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Research Communication

Effect of phosphorus management on yield and economics under direct seeded rice (*Oryza sativa*) and blackgram (*Vigna mungo*) intercropping in a rainfed acidic upland soil

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2019 at ICAR-National Rice Research Institute (NRRI), Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh, Jharkhand to study the effect of phosphorus management on productivity and profitability under direct seeded rice (*Oryza sativa* L.) (DSR) and blackgram [*Vigna mungo* (L.) Hepper] intercropping in rainfed acidic upland soil. The experiment was laid-out in a split-plot design comprised 4 methods of cropping, viz. Sole DSR; Sole blackgram; DSR + blackgram (4:1); and DSR + blackgram (4:2) allotted to main-plots and 4 phosphorus management practices, viz. P control (P_0); Recommended dose of phosphorus (RDP) @17.5 kg P/ha; 50% RDP + phosphate solubilizing bacteria (PSB) @500 g/ha + arbuscular mycorrhiza fungi (AMF) @12.5 kg/ha; and 25% lime requirement (LR) + PSB + AMF in sub-plots. Experiment consisted of 16 treatment combinations, replicated thrice. The rice variety 'Sahabhagi' and blackgram variety 'Uttara' were used. Among the cropping systems, the highest grain yield was recorded in sole rice (3.84 t/ha) and sole blackgram (1.14 t/ha) which was significantly higher than yields under intercropping in both the ratios. Gross (₹96,879/ha) and net returns (₹70,603/ha) of sole blackgram were significantly higher than other cropping systems and followed by DSR + blackgram (4:2). Net benefit:cost (B:C) of sole blackgram was maximum (₹2.69) and lowest in sole rice (₹1.01). Among phosphorus management treatments, 50% RDP + PSB + AMF gave significantly higher net return (₹49,440) and net benefit:cost (₹1.68). Application of 100% RDP and 25% LR + PSB + AMF gave at par returns and net benefit:cost. It may be suggested that under rainfed uplands of eastern India, farmers may adopt either sole blackgram or intercropping of rice and blackgram in 4:2 over sole DSR for higher productivity and monetary returns. For better phosphorus management in soil they should inoculate PSB and AM fungi along with 50% RDP at the time of sowing.

***Key words*:** Blackgram, Economics, Intercropping, Microbial inoculants, Upland soil, Yield

Agricultural production system of upland ecology is mainly monsoon dependent in India where rice (*Oryza sativa* L.) is the major crop. The upland rice ecosystem is extremely diverse as it is grown on lands where slopes are greater than 30% and also on leveled to gently rolling land (0–8% slope). Soils vary from highly fertile Alluvial soils to infertile, highly weathered and acidic type. Generally, the upland soils are low in nitrogen (N) and phosphorus (P) and have high P fixation capacity. In these soils, the productivity of the crop is not only low but also inconsistent. Upland rice is grown in areas with annual rainfall ranging from 1000 to 4500 mm and at altitudes of up to 2000 m above MSL. But erratic rainfall frequently causing drought results in unstable and low yields of upland rice (1–2 t/ha) compared to productivity of (>4 t/ha) irrigated lowland rice (Dass *et al*., 2010; Maiti *et al.,* 2017). Upland rice is grown in unbunded fields under rainfed situation and these fields are prepared and seeded under dry conditions as other upland crops like maize and wheat (Farooq *et al.,* 2011). Due to the acidic nature of soil in uplands of eastern India, phosphorus (P) deficiency has been recognized as one of the main limiting factors (Dass *et al.,* 2005; Saha *et al*., 2005). P-deficiency can be corrected by supplying phosphate to the soils but a large portion of soluble inorganic phosphate applied as chemical fertilizer to the soil is immobilized rapidly and becomes unavailable to plants.

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Microbial inoculants (biofertilizers) like *Rhizobium* possess unique ability to fix atmospheric nitrogen by living symbiotically. Also, phosphate solubilizing bacteria (PSB) plays a vital role in solubilization of various inorganic and organic phosphates added to the soil (Bhavya *et al.,* 2018). Arbuscular mycorrhiza (AM) fungi plays a vital role in supplementing major plant nutrients like nitrogen, phosphorus as well as micronutrients like Fe, Zn (Jaga and Sharma, 2015).

