) indicated that dry direct seeded rice could be a viable alternative to transplanted rice.

Dry DSR differs from transplanted rice in terms of crop establishment as well as subsequent crop management practices. The broadcast sowing/ drilling/ dibbling of dry seeds in soil is called DSR. However, it offers many advantages such as more efficient water use, high tolerance to water deficit, less methane gas emission, reduced cultivation cost, prevents the formation of hard pan in sub-soil and minimizes labour input (Balasubramanian and Hill 2002). It is more conducive to mechanization and also eliminates transplanting shock. Preliminary studies conducted at the PAU, Ludhiana showed that DSR can also be sown successfully without seed bed preparation for several benefits. This type of rice establishment method is also called ZT rice.

N is kingpin in any performance to increase agriculture production. Rice is the major consumer of fertilizer nitrogen and gives high response to applied N. N is the most limiting nutrient for rice growth and yield in almost all environments (Yoshida 1981, Roy and Mishra 1999). One major consequence of inadequate N is reduced leaf area, thereby, limiting light interception, photosynthesis and finally biomass growth, grain yield and water productivity (Sinclair 1990).

Substantial yield and water productivity gains are possible with the application of appropriate dose of N and it varies with location, climate, input availability and genetic potential of rice varieties. The low N use efficiency has been mainly due to its rapid mineralization and proneness to losses through different pathways before it is utilized by the crop. Application of appropriate quantity of N at the right time is, therefore, one of the most important factors to realize high yield and N use efficiency.

There has been decline in yield of rice and wheat in rice-wheat (RW)cropping system (Yadav 1998, Duxbury *et al* 2000) and one of the factors responsible is decline in soil fertility, specially the soil organic matter content (Olk *et al* 1996). Hence, there is an emphasis on building up soil organic matter and one of the ways is to recycle the crop residues. When the wheat is harvested by combine machine, it leaves 25-30 cm high stubbles and spreads the straw on the ground. This wheat straw remains in field un-decomposed during the hot months of May and June due to lack of moisture and when the rice is transplanted in the first week of July with the onset of monsoon rains the residue immobilizes the N applied to rice and crop suffers. To overcome this problem, most farmers remove or burn the wheat residue in the field. In addition to loss of plant nutrients like N, P, S (Biederbeck *et al* 1980), residue burning creates health and environment problems (Graham *et al* 1986, Prasad and Power 1991). Keeping the above into consideration, the present paper was prepared to determine the influence of tillage systems in relation to wheat residue management and nitrogen level on the productivity of rice with the objectives to see the effect of tillage systems and nitrogen levels on the growth and their interactive effect on productivity of rice.

Tillage

A no-till (NT) system is a soil management technique that reduces soil disturbance, increases soil organic matter accumulation and can also increase crop yield (Bayer *et al* 2000, Santos *et al* 2011, and Crusciol *et al* 2012). NT and minimum tillage (MT) systems can produce rice grain yield similar to those produced with conventional puddling (Mabbbayad and Buencosa 1967, Mittra and Pieris 1968, De Datta *et al* 1979 and Rodriguez and Lal 1979). It has also been reported that in clay soil, MT produced the similar grain yield as through puddling (Sharma *et al* 1988). The rice yield was statistically at par in case of zero tillage (ZT) when compared with the conventional tillage (CT) system in direct seeding rice (DSR) (Bhatacharaya *et al* 2006). It was further reported that ZT may be adopted as resource conservation technology (RCT) and producing good crop yield. Another study reported that DSR with conventional seeding (in the prepared field) or rotavator (RT) seeding was better than zero till seeding. However, soil quality parameters (viz. soil organic carbon (SOC) concentration, bulk density and moisture content) were significantly better under conservation tillage (ZT and RT) than CT (Bazaya *et al* 2009). CT recorded significantly higher yield than ZT (Bhatacharaya *et al* 2006). Another study recorded that the direct seeded ZT gave at par yield as compared with transplanted (TP) rice (Singh *et al* 2008). ZT rice after spray of glyphosate @ 0.5 kg a.i/ha gave significantly higher yield over the other methods of establishment.

