

Review Article

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## Influence of FYM, Brown Manuring and Nitrogen Levels on Direct Seeded and Transplanted Rice (*Oryza sativa* L.): A Review

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### ABSTRACT

#### Keywords

FYM, Inorganic fertilizers, Nitrogen levels, Brown manuring, Direct seeded rice, Transplanted rice.

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The application of farmyard manure (FYM) in conjunction with inorganic fertilizers significantly increased yield attributes and yield of rice. Application of FYM improved available nutrients, porosity, organic carbon, cation exchange capacity (CEC), and aggregation of soil and reduced bulk density. Inorganic fertilizers in conjunction with FYM improved quality parameters of rice. Grain yield of direct seeded rice with brown manuring *Sesbania* was statistically at par with conventional transplanting of rice. Rice grain yield increased with increase in dose of nitrogen to a certain level and after that increase in nitrogen level was uneconomical. Maximum nutrients uptake recorded with higher level of nitrogen. Direct seeded rice gave higher water-use efficiency, maintained good physical conditions and provided chance for timely sowing of succeeding wheat crop. Similar quality parameters of rice (hulled, milled and head rice recovery) were recorded with different establishment methods.

### Introduction

Rice (*Oryza sativa* L.) is the principal source of food for more than half of the world population, especially in South and Southeast Asia and Latin America. It is the main staple food crop of India, covering an area of about 39.16 m ha with total production of 85.59 mg of rice during 2012–2013 (Anonymous, 2014). Rice is cultivated mainly through transplanting in puddled field, which results in formation of a hard pan and damages soil structure, though it helps in retention of more water and effective in weed control, but this needs more time, labour, energy. Puddling delays planting of succeeding wheat crop and reduces wheat root growth and this limits

water uptake and consequently lower the crop yield. Moreover, this technique requires continuous ponding of water for establishment of the seedlings in general and for full effectiveness of applied herbicides, in particular. This in turn leads to nutrient losses through leaching besides causing high evapotranspiration (ET) losses during the hot summer months. In addition, it has been realized that at cultivar's fields plant population varies from 16–21 hills m<sup>-2</sup> as against the recommended 33 hills/m<sup>2</sup>, which acts as a yield limiting factor. Presently, the farmers transplant paddy in the first week of June when the daily evaporation rate is very

high (8–10 mm day<sup>-1</sup>). Moreover, in the Indo-Gangetic Plains (IGP) the underground water is being over exploited by excessive pumping to meet the water need of transplanted paddy. As a consequence, it has been causing a sharp decline in ground water table. Therefore, of late, need has acutely been felt to develop technically viable and economically feasible alternate technique for growing paddy in this area. The preliminary research conducted at Punjab Agricultural University indicated that direct seeded rice could be a viable alternative to transplanted rice due to availability of short duration varieties, effective herbicides, non-availability of labour and escalating cost of labour. It is now fast replacing traditional transplanted rice in areas with good drainage and weed control (Balasubramanian and Hill, 2002). Further, it also shortens the cropping cycle due to absence of transplanted shock to the seedlings. Direct seeding cultivation therefore, could also help to ensure the timely sowing in a stipulated time. Fertilizers have contributed substantially to the spectacular increase in crop production. However, application of inorganic fertilizers alone in large quantities over a longer period of time results in imbalance in the supply of other nutrients. The combined use of organic manures and inorganic fertilizers help in maintaining yield stability through correction of marginal deficiencies of secondary and micronutrients, enhancing efficiency of applied nutrients and providing favourable soil physical conditions. Application of farm yard manure (FYM) to soil improves the physical, chemical and biological properties thereby improving the nutrient availability in soils. Fertilizer N-use efficiency varies from 18–40% in rice soils, because applied inorganic N is rapidly lost from the soil by ammonia volatilization and denitrification. Urea is the principal nitrogenous fertilizer in rice-growing Asian countries. Large loss of N from urea necessitates an innovative application technique for increasing the N-use

efficiency. Application of urea in combination with organic material (FYM) minimizes N loss and increasing N-use efficiency.

Brown manuring is a practice of seeding *Sesbania* with rice and applying 2, 4-D @ 400–500 g ha<sup>-1</sup> to knockdown the *Sesbania* at 30 days after seeding. This practice results into falling of *Sesbania* leaves on the ground and forms a mulch and helps in smothering of weeds, conserving moisture and adding about 15 kg N ha<sup>-1</sup> without adding much on cost of production (only seed cost).

