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INFLUENCE OF NITROGEN AND PHOSPHORUS ON YIELD, AVAILABILITY IN SOIL AND UPTAKE UNDER DIRECT SEEDED BASMATI RICE

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ABSTRACT

A field experiment was conducted at Agronomy Farm, Khalsa College Amritsar (Punjab) during season of 2021, to study the effect of 4 levels of each nitrogen (0, 40, 50 and 60 kg N ha^{-1}) and phosphorus (0, 37.5 and 45 kg P_2O_5 ha^{-1}) fertilization on yield, uptake, nutrient-use efficiency and economics of basmati rice (*Oryza sativa* L.). Results showed that progressive increase in level of nitrogen up to 50 kg ha^{-1}, being at par with 60 kg ha^{-1} and significantly increased the most of the yield attributing characters of basmati rice and increased N and P uptake. It also recorded significantly higher grain yield (40.6 q ha^{-1}) and highest uptake of nitrogen by grain (40.8 kg ha^{-1}) of basmati rice over 40 kg N ha^{-1} and control. The straw yield (57.1 q ha^{-1}) and nitrogen uptake by straw was highest at 60 kg N ha^{-1} which was significantly higher over 50 kg N ha^{-1}, 40 kg N ha^{-1} and control. The maximum nitrogen use efficiency was recorded when its level was raised from 0 to 40 kg ha^{-1} and various level of nitrogen brought significant effect on phosphorus use efficiency. Highest availability of nitrogen in soil was recorded at 60 kg N ha^{-1} (215 kg N ha^{-1}) which increased the availability of phosphorus in soil. Successive increase in level of phosphorus up to 45 kg ha^{-1} significantly improved most of the yield attributing characters and N and P uptake by basmati rice over lower levels. It also recorded significantly higher grain yield (36.4 q ha^{-1}), straw yield (51.1 q ha^{-1}) and phosphorus uptake by grain (8.7 kg P_2O_5 ha^{-1}) and straw (7.4 kg P_2O_5 ha^{-1}) over the 37.5 kg P_2O_5 ha^{-1} and control. Raising the phosphorus level from 0 to 37.5 kg ha^{-1} registered the highest phosphorus use efficiency. Available phosphorus was highest at 45 kg P_2O_5 ha^{-1} which increased the availability of phosphorus in soil. Benefit:cost ratio was maximum at 60 kg N ha^{-1} (2.6) and 45 kg P_2O_5 ha^{-1} but at par with the application of 50 kg N ha^{-1}(2.5) and 45 kg P_2O_5 ha^{-1}. Hence, application of 50 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1} is recommended.

Interaction effects of nitrogen and phosphorus were found to be non-significant in respect of all yield attributes, availability in soil and uptake by grain and straw.

(Key words: Nitrogen, phosphorus, basmati rice, nutrient use efficiency, yield, uptake)

INTRODUCTION

India is the second largest producer of rice (*Oryza sativa* L.) in the world with 122.27 million tonnes total production from 42.94 m ha^{-1} area with average productivity of 27.05 q ha^{-1} (Kumar and Garhwal, 2022). Punjab has the second largest acreages under Basmati rice (Anonymous, 2019), where it is cultivated on an area of 3.14 m ha^{-1} with total production of 18.92 million tonnes, yielding approximately 60.21 q ha^{-1} (Anonymous, 2023a). Rice is conventionally grown by manual transplanting in puddled soil with continuous flooding, but this practice causes deterioration of soil health, poses threat to soil microbial biodiversity adversely affects soil physical properties and depletes water resources (Kumar and Ladha, 2011). This, water and labour-intensive, method of rice cultivation requires 30-man days ha^{-1} (Prasad *et al*., 2001) and is needed to be replaced by an environment and pocket friendly alternative management method. Direct seeded rice (DSR), the oldest form of crop establishment, is a better replacement of puddled transplanted rice. It needs less labour, has lower water requirements, low production costs and also improves soil physical conditions. As an environment friendly method, it reduces methane emission and is a better fit in various cropping systems (Saha and Bharti, 2022). Nutrient management is very important in basmati production, optimum fertility level plays a key role in enhancing crop yield and getting higher fertilizer use efficiency. Higher application doses resulted in increased insect-pests incidence and crop lodging consequently affecting its grain quality (Chau and Heong, 2005). Farmers tends to apply more N fertilizer for a greener crop and use sub-optimal doses of phosphorus or entirely skip its application, resulting in imbalanced nutrient application and thus, reduces nutrient use efficiencies (Sapkota *et al*., 2014). Nitrogen is the most limiting nutrient for crop production due to its dynamic nature and is susceptible to loss from