The establishment of rice under different tillage systems proved that rice can be successfully grown under zero-till transplant and proved to be more suitable alternative of conventional method of puddled transplant. The grain yield of rice under ZT (6.74 t/ha) was significantly higher than puddled transplant (6.19 t/ha). Similar results were also reported by Reddy (2004). Experiments were conducted at farmers field to study the effect of ZT system on the growth and yield of rice and observed that grain yield of rice under ZT (6.36 and 6.74 t/ha) was similar to the puddled transplant (6.33 and 6.72 t/ha) in 2002 and 2003, respectively (Reddy *et al* 2005). Saharawat *et al* (2010) reported that number of effective tillers was numerically (9 per cent) higher in DSR as compared to the CT rice. However, Kumar *et al* (2005) studied the effect of different planting methods on the productivity of rice at farmer's field. They were observed that number of effective tillers, spike length and 1000-grain weight was maximum under ZT, which was at par with the unpuddled transplant. Thus as a result, the rice yield was statistically at par in ZT when compared with the unpuddled transplant and puddled transplant. The highest pooled yield (8.5 t/ha) of rice was recorded with drum seeding (wet bed) followed by direct seeding under dry bed and mechanical transplanting-puddled compared to manual transplanting-puddled and mechanical transplanting in unpudddled conditions (Gangwar *et al* 2009). The more the yield under DSR/drum rice was mainly due to more number of effective tillers/m^2.

The direct seeded CT plots had similar grain yield as the direct seeded ZT plots of rice and wheat after 4 years of cropping (Bhattacharyya *et al* 2008). But the ZT practice had lower cultivation costs and crops under ZT could be sown earlier than CT (Singh *et al* 2002). However, the significantly same grain, straw and biological yield was recorded with ZT in standing stubbles after removal of loose straw, CT with and without mulching (Singh 2010).

Sharma *et al* (1995) observed that the higher total productivity of 9.3 t/ha was recorded under direct seeded, puddled condition, followed by transplanting (9.1 t/ha) and direct seeded, dry condition (8.99 t/ha). Owing to substantial saving of labour under direct-seeded, puddle condition higher net returns of '14741/ha was obtained compared with '498/ha under direct-seeded, dry condition and '12981/ha under TP.

Weeds are very serious problem in DSR as compared to (TP) transplanted rice (Walia *et al* 2006). Weeds represent one of the major resources consuming and limiting factors in crop production of growth inhibiting compound a phenomenon referred as allelopathy (Sanjay *et al* 2006). Aerobic soil conditions and dry-tillage practices, besides alternate wetting and drying conditions, are conducive for germination and growth of highly competitive weeds, which cause grain yield losses of 50–91 % (Elliot *et al* 1984 and Fujisaka *et al* 1993). Thus, timely weed control is crucial to increasing rice productivity. Herbicides are considered to be an alternative/supplement to hand weeding. The development of new, improved herbicides for dry-seeded rice is also needed (Gupta *et al* 2003). Several pre-emergence herbicides including butachlor, thiobencarb, pendimethalin, oxadiazon, oxyfluorfen, and nitrofen alone or supplemented with hand weeding, have been reported to provide a fair degree of weed control (Estorninos and Moody 1988, Janiya and Moody 1988, Moorthy and Manna 1993, Pellerin and Webster 2004). But, some difficulties are associated with pre-emergence herbicides, such as their limited application duration (0–5 DAS) and requirement of adequate soil moisture at the time of their application. In such situations, post-emergence herbicides are superior. Hence, it is necessary to evaluate different pre and post-emergence herbicides that are formulated from time to time to provide wider options to farmers for weed control in rice. Increasing costs for labor and restricted supplies of irrigation water has caused farmers to shift from manual transplanting of seedlings to direct-seeding in many Asian countries (Pandey and Velasco 2005). However, there is risk of greater crop yield losses due to weeds in DSR than in TP rice because of simultaneous emergence of crops and weeds and absence of standing water at the early stages of crop to suppress weed growth (Tuong *et al* 2005, Chauhan and Johnson 2010).

