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Research Communication

Varieties and phosphorus fertilization effects on productivity and profitability of direct-seeded upland rice (*Oryza sativa*) in Eastern India

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2016 at Hazaribag, Jharkhand to study the effect of varieties and phosphorus (P) applications on grain yield and economics of direct-seeded upland rice (*Oryza sativa* L.). The experiment was laid out in split plot design with three replications, keeping 3 rice varieties, viz. 'Vandana', 'Anjali' and 'CR Dhan 40', in the main plots and 7 different P rates. viz., 0 kg/ha, phosphorus solubilizing bacteria (PSB) + arbuscular mycorrhizal fungi (AMF), 13.2 kg P/ha through single super phosphate (SSP), 13.2 kg P/ha through SSP + PSB + AMF, 26.4 kg P/ha through SSP, 26.4 kg P/ha through SSP + PSB + AMF and 39.6 kg P/ha through SSP in the sub-plots. The results revealed that yield attributes, viz. effective tillers/m^2 (312), filled grains/panicle (130), panicle weight (27.9 g), 1,000-grain weight (22.5 g), and grain (3.91 t/ha) and straw yields (6.17 t/ha) were higher in 'CR Dhan 40' compared to 'Anjali' (259, 115, 2.04 g, 20.4 g, 3.33 t/ha and 5.64 t/ha respectively) and 'Vandana' (252, 108, 1.78 g, 19.9 g, 3.12 t/ha and 5.53 t/ha respectively). Similarly, application of 39.6 kg P/ha through SSP recorded the highest values for yield attributes, grain (4.25 t/ha) and straw yields (6.79 t/ha), and was at par with 26.4 kg P/ha through SSP + PSB + AMF. Net returns and B:C ratio were also recorded the highest in 'CR Dhan 40' with 39.6 kg P/ha through SSP, which was at par with 26.4 kg P/ha through SSP + PSB + AMF. Thus, integrated application of 26.4 kg P/ha through SSP along with PSB and AMF in 'CR Dhan 40' can enhance grain yield and net returns of direct-seeded upland rice in Jharkhand.

Key words *:* Cultivars, Direct-seeded upland rice, Microbial inoculants, Phosphorus fertilization

Dry direct–seeded rice is a resource conservation technology which requires less labour and water and often matures earlier than transplanted crops. In eastern India, rice is directly sown under rainfed upland conditions but have very low productivity compared to puddled transplanted rice (PTR). The availability of phosphorus (P) is low under direct-seeded upland conditions compared to PTR, and could be one of the major factors behind the low productivity in eastern India. Poor phosphorus acquisition is a major constraint, and therefore P-use efficiency is very low (15–20%). However, P efficiency can be improved by enhancing internal utilisation efficiency with the use of microbial inoculants (Richardson *et al*., 2011). A very few studies have been conducted to enhance the phosphorus-use efficiency (PUE) in eastern regions. The choice of cultivars also influences the PUE (Fageria *et al*., 1988). Hence, there was a need to study the varieties and P rates to understand the PUE in direct-seeded upland rice especially in eastern part of India. Therefore, a study was conducted to understand the effect of varieties and P rates on productivity and profitability of direct-seeded upland rice.

A field experiment was conducted during the *kharif* season of 2016 at the research farm of ICAR-Central Rainfed Upland Rice Research Station, Hazaribag, (23°56' N, 85°21' E, and 614 m above the mean sea-level), Jharkhand. The soil was clay loam with medium organic C (0.62%), low available N (153 kg/ha) and available P (10.30 kg/ha), and high in available K (315 kg/ha) with *p*H of 6.8. The annual rainfall received during the experimental period was 1,450 mm. The experiment was laid out in split plot design with 3 replications. The main plot, consisted of 3 varieties, viz. 'Vandana', 'Anjali' and 'CR Dhan 40', while the 7 different P fertilization treatments, viz. No P; phosphorus solubelizing bacteria (PSB) + arbuscular mycorrhizal fungi (AMF); 13.2 kg P/ha

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through single super phosphate (SSP); 13.2 kg P/ha through SSP + PSB + AMF 26.4 kg P/ha through SSP; 26.4 kg P/ha through SSP + PSB + AMF and 39.6 kg P/ha through SSP were included in the sub plots. The crop was directly sown in to the unpuddled soil with the help of multi-row crop planter by using 50 kg seed/ha at row- to-row spacing of 20 cm. The recommended dose of N and K was 60 kg N/ha and 33.2 kg K/ha respectively. Half dose of N and full dose of K was applied as basal through urea and muriate of potash, respectively. Various doses of P were applied as basal through different combinations of SSP, phosphorus solubilizing bacteria (PSB) and arbuscular mycorrhizae fungi (AMF). The seeds were inoculated with PSB @ 500 g/ha before sowing. AMF (5 kg) was taken, mixed with 15 kg of soil and thereafter broadcasted as per the treatments in to the soil immediately after the sowing of rice. Weeds were managed through a pre-emergence application of pendimethalin @ 0.75 kg/ha followed by 2 hand-weeding at 25 and 45 days after sowing (DAS). All the 3 rice varieties were harvested at 90 days.