The main aim of intercropping is to augment total productivity per unit area and time, besides judicious and equitable utilization of land resources and farm inputs including labour. Cereal + legume intercropping has a greater scope in improving system productivity and soil health in addition to minimizing the adverse impact of moisture and nutrient stress (Dass and Sudhishri, 2010). Intercropping it is generally popularized as an insurance against crop failure under rainfed conditions, and improved and sustainable production is the chief goal of intercropping. The intercrop systems are reported to use resources more efficiently than monocrop system. The equivalent yield and economics of rice showed that intercropping rice with cowpea and pigeon pea in 4:1 and 4:2 ratios was generally more advantageous than rice as a sole crop (Maiti *et al.,* 2017). With this background an experiment was conducted to study the effect of phosphorus management on root nodulation and soil microbiological parameters under direct seeded rice and blackgram intercropping in rainfed acidic upland soil.

The field experiment was conducted during rainy (*kharif*) season of 2019 at ICAR-National Rice Research Institute (NRRI), Central Rainfed Upland Rice Research Station (CRURRS), Hazaribagh, Jharkhand. Soil of the experimental site was silty loam and acidic (4.5 *p*H) having low available N (218.5 kg/ha) and P (10.8 kg/ha), but high available K content (288.8 kg/ha) and soil organic carbon (0.48%). The experiment was laid-out in a split-plot design with 4 methods of cropping, viz. Sole DSR; Sole blackgram; DSR + blackgram (4:1); and DSR + blackgram (4:2) in main plot and 4 phosphorus management treatment, viz. P control (P_0); Recommended dose of phosphorus (RDP) @40 kg P_2O_5/ha; 50% RDP + phosphate solubilizing bacteria (PSB) @500 g/ha + arbuscular mycorrhiza fungi (AMF) @12.5 kg/ha; and 25% lime requirement (LR) + PSB + AMF in sub-plots. Thus, 16 treatment combinations were replicated thrice. The popular rice '*Sahabhagi*' and blackgram '*Uttara*' varieties were used. The observations on crop yield of rice and blackgram were taken as per standard methods. Economics of crops was calculated as per the prices of inputs and produce existing at that time.

Results showed that grain yield of sole DSR were significantly influenced due to the cropping systems as well as P management practices (Table 1). The highest grain yield

Table 1. Effect of intercropping systems and phosphorus management on yield and economics of rice and blackgram

Treatment	Rice		Blackgram		Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Net benefit: cost ratio (₹)
	Grain yield (t/ha)	Straw yield (t/ha)	Seed yield (t/ha)	Stover yield (t/ha)				
Intercropping systems (IS)								
DSR*	3.84	4.88	-	-	28,621	57,573	28,908	1.01
Blackgram	-	-	1.14	3.17	26,246	96,879	70,603	2.69
DSR + Blackgram (4:1)	3.41	4.46	0.21	0.74	32,543	68,696	35,797	1.10
DSR + Blackgram (4:2)	2.73	3.75	0.37	1173.3	32,225	72,169	39,959	1.24
SEm±	0.057	0.043	0.019	0.006		211.0	211.0	0.01
CD (P=0.05)	0.22	0.17	0.075	0.024		730.1	730.1	0.02
Phosphorous management (PM)								
No P, (P_0)	3.04	3,880.6	0.47	1.57	28,493	64,248	35,331	1.24
RDP (17.5 kg P/ha)	3.34	4,460.4	0.60	1.73	29,185	75,868	45,528	1.56
50% RDP + PSB + AMF	3.60	4,686.0	0.62	1.78	29,429	79,880	49,440	1.68
25% LR + PSB + AMF	3.23	4,422.4	0.59	1.71	29,200	75,321	44,968	1.54
SEm±	0.044	0.029	0.023	0.008		170.2	170.2	0.01
CD (P=0.05)	0.133	0.086	0.068	0.025		505.8	505.8	0.02
Interaction IS × PM								
Factor (B) at same level of (A) SEm±	0.004	0.014	0.004	0.014		680.92	680.9	0.02
CD (P=0.05)	0.012	0.043	0.012	0.043		2,178.4	2,178.4	0.07
Factor (A) at same level of (B) SEm±	0.004	0.014	0.004	0.014		3,612.9	3,612.9	0.1
CD (P=0.05)	0.012	0.042	0.012	0.042		11,332.9	11,332.9	0.4