Nitrogen

Nitrogen (N) is one of the most yield limiting nutrients for annual crops around the world and its efficient use is important for economic sustainability of cropping systems. Furthermore, the dynamic nature of N and its propensity for loss from soil-plant systems creates a unique and challenging environment for its efficient management (Fageria and Baligar 2005). Recovery of N in crop plant is usually less than 50 % worldwide (Raun and Johnson 1999). This has led to environmental contamination and concerns regarding use of N fertilizers. The low recovery of N is associated with its loss by leaching, volatilization, de-nitrification and erosion of the soil. Mahajan and Timsina (2011) at Ludhiana observed that DSR required more N than TP rice. Besides rate and timing of N application is important crop management practice for improving N use efficiency and crop yields (Fageria and Baligar 2005).

Zhang *et al* (2009) showed that less N application before anthesis and more N application at or after anthesis may increase post anthesis dry matter accumulation and grain filling. The most appropriate time of N application to rice is panicle initiation, which produced maximum plant height, grains/panicle and grain yield (Bacon 1980, Inthavongra *et al* 1985).

Late application of N delayed the synthesis of abscisic acid, promotes cytokinin activity and causes higher chlorophyll retention and photosynthesis activity in leaves for supply of photosynthates to grains (Sarkar *et al* 2007). Various workers reported that N application during the post-anthesis phase, it is possible to increase the protein content of rice grains, improving their nutritive quality (Souza *et al* 1993). Souza *et al* (1999) observed a negative correlation between grain yield and protein accumulation in rice grains after N application at different times before and after anthesis. Datta *et al* (1988) evaluated DSR and TP rice under similar N management practices and found that N plant recovery was greater for DSR than TP rice. Without applied N, grain yield of transplanted rice was lower than that of DSR. These results suggest that considerable potential exists to increase N use efficiency and grain yield in DSR by manipulating N fertilizer management practices. The use of N fertilizer in the form of urea in flooded rice has increased rapidly in recent years but N use efficiency (NUE) is seldom more than 40 % of applied N (Crasswell and Datta 1980). Poor utilization of fertilizer N by rice is thought to be largely due to N losses from the soil-plant system through NH_4^+ volatilization, nitrification, de-nitrification, runoff and leaching (Tripathi *et al* 1999).

Adequate leaf N should be maintained throughout the growing period of rice, which is critical for achieving high yield (Olfs *et al* 2005). These crop demand-driven, site-specific N applications can add to farmer's productivity and profits (Singh *et al* 2002). The N had a beneficial effect on phosphorus uptake by rice, which was mainly associated with increase in yield and greater exploitation of available pool of phosphorus (P) from the soil (Majumdar *et al* 2005).

N is an important component of rice production technology with high yielding varieties but N use efficiency is very low as it is lost through leaching (Prakasa Rao and Prasad 1980), runoff, ammonia volatization (Prasad *et al* 1999) and denitrification (Aulakh *et al* 1992).

The mean N fertilizer response was the highest at 40 kg N/ha as compared to other N levels (0, 20, and 60 kg N/ha), indicating that further increase in N level had no effect on crop response to fertilizer. The mean grain yield was increased by 64.2 % when plots were supplemented with 40 kg N/ha as compared with control (Mahajan *et al* 2010).

There were significant differences in rice grain yield, quality and water productivity under different water regimes with various N rates (Pan *et al* 2009). The maximum yield under Rice Intensification System (SRI) was 7.3 t/ha in 2005 and 6.9 t/ha in 2006, respectively with 80 kg N/ha as compared with lower doses of N (Limai *et al* 2009). However, the finding of another study revealed that the N rates significantly increased the grain yield up to 140 kg N/ha as compared with lower doses of N of 80 and 100 kg/ha but was at par with 160 kg N/ha (Hirzel *et al* 2011). Similar results were also obtained by Xiang-long *et al* (2007) and Huang *et al* (2008).