### **Influence of FYM on rice**

#### **Yield attributes**

The application of FYM @ 10 t ha<sup>-1</sup> in conjunction with different fertilizer levels exhibited a significant increase in effective tillers per m row length, grain and straw yield of rice over fertilizer treatment alone (Azad and Lehria, 2001). However, Kumar *et al.*, (2003) reported that FYM @ 20 t ha<sup>-1</sup> resulted in significantly higher values of yield attributes (panicle length, filled spikelets panicle<sup>-1</sup> and 1000-grain weight) and grain yield of rice over control and wheat straw applied @ 5 or 10 t ha<sup>-1</sup> as well as 50% N used alone. Mondal *et al.*, (2003) also observed that the number of panicle/m<sup>2</sup> and number of filled grains panicle<sup>-1</sup> was highest (422.7 and 98.3, respectively) with 75% of the recommended dose of NPK (60 kg N+30 kg P<sub>2</sub>O<sub>5</sub>+30 kg K<sub>2</sub>O) along with FYM @ 4 t ha<sup>-1</sup>. The maximum rice grain yield (6 t ha<sup>-1</sup>) was also recorded at 75% of the recommended dose of NPK+FYM @ 4 t ha<sup>-1</sup>. Sujathamma and Reddy (2004) revealed that plant height, tillers, leaf area index and dry matter production of rice were significantly higher with the application of 100% fertilizer N, which was however, comparable with 25% FYM (N)+75% fertilizer N in respect of tiller production during later stages and dry matter

production during early stages. They also recorded that the application of 100% N through fertilizer produced the highest number of panicle  $m^{-2}$ , panicle length and number of total and filled grains/panicle, grain and straw yield of rice as well as N uptake, which were however, comparable with 25% FYM (N)+75 % N, in respect of grain yield.

## **Yield**

Singh *et al.*, (2000a) found that rice yield obtained with recommended NPK was statistically at par with that of 50% of recommended NPK along with 50% N through FYM and 75% of recommended NPK. Bharambe and Tomar (2004) indicated that combined application of 100% recommended dose of NPK fertilizers (100:60:40 kg NPK  $ha^{-1}$ ) with FYM @ 8 t  $ha^{-1}$  found significantly superior in increasing the grain and straw yields of rice (variety Mahamaya). They also indicated that the productivity of rice and wheat was significantly increased with the application of inorganic fertilizers with FYM (8 t  $ha^{-1}$ ). Chitale *et al.*, (2004) found that highest grain yield of rice (60.5 q  $ha^{-1}$ ) was obtained with the treatments in which 50% of N was substituted through green manure in kharif followed by grain yield of 56.8 q  $ha^{-1}$  in which 50% N substitution through FYM which was statistically at par to that of 100% NPK application (58.1 q  $ha^{-1}$ ). The results showed a possibility of saving 50% fertilizer N in rice. Parihar (2004) indicated that 100% NPK recommended along with FYM @ 5 t  $ha^{-1}$  gave highest yield followed by 100% NPK+wheat straw @ 5 t  $ha^{-1}$ . Similarly, the application of 12 t FYM per ha in combination with 80 kg N  $ha^{-1}$  produced the same rice yields (5.7 t  $ha^{-1}$ ) as that obtained from 120 kg N  $ha^{-1}$  (5.6 t  $ha^{-1}$ ) (Gupta *et al.*, 2006). Parasuraman and Mani (2002) observed that with the application of FYM @ 12.5 t  $ha^{-1}$  along with recommended inorganic

fertilizers (120 kg N  $ha^{-1}$ ) produced significantly higher rice grain yield over inorganic fertilizers alone. Roul and Sarawgi (2005) revealed that grain and straw yield were significantly higher under 100% recommended dose of N (RDN) blended with FYM and 100 per cent RDN+5 tonnes of FYM than other treatments on pooled data basis (Table 1).