The observations regarding growth, yield attributes, yield and economics were recorded as per the standard procedures.

Results showed that yield attributes, viz. effective tillers/m^2, number of filled grains/panicle, panicle weight and 1,000-grain weight differed considerably with cultivars and different P fertilization practices (Table 1). Rice cultivar 'CR Dhan 40' recorded higher values of yield attributes followed by 'Anjali' and 'Vandana'. Application of 39.6 kg P/ha through SSP recorded higher yield attributes and was at par with 26.4 kg P/ha through SSP + PSB + AMF. Similarly, the highest grain and straw yield were observed in rice cultivar 'CR Dhan 40' (3.91 and 6.17 t/ha) followed by 'Anjali' (3.33 and 5.64) and 'Vandana' (3.12 and 5.53 t/ha) (Table 1). 'CR Dhan 40' recorded the highest number of effective tillers (312) and had edge over others in terms of weed competitiveness, and therefore gave the highest yield. Application of 26.4 kg P/ha through SSP + PSB + AMF remained at par with 39.6 kg P/ha through SSP in terms of grain and straw yields, which could be attributed to the fact that application of PSB solubilized the fixed form of P in to the soil, while AMF enhanced the mobilization and accusation of P in to the available form compared to inorganic P rates without inoculants as reported by Sepat *et al*. (2012). The economics of direct-seeded upland rice cultivation were also influenced by the cultivars and various P fertilization practices (Table 1). The cost of cultivation was not influenced by the varieties. However, increasing P application rates influenced the cost of cultivation as the cost incurred on various rates. 'CR Dhan 40' recorded the highest net returns (46 × 10^3₹/ha) and B:C ratio (1.78) followed by 'Anjali' (34 × 10^3₹/ha and 1.35) and 'Vandana' (28×10^3₹/

Table 1. Effect of cultivars and phosphorus application on yield attributes, yield and economics of direct-seeded upland rice

Treatment	Effective tillers/m^2	No. of filled grains/ panicle	Panicle weight (g)	1,000-grain weight (g)	Yield (t/ha) Grain	Yield (t/ha) Straw	Cost of cultivation (×10^3₹/ha)	Net returns (×10^3₹/ha)	Benefit : Cost ratio
Cultivars									
'Vandana'	252	108	1.78	19.9	3.12	5.53	24.4	28.0	1.14
'Anjali'	259	115	2.04	20.4	3.33	5.64	24.4	34.1	1.35
'CR Dhan 40'	312	130	2.79	22.5	3.91	6.17	25.6	46.1	1.78
SEm±	4.09	2.07	0.02	0.35	0.07	0.09	-	0.38	0.03
CD (P=0.05)	12.39	2.27	0.06	1.06	0.21	0.28	-	1.52	0.09
Phosphorus application									
P1	225	107	1.71	20.0	2.62	4.86	22.6	21.8	0.96
P2	232	108	1.73	20.2	2.77	5.05	22.8	29.3	1.28
P3	266	115	2.14	20.6	3.27	5.45	24.4	36.3	1.48
P4	274	118	2.18	20.8	3.30	5.53	24.6	38.7	1.56
P5	301	125	2.55	21.4	3.76	6.10	26.2	40.2	1.53
P6	308	126	2.56	21.7	4.20	6.70	26.4	42.9	1.61
P7	314	128	2.59	21.9	4.25	6.79	28.0	43.2	1.54
SEm±	2.40	1.98	0.01	0.07	0.06	0.08	-	0.35	0.01
CD (P=0.05)	7.27	5.95	0.03	0.21	0.18	0.24	-	1.02	0.04