Increase in N level increased plant height, maximum plant height (104.6 cm) was recorded in plots supplemented with 60 kg N/ha, which was at par with plant height at 40 kg N/ha. Minimum plant height (94.4 cm) was observed in the unfertilized plots. Prasad *et al* (2003) reported that the effect of N on the growth and yield of early rice and observed that the level of N had significant effect on the plant height, number of tiller/m^2, leaf area index (LAI) and dry matter accumulation. Crop growth rate was also increased with the increased with increasing levels of N. Increasing levels of N significantly increased the grain and straw yield up to 80 kg N/ha as compared with lower doses of 40 and 60 kg N/ha but was at par with 100 kg N/ha. In another study, Mannan *et al* (2010) reported that N level of 75 kg/ha found superior as regards of grain, straw yield, grains/ panicle and panicles/m^2 than other treatments. Singh *et al* (1999) observed that application of 90 kg N/ha significantly increased the grain and straw yields of basmati which were at par with 60 kg N/ha and both these were significantly higher as compared to control and 30 kg N/ha. Prasad *et al* (1992) reported significant response to N was higher but only up to 80 kg/ha, beyond which the differences were non-significant. They also recorded increase in number of tillers, test weight and leaf area index with 80 kg N/ha. Another study reported that each unit increase in N level led to significant increase in growth, yield attributing characters and yield of rice. The maximum grain yield 6.55 t/ha was recorded with highest level of N i.e. 225 kg N/ha. However, maximum response of applied N was observed at 75 kg N/ha and thereafter it decreased with the increase in N level (Shivay and Singh 2002). Similarly, grain yield of wet seeded rice increased significantly with the application of N fertilizer as compared to control.

Another study reported that grain yield and yield attributes were significantly influenced by N, maximum yield of 4.7 t/ha was recorded with 80 kg N/ha due to highest number of panicles/ m^2, increase in panicle length and filled grains/ panicle which were significantly superior to 40 kg N/ha and control (Kumar *et al* 1986). Similar results of increased grain yield with nitrogen have been reported by Lawal and Lawal (2002), Prasad *et al* (1994), Meelu and Bhandari (1978) and Samui *et al* (1977). Bhattacharyya and Singh (1992) reported that wet seeded rice responded up to 80 kg N/ha. Increasing N significantly increased the grain and straw yield up to 80 kg N/ha as compared with lower doses of N of 40 and 60 kg /ha but was at par with 100 kg N/ha. Similar results were also recorded by Thakur *et al* (1988) and Farazi and Mirlohi (2000).

Another study reported that for wet DSR the N fertilizer rates ranged from 60-120 kg/ha for wet and dry seasons of Philippines (De Datta *et al* 1998). It was further reported that to maximize the rice productivity, apply N in splits. It helps for efficient mobilization of reserved and current photosynthates for the purpose of grain filling. Increasing grain yield and yield attributes by splitting N application could be attributed to reduction in N losses as well as increase of N recovery and N uptake compared to single dose application (El-Refaee *et al* 2007). Laroo *et al* (2007) reported 49.5 and 48.5 % increase in basmati grain yield with the application of 100 and 150 kg N/ha respectively over control. Similar result were obtained by Ehsnullah *et al* (2001) and reported that 125 kg N/ha produced significantly higher number of grains/panicle, 1000-grain weight and grain yield than that of 100 kg N/ha. However, panicles/m and straw yield were statistically at par with 125 and 100 kg N/ha in fine rice.

Prasad *et al* (2003) concluded that all yield attributing characters increased significantly with the increase in levels of N from 40 to 100 kg/ha in fine rice. However, application of 100 kg N/ha significantly increased the plant height, total number of tillers/ hill, dry matter production, grain and straw yields. Another study reported that the grain yield of rice increased significantly with the application of 100 kg N/ha over 50 kg N/ha (Verma *et al* 2008). It has been reported that application of 100 kg N/ha gave 15.5, 2.5 and 6.5 q/ha more grain yield than those of control, 50 and 150 kg N/ha, respectively (Singh *et al* 1997).

Another study reported that increase in level of N brought significantly improvement in rice yield and yield attributes even up to 120 kg N/ha. There has been 29.6, 50.7 and 59.6 % increase in yield owing to 40, 80, 120 kg N/ha over the control (Paikaray *et al* 2001). Kumar *et al* (2007) reported that application of 120 kg N/ha produced significantly higher grain yield as compared to control but was at par grain yield obtained with 180 kg N/ha. The similar results were also reported by Dhal and Mishra (1993), Murthy *et al* (1992), Thakur (1989), Reddy and Reddy (1989), Thakur *et al* (1988), Dalal and Dixit (1987) and Pandey and Singh (1985).