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soil–plant systems make its management more difficult. Nitrogen is a key nutrient for rice production and is required in large quantity (Pradhan *et al.,*2022). Increased grain yield with increased N application up to an optimum level has been reported thus it's important to maintain N fertilizer application (Kaur *et al.,* 2016). Optimum phosphorus (P) fertilizer application plays crucial in the early phases of vegetative growth, it helps in early root development facilitating better nutrient uptake and also encourages tillering (Slaton *et al.,* 2002). The cooking quality of rice can also be improved by moderately increasing the P fertiliser dose during the initial stage (Chang *et al.,* 2007). Direct seeded rice has different fertilizer requirements than transplanted basmati rice (Mahajan *et al.,* 2011). Response of combined application of optimal N and P doses in direct seeded rice has gotten very little attention and is often compared with constant flooding (Chen *et al.,* 2018). Keeping this in view, an attempt was made to study and unveil the suitable doses of N and P fertilizer in direct seeded basmati rice for getting higher returns and better fertilizer use efficiency.

MATERIALS AND METHODS

The field experiment was conducted during the *kharif* season of 2021 at research farm of Khalsa College, Amritsar (Location 31.63°E and 74.87°N, 234 metres above mean sea-level). The climate can be described as cool winter (November to February) with mean temperature 13.9°C, hot summer (March to June) with mean temperature 44.2°C, and 19.4 mm rainfall in the monsoon season (Mid-June to Mid-September). The soil at the experimental site was loamy sand with a pH 8.85, organic carbon content 0.56%, available nitrogen 199 N kg ha^{-1}, phosphorus 18 kg P_2O_5 ha^{-1} and potassium 305 kg K_2O ha^{-1}. The experiment was laid out in split plot design with 4 levels of nitrogen application doses as main plot (N_0, N_{40}, N_{50}, and N_{60}), 3 phosphorus levels (P_0, $P_{37.5}$, and P_{45}) as sub plot treatments and the treatments were replicated 4 times. After pre-sowing irrigation, field was prepared by ploughing twice with disc harrow, 2 passes of cultivators, followed by planking. Sowing of basmati variety 'Pusa Basmati-1718' was done on June 22, 2021 using seed @ 20 kg ha^{-1} with seed drill at an inter row spacing of 20 cm. Fertilizer doses were applied as per the treatments, phosphorus was applied using DAP at the time of sowing, while nitrogen was applied in splits at 3, 6, and 9 weeks after sowing. All other field operations were followed as per the recommendation of PAU for direct seeded rice (Anonymous 2023b). The crop was harvested and threshed plot wise on 10 November 2021. To analyse nutrient content in soil the samples were taken from upper soil layer after the harvesting of crop and analysis was carried as per standard procedures *viz.,* for available nitrogen modified Kjeldhal Method (Piper ,1966) was used. Phosphorus content was determined with the vanadomolybdate phosphorus yellow colour method in the nitric acid as described by Jackson (1967). The uptakes of these nutrients were also calculated by multiplying nutrient concentration of grain and straw with their respective yields and sum of the uptake of straw, grain at harvest was expressed as the total N uptake (kg ha^{-1}) (Sivasabari *et al.,* 2021). Partial factor productivity (PFP) was worked out to study production efficiency, which was calculated in units of crop yield $unit^{-1}$ nutrient applied and expressed in kg ha^{-1} (PFP = Yield / amount of nutrient applied) (Cassmen *et al.,* 1996). Economics was worked out on the basis of prevalent market prices of inputs and outputs, which were used to derive Benefit :Cost (B:C ratio = Returns /Total cost). Statistical analyses of data were carried out using PROC GLM in SAS 9.3 software (Anonymous, 2011). Multiple comparisons were made using ADJUST= LSD at $P<0.05$ to determine significant effects and alphabets were denoted to depict significantly different treatments.

