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Response of foliar application of iron and green manuring in dry direct-seeded and transplanted rice (*Oryza sativa*)*

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Rice (*Oryza sativa* L.) production in northwest part of Indo-Gangetic Plains (NW-IGP) is critical for food security of India because this region contributes more than 40% of the rice procured by government of India for its buffer stock and distribution to public. Rice in this region is grown following the traditional system of puddled transplanted rice (PTR) and requires huge labour and large amount of water. Water and labour, however, are becoming increasingly scarce in the region raising the questions of environmental sustainability and sustainability of rice production systems. In NW-IGP, increasing use of groundwater for rice cultivation has led to declines in water table by 0.1 to 1.0 m/yr, resulting in water scarcity and increased cost for pumping water (Rodell *et al.* 2009). Implementation of the Mahatma Gandhi National Rural Employment Guarantee Act, introduced by the Indian government in 2005 (GOI 2011), promising 100 days of paid work in people's home village, has been creating a labour scarcity in Punjab and Haryana which are the cereal bowl of north-west India. This suggests that alternatives to puddled transplanted rice are required to save water and increase crop and labour productivity. Dry seeding of rice with subsequent aerobic soil conditions eliminates the need of puddling and maintaining submerged soil conditions, thus reducing the overall water demand and providing opportunities for water and labour savings. Since the concept of dry direct seeding (DSR) under high input environment is new, relatively few insights exist for fertilizer N use for higher productivity in DSR. Alternate moist-dry soil conditions in DSR may stimulate nitrification-denitrification processes, resulting in a loss of nitrogen through N_2 and N_2O. Therefore, green manuring in direct-seeded rice may improve nitrogen-use efficiency through increased crop uptake of soil NO_3, reduced risk of soil nitrate leaching (Shipley *et al.* 1992) and reduced water run-off. Dry seeding and subsequent aerobic cultivation of rice suffer from Fe deficiency (Singh *et al.* 2002). The available information pertaining to ways and means for ameliorating Fe deficiency and increasing N-use efficiency in rice has mostly been confined to puddled transplanted rice. Such information is yet to be generated for direct-seeded aerobically-grown rice. In view of the limited information available on these aspects, a field experiments was conducted to compare crop growth and N use oby rice under flooded and aerobic conditions in response to green manuring and foliar application of Fe.

Field experiments were conducted at Rice Section, Punjab Agricultural University, Ludhiana (30°56′N, 75°52′E and 247 m m.s.l.), India during 2006 and 2007 to evaluate the effect of green manuring and foliar application of Fe on productivity of dry-direct seeded (DSR) and puddle transplanted rice. The soil was loamy sand with *p*H 7.3, total nitrogen 0.32 g/kg, organic carbon 0.28%, Olsen P 8 mg/kg. The experiment was established with a split-plot design in three replicates. The main plots comprised two crop establishment methods (DSR and PTR) and sub-plots four nutrient application treatments (T_1: Recommended dose of nitrogen (RF), T_2: RF + green manuring (GM), T_3: RF + foliar application of Fe, T_4: RF +GM + foliar application of Fe. Cultivar PR 115 (120–125 days growth duration) was chosen for the study. Recommended N was applied through urea (120 kg/ha) in four equal splits (basal, 21 days after sowing (DAS), 42 DAS and 63 DAS). For green manuring, sunnhemp (*Crotolaria juncea*) was grown in the respective treatments before the sowing/transplanting of crop and 30 days old crop was incorporated in the soil (~5 tonnes/ha on dry weight basis) before planting. For foliar application of Fe, three sprays of 1% $FeSO_4$ were done at 21, 28 and 35 DAS/DAT (days after transplanting). For weed control in transplanted rice, pendimethalin @ 0.75 kg/ha was applied 3 DAT. In DSR, pendimethalin @ 0.75 kg/ha was applied as