Singh *et al* (2007) obtained response up to 120 kg N/ha, where applied N fertilizer increased grain yield of direct seeded rice by 62 % compared to control. Beyond 120 kg N/ha, no increase in grain yield was observed but its application resulted in more production of rice straw.

Another study reported that the successive increase in N application significantly increased the grain and straw yields up to 120 kg N/ha and increased grain yield of DSR by 62 % as compared with control. The application of 120 kg N/ha gave significantly higher grain and straw yields over 40 kg N/ha (Sharma *et al* 2007). These results are in concurrence with the finding of Alegeson and Siddeswaran (2002). Naw *et al* (2007) reported the effect of N on the productivity of aromatic rice was increase in grain yield with the application of 100 and 150 kg N/ha over control (2.0 and 1.95 t/ha). It was 49.5 and 48.5 per cent more, respectively. The beneficial effect of N application on various yield attributing characters viz. number of panicle/hill, panicle weight, panicle length, number of filled grain/panicle and 1000-grain weight led to increased grain yield with increasing levels of N. Significantly higher yield at the higher level of N obtained owing to the better N uptake which led to greater dry matter production (Chopra and Chopra 2000). Similar kinds of results were also reported by Rammohan *et al* (2002) and Om *et al* (1999).

It has been concluded that the successive increments of N significantly increased the grain and straw yield up to 120 kg N/ha as compared to 160 kg N/ha (Singh and Tripati 2007). Similar results were also showed by Thakur (1993) that increasing levels of N increased plant height, effective tillers/m^2 and grains/panicle significantly up to 120 kg N/ha whereas length of panicle and 1000-grain weight increased only up to 80 kg N/ha.

It has been reported that a significant increase in grain and straw yield of rice when the rate of N application was increased from 0-120 kg N/ha (Singh and Sharma 2000). Further increase in N application from 120 to 180 kg N/ha had no significant effect on the grain and straw yield of rice.

Reddy and Reddy (1989) observed that the number of panicles, filled grains/panicle and test weight increased with 40-120 kg N/ha as compared to control. Similarly, increasing levels of N increased growth and yield attributes significantly.

Sharma *et al* (2007) reported that application of 120 kg N/ha gave significantly higher grain and straw yields over 40 kg N/ha. Murthy *et al* (1992) laid out an experiment to know the influence of N levels on rice and started that the productivity of rice was lowest in control (3.5 t/ha) and gradually increased to 5.5 t/ha with an increase in nitrogen levels up to 120 kg N/ha. The increase was owing to vigorous growth and increased physiological efficiency at higher N levels. Similarly, the application of 120 kg N/ha significantly increased the grain yield of rice as compared to the lower (60 kg N/ha) and higher doses (180 kg N/ha).

An increase in N from 80 to 120 kg N/ha in rice significantly increased the plant height, total tillers, dry matter accumulation, panicle number, filled grains/panicle, N-uptake as well as grain and straw yields, the highest level of N i.e. 160 kg/ha however did not improve these characters (Kumar *et al* 1995). Lawal and Lawal (2002) from Nigeria reported that application of fertilizer up to 80 kg N/ha significantly increased crop growth rate, number of ear bearing tillers/m^2, and per cent filled grains of rice. However, plant height, test weight, grain weight/panicle and grain yield responded up to 120 kg N/ha. Patel *et al* (1986) recorded that N application significantly increased the grain yield with increasing levels up to 180 kg N/ha. However, considering the economics, application of 120 kg N/ha was found to be more remunerative than 180 kg N/ha. The response per kg of N was 17.6 and 16.7 kg of rough grain at 120 and 180 kg N/ha, respectively.

It has also been concluded that the concentration of N in flag leaf was positively correlated with the amount of N applied and also reported that grain yield, 1000- grain weight and panicle number in dry seeded rice increased with increase in amount of N applied up to 150 kg/ha (Jong *et al* 1999). Ramesh *et al* (2009) revealed that application of 150 kg N/ha registered significantly higher number of tillers, panicles, filled grains/panicle, 1000-grain weight and grain yield than 100 kg N/ha. Similarly, Gautam *et al* (2005) observed the highest grain (5.27 t/ha) and straw (7.41 t/ha) yields with the application of 160 kg N/ha in coarse rice. Rice grain yield increased significantly as N rate increased up to 160 kg/ha irrespective of establishment methods (Singh *et al* 2002). Deshmukh and Tiwari (1996) reported that the grain yield of rice increased significantly with increasing levels of N from 40 to 160 kg/ha. This is due to the beneficial effect on growth and biomass production.