*Direct seeded rice

(3.84 t/ha) was recorded in sole DSR followed by DSR + blackgram (4:1) and DSR + blackgram (4:2) and the difference between the sole DSR and both the intercropping systems (4:1 and 4:2) was significant. Among the P management treatments, the highest grain yield (3.60 t/ha) was recorded with treatment having 50% RDP + PSB + AMF which was significantly higher over all the other treatments. Treatment including soil amelioration through 25% LR + PSB + AMF showed statistically at par grain yield with 100% RDP application. Significantly higher grain and straw yields of sole DSR may be explained in the light that in an environment of competition for space, sunlight, water, soil minerals among others, in most cases, growth and development would favour a cereal sole crop compared to the same cereal crop under a polyculture. In case of rice grain yield, the maximum reduction in rice grain yield due to blackgram intercropping was attributed to the luxuriant growth of blackgram and its thick shading effect on the associated rice crop, which ultimately resulted in poor growth and low yield of the rice crop. Other possible reasons are that absorption of nutrients are more in sole planting system owing to better utilization of nutrient, more space and less competition for nutrient uptake than the intercropping systems (Singh *et al.,* 2013).

Due to P management there was superior root nodulation and yield attributes of blackgram which resulted in superior economic yield depended not only on the size of photosynthetic system, its efficiency, and active duration but also on translocation of assimilates from source to sink. However, application of only microbial inoculants was not sufficient to supply full P requirement of crop and needed additional P through inorganic source in the early crop stages. The application of P enhanced the water absorption and nutrient uptake from the soil (Kato *et al*., 2006). This might be one of the reasons behind superior growth and yield of rice crop due to P fertilization in the treatment 50% RDP + PSB + AMF. Application of 100% RDP was at par with 25% LR + PSB + AMF owing to better P utilization during initial stages of crop growth under these treatments. Application of 100% RDP resulted in better nutrient uptake at initial stages. The treatment containing 25% LR + PSB + AMF did not have any phosphorous application during initial stages lead to less utilization of P in soil although lime might have enhanced the capacity to translocate photosynthates towards economic sink, resulting in greater seed yield. This was mainly due to higher biological production and developed root system with enhanced root activity. Shekhawat *et al*., (2018) found that balanced fertilization of blackgram crop involving nutrient combination of phosphorus with vermicompost and biofertilizers most effectively enhanced yield in blackgram. Dongare *et al*., (2016) reported that the application of dual seed inoculation of *Rhizobium* + PSB produced significantly higher grain and stover yield in summer greengram. The significantly higher straw yield due to biofertilizer application could be attributed to more vegetative growth as a result of effective nutrients utilization which absorbed by extensive root system and prolific shoot development, on account of improved nourishment (Yadav *et al.,* 2017). Integrated seed inoculation with *Rhizobium* + PSB + AM fungi in summer greengram gave significantly higher seed and stover yield as compared to un-inoculated treatments (Naragund *et al*., 2020; 2022).

Cost of cultivation was lowest in sole blackgram (₹26,246) and highest in DSR + blackgram (4:1) intercrop (₹32,543) which happened due to higher expenditure especially on weeding for both the intercrops under rainfed upland soil (Table 1). But it can be inferred that though the cost of cultivation is high in intercropping than sole cropping, it is always beneficial in terms of overall return. Gross return and net returns were highest in sole blackgram (₹96,879, ₹70,603/ha, respectively) which might be owing to high market price of blackgram than rice and returns under intercrop were followed by DSR + blackgram (4:2) and lowest recorded in sole DSR. Sole blackgram (₹2.69) recorded significantly higher net B:C ratio than other three treatments. Shekhawat *et al.,* (2018) reported that application of 40 kg P_2O_5/ha + vermicompost 2.5 t/ha + *Rhizobium* + PSB in blackgram recorded higher net returns when compared to control.

Amongst phosphorous management treatments, 50% RDP + PSB + AMF gave highest gross return (₹79,880) and net return (₹49,440) and net B:C ratio followed by RDP (₹1.56); and treatment with 100% RDP and 25% LR + PSB + AMF gave at par returns and net B:C ratio. Lowest net B:C ratio was recorded in P control (₹1.24). Integrated seed inoculation with *Rhizobium* + PSB + AM fungi in summer greengram gave significantly higher net return and net B:C ratio as compared to un-inoculated treatments (Naragund *et al*., 2020).

Thus it may be suggested that under rainfed uplands of eastern India, farmers may adopt either sole blackgram or intercropping of rice and blackgram in 4:2 ratio over sole DSR for higher productivity, monetary returns and better soil microbial parameters. For better phosphorus management in soil farmers should inoculate phosphate solubilizing bacteria (PSB) and AM Fungi along with 50% RDP at the time of sowing.

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