RESULTS AND DISCUSSION

Effect of nitrogen levels on yield, nutrient uptake and availability in soil

On perusal of data, it was observed that with increasing nitrogen levels there was a significant increment in grain yield. Although highest grain yield was recorded with the application of in 60 kg N ha^{-1} (40.6 q ha^{-1}) but was statistically similar to that obtained with 50 kg N ha^{-1} (38.9 q ha^{-1}) and significantly higher than yield obtained with application of 40 kg N ha^{-1} (Table 1). The per cent increase in yield by 60 and 50 kg N ha^{-1}over 40 kg N ha^{-1} was 14.0 and 9.3 respectively. While comparing grain yield with control, per cent increase of 161.9 and 151.0 was recorded in grain yield with application of 60 and 50 kg N ha^{-1} respectively. Kaur *et al.* (2016) has also reported an increase in grain yield at decreasing rate in direct seeded basmati rice with increasing levels of nitrogen fertilizer. Different levels of nitrogen also had a significant effect on straw yield, application of nitrogen at 60 kg ha^{-1} resulted in the highest straw yield (57.1 q ha^{-1}), which was 5.7%, 12.4% and 42.2% higher over 50 kg N ha^{-1}, 40 kg N ha^{-1} and control. Similar results were also reported by Javeed *et al.* (2017), that straw yield was increased by increasing nitrogen dose. Analysis of the data indicated that increasing levels of nitrogen fertilizer in basmati rice significantly enhanced N uptake in grain as well as straw. Application of 60 and 50 kg N ha^{-1} reported statistically similar N uptake in grain. However, upon application of 60 kg N ha^{-1} significantly higher uptake of N in straw, P in grain and straw was observed. In confirmation to our results, Hossain *et al.* (2005) also reported that subsequent addition of N at each level helped plants to increase N uptake. There was a significant effect of varying nitrogen levels on available nitrogen in soil, with the application of 60 kg N ha^{-1} significantly higher available nitrogen (215 kg N ha^{-1}) in soil was observed in comparison to other lower levels of application. Similar result was reported by Srivastava *et al.* (2009) revealing that available nitrogen in soil was increased by using 100 % recommended dose of fertilizers.

Effect of phosphorus levels on yield, uptake and availability in soil

Grain yield significantly improved with the increase in level of phosphorus, Application of 45 kg P_2O_5 ha^{-1} recorded highest grain yield (36.4 q ha^{-1}) which was statistically superior over application of 37.5 kg P_2O_5 ha^{-1} and both the treatments yielded significantly higher than control. Application of 45 kg P_2O_5 ha^{-1} and 37.5 kg P_2O_5 ha^{-1} recorded 17.3 and 28.6% higher grain yield over control respectively. Every addition in graded level of phosphorus resulted in significantly higher straw yield over lower levels (Table 1). With the application of 45 kg P_2O_5 ha^{-1}, 51.1 q ha^{-1} straw yield was recorded, which was 6.9% and 10.1% higher than that obtained with 37.5 kg P_2O_5 ha^{-1} and control. This might be due to the effect of phosphorus availability to the plant, enhancing root development and metabolic processes which resulted in more translocation of photosynthates toward the productive part (Gharib *et al.,* 2011). Similar result was also observed by Hasanuzzaman *et al.* (2012), they revealed that approximately 50 kg P_2O_5 ha^{-1} was sufficient to get a highest yield from rice.

The data showed that with increasing phosphorus levels up to 45 kg P_2O_5 ha^{-1} resulted in significantly higher uptake of phosphorus in grain over lower levels. It recorded 9.8 kg uptake of total phosphorus which was 12.6% and 28.7% more than obtained under 37.5 kg ha^{-1} and control. The phosphorus absorption by grains is inversely correlated with nitrogen absorption. Total uptake of phosphorus by straw was also affected significantly due to varying level of phosphorus. Application of phosphorus at 45 kg P_2O_5 ha^{-1} recorded the total uptake of 8.6 kg P_2O_5 ha^{-1}, indicating a significant increase of 12.1 % and 20.2% over 37.5 kg P_2O_5 ha^{-1} and control. Similar findings were made by Kumar *et al.* (2017) reporting that raising the phosphorus level improved the uptake of phosphorus by straw. Available nitrogen was increased the availability of phosphorus in soil and maximum were found at N_{50} and P_{45} which was 201 kg N ha^{-1} and 191.7 kg P_2O_5 ha^{-1}.