Sathiya *et al* (2008) reported that the application of 175 kg N/ha resulted in higher growth attributes, yield attributes and grain yield as compared to 100 and 125 kg N/ha. Crop growth rate was also increased with the increasing N level. Khan *et al* (2006) reported linear increase in grain yield up to 180 kg N/ha. N dose of 180 kg/ha resulted in significantly higher grain yield of rice as compared to lower dose of 60, 120 and 150 kg N/ha. This was mainly attributed to the higher number of panicles/m^2 and grain/panicle. Higher N dose of 240 kg/ha resulted in lodging of crop at maturity which declined the grain yield of rice.

N use efficiency when used to indicate the overall efficiency of N is defined as the ratio of biological yield or economic yield to the fertilizer N used. The biological yield can include either above ground plant dry matter or plant N, whereas the economic yield includes either grain yield or total plant N. More commonly used measures of NUE are: agronomic efficiency (AE), recovery efficiency (RE), and physiological efficiency (PE), computed by different methods. The ratio of increased yield to N applied is commonly referred to as agronomic efficiency of N. A review of worldwide data on NUE for cereal crop from researcher-managed experiment plots reported single year fertilizer recovery efficiency of 57 % for wheat and 46 per cent for rice (Ladha *et al* 2005).

Application of N fertilizer increased grain yield of rice when the rice was exposed to water deficit (Castillo *et al* 2006). In rice production, efficient use of N fertilizer is a critical factor in achieving high and stable yield, while minimizing negative effects to the environment (Ntamatungiro *et al* 1999, Hirel and Lemaire 2005, Tylaran *et al* 2009). Mahajan and Timsina (2011) at Ludhiana observed that DSR (non-basmati) required more N than TP rice. Besides rate and timing of N application is important crop management practice for improving N use efficiency and crop yields (Fageria and Baligar 2005). Sahrawat (1979) reported that mineral N through inorganic fertilizer was more susceptible to different type of N losses and hence it had low N use efficiency as compared to organic materials. There is continuous supply of N by organic manures and tying up of in organic soil N prevents its loss through denitrification, volatilization or leaching (Gill and Meelu 1982 and Singh 1984). Integrated approaches of organic and inorganic nutrients management have shown as increased efficiency of applied N fertilizer in rice (Buresh and De Datta 1991). Recovery efficiency of applied N was quite closer in case of organics and inorganics. This is because of minimal loss of N in case of organic sources and N was available to the crop for longer period.

Crop residue

Crop residues may be incorporated partially or completely into the soil depending upon methods of cultivation. Ploughing is the most efficient residue incorporation method. Unlike removal or burning, incorporation of straw increases soil organic matter and soil N, P and K contents. In few studies, rice yield was lower during the first one to three years of rice straw incorporation 30 days prior to rice planting because of immobilization of soil N in presence of crop residues with wide C/N ratio but in later years, straw incorporation did not affect yield adversely.

Accumulation of organic matter and nutrients near the soil surface under NT and reduced tillage were favorable consequences of not inverting the soil and by maintaining a mulch layer on the soil surface (Tebrugge and During 1999). With annual plough less tillage, plant residues will be left on the soil surface, resulting in increased organic matter in the top soil (Rasmussen 1999). The study by Gosai *et al* (2009) revealed higher concentration of soil organic matter in the no-till and shallow-tilled plots compared to the other conventionally tilled plots that confirms to the finding of Doran (1987), Robbins and Voss (1991) and Angers *et al* (1995).