*Short note

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pre-emergence at 3 DAS and bispyribac Na @ 25 g/ha as post-emergence at 18 DAS. For DSR, seed @ 30 kg/ha was direct-seeded in rows 20 cm apart and irrigation was applied immediately after sowing and the subsequent irrigations were applied at 3-4 days interval to keep the soil moist. The land preparation for PTR treatment consisted of one dry ploughing, followed by irrigation and two harrowings in standing water. Two rice seedlings/hill were transplanted at 20 cm × 15 cm spacing. The field was kept submerged for 15 days after the transplanting of crop and thereafter irrigations were applied at three days interval. In both the systems, irrigation was stopped 15 days before crop maturity. To determine dry matter, samples were collected with the help of quadrate (0.5m × 0.5m) in each plot at tillering, panicle initiation and flowering stage, sun-dried, followed by oven drying at 70°C for 48 h and weighed. Total N content of these plant samples was determined by micro Kjeldahl method. Five hills were selected randomly from each plot to record agronomic parameters, ie number of productive tillers/m^2, panicle weight, grains/panicle and spikelet sterility (%). Net area of 6 m^2 (4m × 1.5 m) from each plot was harvested at maturity and grain yield recorded at 14% moisture. Analysis of variance was performed using CROPSTAT version 7 (IRRI, Manila, Philippines). The results for 2006 and 2007 were not significantly different and hence were pooled for analysis.

Results revealed that crop dry matter remained unaffected by crop establishment method at tillering stage, but at panicle initiation (PI) and flowering stage, it decreased significantly (9.9% and 4.3%, respectively) in DSR as compared to PTR (Table 1). Dry matter accumulation by crop with T_4 treatment was significantly higher than rest of treatments at panicle initiation and flowering stage. At flowering stage, mean N uptake by the crop in PTR increased by 6% as compared to DSR and it was highest with T_4 treatment. Paddy grain yield decreased significantly in DSR as compared to PTR (Table 2). Although panicles/m^2 decreased significantly in PTR, it was compensated by more grains/panicle and higher 1000-grain weight in PTR than DSR. The increase in spikelet sterility in DSR (24.4%) as compared to PTR (21.5%) was responsible for fewer numbers of grains/panicle. Lower grain yield in DSR may be attributed to fewer number of grains/ panicle, lower 1000-grain weight and high spikelet sterility as compared to PTR. Across the crop establishment methods, lowest grain yield (5.3 tonnes/ha) recorded with recommended fertilizer (T_1) increased by 9.4, 17.0 and 20.8% with T_2, T_3 and T_4, respectively (Table 1). Grain yield in T_3 and T_4 treatments was statistically same. Panicles per m^2 increased by 2.6, 6.5 and 11% and grains per panicle increased by 3.6, 10.8 and 10.9% in T_2, T_3 and T_4 treatments, respectively as compared to T_1 whereas increase in 1000-grain weight in T_4 was significant over T_1. Spikelet sterility (%) in T_2, T_3 and T_4 treatments decreased to the extent of 5.2, 10.8 and 14.9% respectively over T_1. Higher grain yield in T_4 treatment mainly attributed to better crop growth, more panicle/m^2 and grains/panicle as compared to other treatments. The results indicate that both Fe spray and green manuring improved crop growth, grain yield and N uptake of rice. In DSR, significant improvement in yield was observed in response to Fe spray as well as green manuring. However, in PTR, grain yield significantly improved only with green manuring. The data in Fig 1 revealed that grain yield in both the systems (DSR and PTR) was at par when green manure and Fe spray were applied along with RF, but PTR significantly outyielded DSR when only RF was applied or green manure or Fe spray were applied separately along with RF. In DSR, grain yield

Table 1 Dry matter (g/m^2) and N uptake by crop as influenced by crop establishment methods and fertilization source (mean of two years)

Treatment	Dry matter (g/m^2)			N uptake by the crop at flowering (kg/ha)
	Tillering	Panicle initiation	Flowering	
Crop establishment method				
DSR	22.5	35.5	56.6	70.3
PTR	22.9	39.4	59.2	74.5
LSD (*P*=0.05)	NS	1.6	2.0	2.2
Fertilization source				
T_1:RF	19.1	34.1	52.8	63.0
T_2: RF +Fe	22.4	35.8	55.2	67.9
T_3: RF+GM	24.1	38.6	60.1	75.4
T_4: RF+GM+Fe	25.3	41.4	63.5	83.4
LSD (*P*=0.05)	1.1	2.2	2.8	3.1