## **Soil properties**

### **Physical properties**

The incorporation of wheat straw along with application of FYM reduced the bulk density of soil and increased the porosity of the soil Bhagat and Verma (1991). Mishra and Sharma (1997) observed that application of FYM @ 10 t  $ha^{-1}$  before rice transplanting significantly reduced bulk density (1.41  $mg\ m^{-3}$ ) than no manure application (1.52  $mg\ m^{-3}$ ). The decrease in bulk density has been ascribed to better organic carbon content and improved soil aggregation. Tiwari *et al.*, (2000) recorded the lowest bulk density (1.20  $mg\ m^{-3}$ ) of Typic Haplusterts fewer than 100% NPK+FYM and 1.49  $mg\ m^{-3}$  in plots receiving N alone or no fertilizers.

### **Chemical properties**

(Maskina *et al.*, 1988) reported that the use of FYM improved the general soil productivity by increasing soil organic carbon and available nutrients. Sharma and Mitra (1990) also reported marked improvement in organic carbon and available N, P and K in FYM amended plots in rice-wheat rotation. The combined application of FYM and chemical fertilizers to soil in rice-wheat rotation increased the available N, P and K status of soil and also improved its organic carbon content (Brar *et al.*, 1995). Similarly, (Dhiman *et al.*, 1999) reported that organic carbon; available P and K were highest where

an additional FYM application was made. The application of FYM with inorganic fertilizers was more effective as compared to inorganic fertilizers alone in building up soil fertility status (Bajpai *et al.*, 2002). Bharambe and Tomar (2004) indicated that combined application of FYM and inorganic fertilizers was more effective as compared to inorganic fertilizers alone in building up fertility status of soil and increasing the productivity of rice.

### Quality parameters

Rao *et al.*, (1993) indicated that higher levels of N (60, 90 kg ha<sup>-1</sup>) decreased the head rice recovery by 3 to 8 per cent and increased amylose content of long slender grain varieties by 3.0 to 9.9% but not of short slender grain varieties. Dixit and Gupta (2000) reported that quality parameters like hulling percentage, milling percentage, protein and amylose content increased due to use of FYM and NPK fertilizers. Highest carbohydrate (84.9 q ha<sup>-1</sup>) and protein (7.72 q ha<sup>-1</sup>) yield of the rice-rice system was obtained when 50% N was substituted through FYM (Raju and Reddy, 2000). Rao *et al.*, (2006) reported that the conjunctive use of 25% N through FYM over and above 100% recommended dose of N through fertilizer and 60 kg ZnSO<sub>4</sub> ha<sup>-1</sup> resulted in best quality parameters viz., Protein, amylose content and head rice recovery which can be attributed to uninterrupted availability of N coupled with increased absorption and assimilation by plants (Rao *et al.*, 2006). (Mishra *et al.*, 2006) reported that the milling percentage, kernel breadth before and after cooking were significantly higher due to application of organic sources where *Sesbania* green manuring coupled with FYM @ 10 t ha<sup>-1</sup> proved significantly superior.

### Influence of brown manuring

Aslam *et al.*, (2008) found that paddy yield in bed transplanting (4.43 t ha<sup>-1</sup>) and direct

seeding+brown manuring (4.23 t ha<sup>-1</sup>) were at par and significantly higher than direct seeding without brown manuring (3.36 t ha<sup>-1</sup>) that produced the lower yield (Table 2). Sharma *et al.*, (2008) found that direct seeding with *Sesbania* co-culture as a brown manuring yielded (3.65 t ha<sup>-1</sup>) at par, compared to conventional transplanting (3.69 t ha<sup>-1</sup>) and significantly higher than direct seeding without brown manuring (3.24 t ha<sup>-1</sup>) and also it saved 43.6% water over conventional transplanting (Table 3). In integrated weed-management practices, butachlor @ 1.5 kg ha<sup>-1</sup> as pre-plant surface application+brown manuring with *Sesbania rostrata*+2,4-D @ 0.50 kg ha<sup>-1</sup> recorded the highest grain yield (3.88 t ha<sup>-1</sup>), which was significantly on a par with that obtained from season-long weed-free situation (3.98 t ha<sup>-1</sup>). The highest net returns (₹19,029 ha<sup>-1</sup>) and benefit: cost ratio (1.19) was also recorded in same treatment (Kumar and Mukherjee, 2008). Singh *et al.*, (2009) recorded that rice yield in direct seeding+brown manuring (3.50 t ha<sup>-1</sup>) were at par, compared to conventional transplanting (3.56 t ha<sup>-1</sup>) but, significantly higher than direct seeding without brown manuring (3.22 t ha<sup>-1</sup>) and also it saved 39.4% water over transplanting.