More plant residues were left on or near the soil surface no-tillage, which led to lower evapotranspiration and higher content of soil water in the upper (0-10cm) soil layer (Rasmussen 1999). The plant available water content was significantly higher with ZT than CT in rice-wheat cropping system (Bhattacharyya *et al* 2006 and Bhattacharyya *et al* 2008). Surface residues maintained under ZT system moderate moisture fluctuations and thus reduce both evaporation and runoff (Blevins and Frye 1993). However, different types and extent of tillage did not have any major influence on the moisture content at harvest, although it was high at the time of initial tillage and reduced with subsequent tillage operations (Srivastava *et al* 2000). It has been well established that increasing amounts of crop residues on the soil surface reduce the evaporation rate (Gill and Jalota 1996; Prihar *et al* 1996). Residue mulch or partial incorporation in soil by conservation tillage has also been shown to increase the infiltration by reducing surface sealing and decreasing runoff velocity (Box *et al* 1996).

Aeration is important for both the agricultural and environmental functions of soil. Plant roots and soil fauna require oxygen, and aerobic microbes are important decomposers. Air permeability is a measure of how easily air convection occurs through soil in response to pressure gradients. Pressure gradients can be generated naturally by air turbulence above the soil surface, and this can lead to air flows through the tilled layers of soils especially when they contain pores larger than about 5 mm (Farrell *et al* 1966; Kimball and Lemon 1971). Air flow will occur only if there is a continuous network of air filled pores. Air permeability is the useful indicator of pore connectivity. Air permeability decreases with increase in soil bulk density in no tillage just beneath the depth of tillage (Rasmussen 1999).

The major disadvantage of incorporation of cereal straw is the immobilization of inorganic N and its adverse effect due to N-deficiency. The combined use of rice or wheat straw and inorganic fertilizer can however, increase the yield of rice and wheat in rice-wheat systems. Of course, proper fertilizer management practices can reduce N immobilization due to incorporation of crop residues into the soil. These practices include appropriate method, time and rate of fertilizer-N application: i) placement of N fertilizer below the surface soil layer that is enriched with carbon after incorporation of crop residue, ii) application of N fertilizer at a higher rate than the recommended rate, and iii) application of N 15-20 kg/ha as starter dose with straw incorporation increases yields of wheat and rice compared with either burning of straw or its incorporation in the soil.

The yield obtained with wheat residue incorporation with 80 kg N/ha was statistical at par with cowpea in crop rotation and significantly higher than that under the control and statistically similar to that of no organic N and 120 kg N/ha (Paikaray *et al* 2001). It indicated that saving of 40kg N/ha when we incorporate the residue in field. Higher yield with supply of organic N might be attributing to more nutrient availability with its incorporation to rice crop. These results were in close conformity with the finding of Thakur *et al* (1995) and Beri *et al* (1989).

Sharma (2002) concluded that application of 40 kg N/ha (one third of the total dose for rice) at the time of wheat residue incorporation, 40 kg N/ha at the time of transplanting and rest at panicle initiation increased the grain yield by 0.5-0.7 t/ha, straw yield 0.5 1.0 t/ha, N uptake by 10 kg/ha, apparent N recovery by 10 % and agronomic efficiency of N by 5-7 kg grain/kg fertilizer-N over no N application at the time of incorporation of wheat residue was better conserved and resulted in higher available N content in soil that N applied along with transplanting. Advantage of incorporation of wheat residue over its removal or burning was seen only when 40 kg N/ha was applied at the time of its incorporation. Wheat incorporation and FYM with higher doses of fertilizer N increased the available N, P and K content in soil compared with initial values, whereas in control plots they declined significantly (Bhat *et al* 1991).

Mulching involves covering of soil surface to conserve moisture, control weeds and increase the population of micro-flora thereby augmenting the crop yield (Banik and Sharma 2008). It also increases the soil water storage in the root zone and ultimately the yield. The average grain yield was 2.65% higher in the residue incorporation treatment as compared with without residue treatment. However, the effect of straw incorporation on the characteristics of growth and development has been rarely reported in rice, especially in direct-seeding rice (Guo-Wei *et al* 2009).

Grain and straw yields of rice were affected significantly. Wheat straw was applied 5 or 10 t/ha alone gave better grain yield of rice than the control. Increased application of chemical fertilizer alone, from 50 to 75 and 100 % of the recommended dose of N, also increased yield significantly. Combined application of wheat straw either applied 5 or 10 t/ha with increasing dose of N too increased the grain and straw yields of rice (Kumar *et al* 2003).

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