*DSR, Dry-direct- seeded rice; PTR, puddled transplanted rice; RF, recommended nitrogen (120 kg/ha); GM, green manuring, Fe, foliar spray of iron

Table 2 Yield contributing characters and grain yield as influenced by crop establishment methods and fertilization source (mean of two years)

Treatment	Panicles/ m^2	Grains/ panicle	1000 grain weight (g)	Spikelet sterility (%)	Grain yield (tonnes/ha)
Crop establishment method					
DSR	333	116	23.9	24.4	5.6
PTR	315	120	25.9	21.5	6.3
LSD(*P*=0.05)	8	3.1	0.4	1.0	0.15
Fertilization source					
T_1:RF	309	111	24.6	24.9	5.3
T_2: RF +Fe	317	115	24.9	23.6	5.8
T_3: RF+GM	329	122	25.1	22.2	6.2
T_4: RF+GM+Fe	343	123	25.4	21.2	6.4
LSD (*P*=0.05)	12	4.4	0.6	1.4	0.21

*DSR, Dry direct-seeded rice; PTR, puddled transplanted rice; RF,recommended nitrogen (120 kg/ha); GM: green manuring, Fe, foliar spray of iron

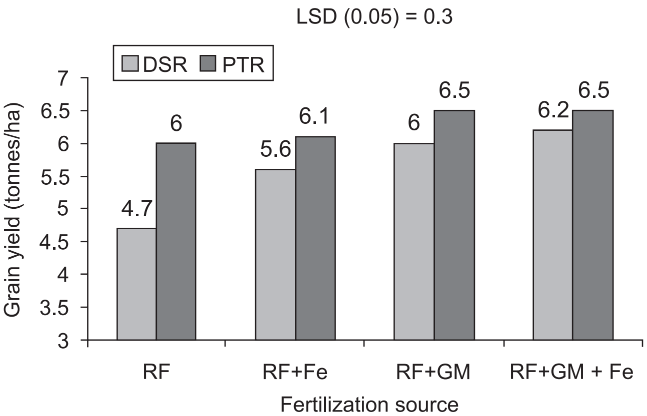

Fig 1 Interactive effect of crop establishment methods and fertilization source on grain yield of rice

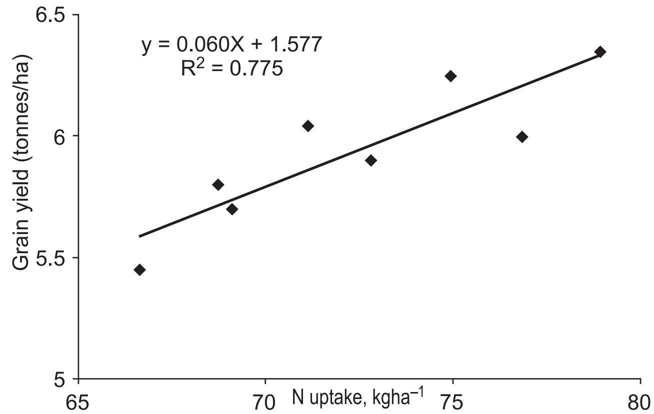

Fig 2 Relationship between N uptake by the crop at flowering stage and grain yield of rice

increased by 33.5% in T_4 treatment as compared to T_1 treatment, while in PTR it increased by 7.6%. Interestingly, green manured DSR plots recorded same yield as PTR plots without green manuring. Increase in grain yield as result of green manuring might have been due to higher N uptake as evident in Table 1 which revealed that N uptake at flowering increased significantly with addition of green manuring. Relationship between N uptake by the crop and grain yield depicted in Fig 2 revealed that N uptake accounted for 77% variation in grain yield. Violante *et al.* (2003) reported that organic matter produced by green manuring plays a very important role in the hydrolytic reactions of Fe and on the formation, nature, surface properties, reactivity and transformation of Fe-oxides. So green manuring helped in better uptake of Fe in DSR, thus resulting in improved yield when Fe was applied in green manured plots.

SUMMARY

Deficiency of N and Fe significantly influenced performance of rice, especially on coarse texture soil. The present study leads to the conclusion that grain yield of DSR can be increased by green manuring and foliar application of Fe. Green manuring also resulted in increase in yield of PTR. Green manured DSR plots recorded same yield as PTR plots without green manuring.

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