At Haryana, Singh *et al.*, (2008b) conducted an experiment and results revealed that *Sesbania* sown along with rice gave maximum yield (5.54 t ha<sup>-1</sup>) and it was on par with *Sesbania* sown at 5 days of rice (5.41 t ha<sup>-1</sup>) and significantly higher than sole crop of rice (4.70 t ha<sup>-1</sup>). They also revealed that maximum weed density was observed in sole crop of rice (68 weeds m<sup>-2</sup>) as compared to only (15 weeds m<sup>-2</sup>) in *Sesbania* sown along with rice. Singh *et al.*, (2008c) found that direct seeding with *Sesbania* co-culture as a brown manuring yielded (4.51 t ha<sup>-1</sup>) significantly at par with conventional transplanting (4.70 t ha<sup>-1</sup>) and significantly higher than direct seeding without brown manuring (4.00 t ha<sup>-1</sup>). They also found that

maximum weed density was observed in direct seeding without brown manuring (40 weeds  $m^{-2}$ ) whereas, direct seeding with brown manuring (15 weeds  $m^{-2}$ ) and conventional transplanting (16 weeds  $m^{-2}$ ) gave at par weed density.

### **Influence of levels of nitrogen on yield attributes and yields of rice**

Lawal and Lawal (2002) reported that application of fertilizer up to 80 kg N  $ha^{-1}$  significantly increased crop growth rate, number of ear bearing tillers  $m^{-2}$ , and per cent filled grains of rice. While, plant height, test weight (1000-grains weight) and grain weight panicle<sup>-1</sup> responded to fertilizer up to 120 kg N  $ha^{-1}$ . The maximum grain yield of rice was obtained with 120 kg N  $ha^{-1}$  which was significantly higher than those obtained with 80 kg N  $ha^{-1}$  and control. Prasad *et al.*, (2003) found that all yield attributing characters increased significantly with the increase in levels of nitrogen from 40 to 100 kg  $ha^{-1}$ . Whereas, an application of 200 kg N  $ha^{-1}$  significantly increased the plant height (127.3 cm), total number of tillers hill<sup>-1</sup> (16.3), dry matter production (16.0 t  $ha^{-1}$ ), grain and straw yields (6.5 and 9.5 t  $ha^{-1}$ ) of hybrid rice. While 100 kg N  $ha^{-1}$  resulted in highest benefit: cost ratio of crop (Meena *et al.*, 2003). Similarly, Singh *et al.*, (2007) recorded that tiller density and panicle length increased significantly with N application up to 120 kg N  $ha^{-1}$ .

### **Yield**

Singh and Sharma (2000) observed a significant increase in grain and straw yields of rice when the rate of N application was increased from 0 to 120 kg N  $ha^{-1}$ . Further increase in N application from 120 to 180 kg N  $ha^{-1}$  had no significant effect on grain and straw yields of rice. Similarly, Jaiswal and Singh (2001) reported that application of 120 kg N  $ha^{-1}$  significantly increased the grain

yield of rice by 29.7 and 23.7 percent over 60 kg N  $ha^{-1}$ . It was due to the higher values of yield attributes, which resulted with the higher level of nitrogen. Gill and Walia (2014) revealed that significantly higher grain and straw yield of basmati rice was obtained with 125% of recommended dose of nitrogen (90 kg urea  $ha^{-1}$ ) over control, 75 and 100% of recommended dose of nitrogen. Similarly, grain yield of wet-direct seeded rice increased significantly with the application of fertilizer N as compared to no N control. The N response of wet direct seeded rice was observed up to 120 kg N  $ha^{-1}$  where applied N fertilizer increased grain yield by 62% compared to control. Beyond 120 kg N  $ha^{-1}$ , no increase in grain yield was observed but its application resulted in more production of rice straw (Singh *et al.*, 2007). However, Khan *et al.*, (2006) recorded significant increase in the rice grain yield occurred up to 180 kg N  $ha^{-1}$ . Above 180 kg N  $ha^{-1}$  the rice grain and straw yield declined because of crop lodging and delayed maturity at higher N dose i.e., 240 kg N  $ha^{-1}$ . The beneficial effect of N can be explained in the light of the fact that it increased the number of panicles/ $m^2$  and number of grains per panicle that ultimately contributed to higher grain yield.