P_1, 0 kg P_2O_5; P_2, PSB + AMF; P_3, 30 kg P_2O_5 through SSP; P_4, 30 kg P_2O_5 through SSP + PSB + AMF; P_5, 60 kg P_2O_5 through SSP; P_6, 60 kg P_2O_5 through SSP + PSB + AMF; P_7, 90 kg P_2O_5 through SSP, PSB, phosphate solubilising bacteria; AMF, arbuscular mycorrhizal fungi; SSP, single superphosphate. Details of phosphorus application are given in Materials and Methods

ha); and 1.14). Application of 39.6 kg P/ha through SSP recorded the highest net returns being at par with 26.4 kg P/ha through SSP + PSB + AMF as lesser cost was involved for microbial inoculants (Gaind and Singh 2016). Rice varieties and P practices influenced the nutrient uptake and PUE (Table 2). Higher N and P uptake in grain, straw and total was observed in 'CR Dhan 40' compared to 'Anjali' and 'Vandana'. Higher P acquisition efficiency and higher yield potential lead to the highest N and P uptake in 'CR Dhan 40'. Phosphorus application with 39.6 kg P/ha through SSP recorded the highest P uptake in grain, straw and total, being at par with application of 26.4 kg P/ha through SSP + PSB + AMF. The enhanced solubilization and mobilization of soil P with microbial inoculants could be the factor for higher N and P uptake (Richardson and Simpson 2011). The agronomic efficiency was not influenced by the varieties except for the recovery efficiency of applied P (Table 2). The recovery efficiency of applied P was the highest in 'CR Dhan 40' (11.54%) followed by 'Anjali' (17.34%) and 'Vandana' (17.26%). The application of 26.4 kg P/ha through SSP + PSB + AMF recorded the highest agronomic (25.50 kg grain increased/kg P applied) and recovery efficiency (17.26%) of applied P remaining at par with 39.6 kg P/ha through SSP. Sepat *et al*. (2012) also reported higher agronomic and recovery efficiency of applied P when microbial inoculants were applied along with inorganic P. The inoculation of PSB solubilized the fixed native pool of soil P through secretion of organic acids. Likewise, fungal hyphae of AM mobilized the soil P near the rice roots (Maiti *et al*., 2013).

It may be concluded that 'CR Dhan 40' was the best rice variety in terms of yield, net returns and P-use efficiency. Integrated application of 26.4 kg P_2O_5 through SSP + PSB + AMF gave higher yield, net returns and P-use efficiency. Therefore, integrated application of 26.4 kg P_2O_5 through SSP + PSB + AMF in 'CR Dhan 40' is suggested to enhance the productivity and profitability of direct-seeded upland rice in eastern regions of India.

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Table 2. Effect of cultivars and phosphorus fertilization on nitrogen and phosphorus uptake and phosphorus use efficiency

Treatment	N uptake (kg/ha)			P uptake (kg/ha)			Agronomic efficiency (kg grain increased/kg P applied)	Recovery efficiency of applied P (%)
	Grain	Straw	Total	Grain	Straw	Total		
Cultivars								
'Vandana'	38.4	30.3	68.8	5.15	4.83	9.98	13.17	9.15
'Anjali'	40.5	31.9	72.2	5.52	5.28	10.81	16.38	9.18
'CR Dhan 40'	50.6	35.7	86.3	6.77	6.23	13.00	16.01	11.54
SEm±	0.73	0.78	1.28	0.11	0.14	0.18	1.91	0.09
CD (P=0.05)	2.21	2.36	3.88	0.33	0.43	0.55	NS	0.27
Phosphorus application								
P_1	31.2	24.3	55.6	2.65	2.98	5.64	-	-
P_2	33.4	26.4	59.9	3.26	3.59	6.86	-	-
P_3	40.7	29.4	70.2	4.77	4.69	9.46	21.62	12.73
P_4	41.4	30.7	72.2	5.65	5.19	10.84	22.58	17.34
P_5	48.1	35.7	83.9	7.11	6.44	13.56	19.17	13.19
P_6	53.3	40.5	93.9	8.51	7.48	16.00	25.50	17.26
P_7	54.0	41.5	95.5	8.73	7.78	16.48	17.46	9.20
SEm±	0.29	0.63	0.78	0.05	0.11	0.13	1.71	0.05
CD (P=0.05)	0.88	1.90	2.36	0.14	0.33	0.39	5.18	0.15

P_1, 0 kg P_2O_5; P_2, PSB + AMF; P_3, 30 kg P_2O_5 through SSP; P_4, 30 kg P_2O_5 through SSP + PSB + AMF; P_5, 60 kg P_2O_5 through SSP; P_6, 60 kg P_2O_5 through SSP + PSB + AMF; P_7, 90 kg P_2O_5 through SSP, PSB, phosphate solubilising bacteria; AMF, arbuscular mycorrhizal fungi; SSP, single superphosphate. Details of phosphorus application are given in Materials and Methods; NS, non-significant

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