### **Nutrient-uptake of rice**

Nitrogen at 120 kg N  $ha^{-1}$  increased the nitrogen uptake by 41.9 and 34.8% over 60 kg N  $ha^{-1}$  in grain and straw, respectively. Higher uptake of N might be due to better established roots, better plant growth and yield under increased N level (Jaiswal and Singh, 2001). Similarly, total N uptake by rice increased significantly with the increasing N rates up to 160 kg N  $ha^{-1}$ . However, the recovery, agronomic and physiological efficiencies of applied N were highest in the 120 kg N  $ha^{-1}$  treatment (Singh *et al.*, 2007). Laroo *et al.*, (2007) revealed that N uptake was significantly influenced due to different levels of N application. Based on the total N uptake

(grain+straw), there was 49.9, 63.9 and 70.4% increase in N uptake over the control with 50, 100 and 150 kg N ha<sup>-1</sup>, respectively.

### **Influence of methods of sowing on yield attributes and yields of rice**

#### **Yield attributes**

Dhiman *et al.*, (1999) reported that non-scented varieties performed better under transplanted condition due to more number of grains per panicle and panicle weight as compared to direct seeded rice in clay loam soil. However, Zhang and Zhu (1999) reported that no-tillage direct sown rice gave greater plant height and number of effective tillers than transplanted rice. Samra and Dhillon (2000) reported that rice transplanted after puddling gave significantly higher yield over puddled broadcast sprouted seeds and line sowing of sprouted seeds without puddling due to no lodging and more number of panicles m<sup>-2</sup>, test weight and grain weight panicle<sup>-1</sup> in loamy sand soil. Jaiswal and Singh (2001) while working at Faizabad obtained significantly higher yield of transplanted rice than direct broadcasting of pre-germinated seeds in loam soil due to significantly higher number of panicles m<sup>-2</sup>, grains per panicle and panicle length. Similar results were reported by Singh *et al.*, (1990) and Singh *et al.*, (1997).

#### **Yield**

Budhar and Tamilselvan (2002) revealed that wet seeding of rice by manual broadcasting (57.2 q ha<sup>-1</sup>) and wet seeding by drum seeder (56.6 q ha<sup>-1</sup>) has recorded higher yield and it was statistically at par with the traditional transplanting method (55.8 q ha<sup>-1</sup>). In another studies, Singh *et al.*, (2005b) found that crop established by conventional method resulting in higher grain yield (49.2 q ha<sup>-1</sup>) followed by broadcasting of sprouted seeds (45.7 q ha<sup>-1</sup>), which was significantly higher over dry

seeding (40.8 q ha<sup>-1</sup>). Transplanting method and broadcasting of sprouted seeds increased the grain yield of rice by 17.2 and 10.8%, respectively over dry seeding due to better growth and development. However, Singh *et al.*, (2005a) studied the influence of crop establishment methods on rice and found that puddling followed by transplanting of rice (77.2 q ha<sup>-1</sup>), puddling and broadcasting of sprouted seed (75.8 q ha<sup>-1</sup>) and zero tillage transplanting (73.9 q ha<sup>-1</sup>) gave the comparable yield. Gill *et al.*, (2006a) studied the performance of various methods of rice seeding and revealed that maximum grain yield (48.3 qha<sup>-1</sup>) was recorded in direct seeding which was significantly more than the transplanting (43.8 q ha<sup>-1</sup>) with a margin of 5.5 q ha<sup>-1</sup>. However, Gill *et al.*, (2006b) concluded that maximum grain yield (68.6 q ha<sup>-1</sup>) was recorded with transplanting method, which was however at par with wet direct seeding (64.6 q ha<sup>-1</sup>) (Table 4).

Sanjay *et al.*, (2006a) enumerated that grain yield of rice was significantly influenced by planting systems. Line transplanting system recorded significantly higher grain yield (55.3 q ha<sup>-1</sup>) as compared to direct seeding using drum seeder (54.3 q ha<sup>-1</sup>) and broadcast sowing (30.5 q ha<sup>-1</sup>) whereas, direct seeding using drum seeder recorded significantly higher straw yield (73.7 q ha<sup>-1</sup>) compared to line transplanting (69.9 q ha<sup>-1</sup>) and broadcast sowing (55.4 q ha<sup>-1</sup>). However the direct seeding using drum seeded recorded significantly higher grain (61.7 q ha<sup>-1</sup>) and straw yield (112.7 q ha<sup>-1</sup>) as compared to line transplanting grain yield of 57.1 q ha<sup>-1</sup> and straw yield of 105.3 q ha<sup>-1</sup> (Sanjay *et al.*, 2006b). Gill and walia (2014) reported that basmati rice grain yield was significantly higher with machine transplanting after puddling than conventional transplanting of basmati rice but was statistically at par with direct seeded basmati rice with brown manuring.

## Maturity

The direct seeded tropical low land rice sown by broadcast method in puddled seed bed produced more tillers, vegetative growth and shorten the crop duration by more than one week and 10–12 days earlier maturity (Nagappa *et al.*, 2002). Budhar *et al.*, (1990) reported increased number of panicles and early maturity in rice under direct seeding compared to transplanting of rice in case of short duration cultivar. Broadcasting of sprouted seeds and drum seeding methods had 7.2 and 6.9 days earlier flowering than transplanted crop (Santhi *et al.*, 1998). Budhar and Tamilselvan (2002) reported that the direct seeding by manual broadcasting and drum seeder reduced the time in 50% flowering by 7 days compared with transplanting and throwing of seedlings on red sandy loam soils.

## Water requirement of rice

Direct sowing with sprouted seeds on puddled soil gave an equal yield with transplanted rice but the water-use efficiency was higher with partial submergence at Delhi on sandy clay

loam soil (Hukkeri and Sharma, 1980). Narayansamy *et al.*, (1993) also reported from Thanjavur in Tamil Nadu that in direct sown rice under puddle conditions, the crop used less water (878–894 mm) than in transplanted rice (1153–1177 mm) and had the highest water-use efficiency in clay loam soil. Thabonithy and Murali (1994) reported that dry seed broadcasted on unpuddled soil was the best method of rice establishment on heavy clay soils with the total water requirement of 1040 mm in comparison to 1154 mm of transplanted rice. However, Goel and Verma (2000) observed that the average water-use efficiency was 10.7% more in transplanting method. Tabbal *et al.*, (2002) reported that direct wet seeded rice yielded higher than traditional transplanting by 3–17%, required 19% less water during crop growth period and increased water productivity by 25–48% with continuous standing water conditions. They also found that under water saving irrigation i.e. keeping the soil continuously around saturation, wet seeded rice out yielded transplanted rice by 6–36% and were a suitable establishment method to save water and retain high yields at Philippines (Table 4).

**Table.1** Effect of different stand establishment techniques on rice yields and its attributes

Treatments	Plant height (cm)	Productive Tillers m <sup>-2</sup>	Panicle length (cm)	Number of grains panicle <sup>-1</sup>	1000-grain weight (g)	Paddy yield (t ha <sup>-1</sup> )
Double zero tillage	136.1	219.0	27.93	96.50	23.17	4.80
Direct seeding	126.1	231.7	25.23	72.67	22.17	3.36
Brown manuring	128.2	186.3	27.67	93.83	22.83	4.23
Bed planting	129.2	206.7	27.93	95.73	23.17	4.43
Conventional planting	130.2	200.2	27.93	98.57	23.50	4.72
LSD ( <i>p</i> =005)	2.782	26.65	0.9019	8.851	0.9676	0.2844

Source: Aslam *et al.*, 2008

**Table.2** Effect of different crop establishment techniques on yield and water productivity of basmati rice

Crop establishment technique	Grain Yield (t ha <sup>-1</sup> )	Water applied (m <sup>2</sup> )	Irrigated water productivity (kg m <sup>-3</sup> )	Rainfall (mm)	Gross water productivity (kg m <sup>-3</sup> )	Water saving (%)
Conventional tillage	3.69	1.26	0.29	0.20	0.25	-
Unpuddled transplanting	4.00	1.25	0.32	0.20	0.27	-
Raised bed transplanting	2.95	0.95	0.31	0.20	0.26	24.60
Direct seeded rice	3.24	0.76	0.42	0.23	0.32	39.68
Direct seeded rice+Sesbania	3.65	0.71	0.51	0.23	0.38	43.65
Direct seeded rice at transplanting time	2.91	0.64	0.46	0.23	0.43	49.20
LSD ( <i>p</i> =005)	0.32					

Source: Sharma et al., 2008

**Table.3** Grain yield and Water productivity of puddle irrigated rice under different methods of sowing (mean data of two seasons)

Treatment				Method of sowing			
Direct Seeded Rice				Transplanted Rice			
Date of Sowing	Grain Yield (q ha <sup>-1</sup> )	Irrigation water applied (cm)	Water productivity (g kg grain <sup>-1</sup> m <sup>-3</sup> )	Date of transplanting	Grain Yield (q ha <sup>-1</sup> )	Irrigation water applied (cm)	Water productivity (g kg grain <sup>-1</sup> m <sup>-3</sup> )
1 <sup>st</sup> June	49.9	108	0.46	25 <sup>th</sup> June	47.9	132	0.36
10 <sup>th</sup> June	51.3	114	0.45	5 <sup>th</sup> July	46.4	120	0.39
20 <sup>th</sup> June	43.6	108	0.40	10 <sup>th</sup> July	33.8	118	0.29
Mean	48.3			Mean	43.8		

Source: Gill et al., 2008

**Table.4** Yield, water input and water productivity in transplanted and wet seeded rice

Treatment	Transplanted			Wet Seeded		
	Yield (kg ha <sup>-1</sup> )	Water input (mm)	Water productivity (g kg grain <sup>-1</sup> m <sup>-3</sup> )	Yield (kg ha <sup>-1</sup> )	Water input (mm)	Water productivity (g kg grain <sup>-1</sup> m <sup>-3</sup> )
1*	6987a	728a	0.96	8173a	577a	1.42
2*	6200a	491b	1.26	8441a	456a	1.85
3*	6626a	477b	1.39	7410a	391a	1.90
4*	6135a	600ab	1.02	8199a	456a	1.80
Mean	6487	574	1.16	8056	470	1.74

Source: Tabbal *et al.*, 2002

\* 1: Continuous standing water (2-5 cm depth); 2: Standing water until panicle initiation, saturated soil thereafter; 3: Continuous saturated soil; 4: Application of irrigation water (up to 5-7 cm depth) one day after standing water has disappeared

\*Rainfall during the experiment was 20 mm

### Physical conditions

Sharma *et al.*, (1995) observed that direct seeding of rice helped to maintain good physical conditions of soil which proved advantageous in attaining desired tilth and timely sowing of the succeeding crop. Otani *et al.*, (1996) found non-puddling was superior to puddling in water retentivity, drainage, tillage facility and soil bearing capacity.

### Quality parameters

Nagoshi *et al.*, (1995) compared three methods of cultivation of rice i.e., transplanting of young seedlings, nurseling seedlings and direct sowing in flooded fields and reported that protein content of milled rice was minimum and taste index was maximum in direct sown rice. Won *et al.*, (1996) reported that transplanting, drilling and hill sowing gave significantly similar milled rice yields. But Sorour *et al.*, (1998) reported that mechanical transplanting gave higher hulling, milling and head rice recovery percentages than traditional transplanting, broadcasting and mechanical drilling. Singh (2002) compared furrow planting and

transplanting in flat puddled field (recommended) and found non-significant differences in brown rice, milled rice and head rice recovery and also observed that brown rice, milled rice and head rice recovery of transplanted rice in flat puddle field or in furrows was significantly more over the direct seeded rice due to more thousand grain weight of transplanted rice. Gill and Walia (2014) reported that quality characters of basmati rice like brown, milled and head rice recovery were statistically at par among machine transplanting, direct seeding and conventional transplanting methods of establishment of basmati rice.

In conclusion,

- i. The use of FYM in conjunction with inorganic fertilizers help to increase the yield attributes as well as yield of crop.
- ii. Available nutrients, porosity, organic carbon, cation exchange capacity (CEC), aggregation of soil improved with application of FYM and bulk density reduced.
- iii. Application of chemical fertilizers in conjunction with FYM will improve the quality of agricultural produce without

losing quantity as compared to chemical fertilizers alone.

- iv. Direct seeded rice with brown manuring *Sesbania* gave comparable yield to conventional transplanting of rice.
- v. Yield of rice increased with increase in dose of nitrogen upto a certain level, after that increase in nitrogen dose was uneconomical.
- vi. Direct seeded rice gave higher water-use efficiency, maintained good physical conditions and provided chance for timely sowing of succeeding wheat crop.
- vii. Similar quality parameters of rice (hulled, milled and head rice recovery) were recorded with different establishment methods.

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