Nutrient use efficiency

Nutrient use efficiency showed negative response with increasing levels of nitrogen fertilization (Table 1). Raising the nitrogen level from 0 to 40 kg N ha^{-1}, registered the highest partial factor productivity. Afterwards, it showed significant decline up to 60 kg N ha^{-1}. Lowest value of all these were recorded at 60 kg N ha^{-1}. PFP_N increased with every increase in level of phosphorus up to 45 kg P_2O_5 ha^{-1}. This treatment improved the partial factor productivity of nitrogen (PFP_N) by 12.6% and 24.1% 50 kg N ha^{-1} and 60 kg N ha^{-1}. Decline in partial factor productivity at higher level of N may be attributed to nutrient imbalance and decline in indigenous soil N supply. Our findings confirm results of Karim and Ramasamy (2000) in rice. They revealed that partial factor productivity declined steadily with successive increase in level of fertilizer. Data further indicated that PFP_P showed negative response with increasing levels of phosphorus fertilizer. Raising the phosphorus level from 0 to 37.5 kg P_2O_5 ha^{-1}, registered that highest PFP_P. Afterwards, it showed significant decline up to 45 kg P_2O_5 ha^{-1}. This treatment improved that partial factor of phosphorus (PFP_P) by 8.6% over 37.5 kg P_2O_5 ha^{-1}. Similar results were given by Ortiz-Monasterio *et al.* (2001), they concluded that when P supply is low, the correlation between root length density and P uptake or gain yield was usually 0.50-0.60 but with adequate P supply this correlation was lower.

Benefit: Cost ratio (B:C Ratio)

The maximum B:C ratio was recorded at 60 kg N ha^{-1} *i.e.* 2.6 and 45 kg P_2O_5 ha^{-1} *i.e.,* 2.3 which was statistically at par with 50 kg N ha^{-1} *i.e.,* 2.5. Hence, we recommended the 50 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1} was the best treatment for the farmer under direct seeded basmati rice condition from the economical point of view.

Interaction effect

Interaction effects were found non-significant.

In direct seeded basmati rice, the maximum grain yield and uptake of nitrogen by grain were recorded at 60 kg N ha^{-1} which were statistically at par with 50 kg N ha^{-1}. While the highest straw yield, uptake by straw and maximum availability of nitrogen in soil was recorded at 60 kg N ha^{-1} which was comparable to other treatments. With increasing the content of nitrogen, nutrient use efficiency was reduced. Furthermore, in phosphorus levels, maximum grain yield, availability of phosphorus in soil and uptake in grain and straw was observed at 45 kg P_2O_5 ha^{-1} which was substantial from other treatments. While discussing about nitrogen and phosphorus interaction, phosphorus increases the availability of nitrogen in the soil, grain and straw. Considering the economics maximum benefit: cost ratio was recorded at 60 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1} but it was nearer to 50 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1}. Hence, application of 50 kg N ha^{-1} and 45 kg P_2O_5 ha^{-1} is recommended under direct seeded basmati rice in Amritsar condition.

Table 1. Effect of nitrogen and phosphorus levels on yield, nutrient uptake, availability in soil, nutrient use efficiency and benefit: cost ratio

Treatments	Grain Yield (q ha^{-1})	Straw yield (q ha^{-1})	Nitrogen uptake (Grain) (kg ha^{-1})	Nitrogen uptake (Straw) (kg ha^{-1})	Phosphorus uptake (Grain) (kg ha^{-1})	Phosphorus uptake (straw) (kg ha^{-1})	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	PFP (N)	PFP (P)	Benefit-cost ratio
Nitrogen Levels (kg ha^{-1})											
N_0- Control	15.5	33.0	14.9	17.3	3.2	3.9	156.0	16.1	0	39.9	1.0
N_{40}– 40 kg N ha^{-1}	35.6	50.0	34.8	26.5	8.0	6.5	184.0	16.3	89.1	93.5	2.3
N_{50}- 50 kg N ha^{-1}	38.9	53.8	38.4	29.2	8.9	7.5	201.0	18.5	77.8	100.7	2.5
N_{60} – 60 kg N ha^{-1}	40.6	57.1	40.8	31.3	9.8	8.6	215.0	18.7	67.7	104.6	2.6
SE (m) ±	0.74	1.24	0.80	0.73	0.24	0.12	0.92	2.60	1.21	1.34	-
CD (P=0.05)	2.24	3.73	2.40	2.20	0.74	0.38	2.78	-	3.64	4.04	-
Phosphorus Levels (kg ha^{-1})											
P_0 - Control	28.3	46.4	28.3	24.5	6.20	5.9	186.0	11.8	67.6	0	1.9
$P_{37.5}$– 37.5 kg P_2O_5 ha^{-1}	33.2	47.9	32.7	25.7	7.6	6.5	190.3	19.2	79.9	88.6	2.1
P_{45} – 45 kg P_2O_5 ha^{-1}	36.4	51.1	35.6	28.0	8.7	7.4	191.7	21.2	87.1	80.9	2.3
SE(m) ±	0.41	0.86	0.43	0.63	0.18	0.15	0.91	0.66	0.70	0.94	-
CD (P=0.05)	1.25	2.58	1.31	1.90	0.56	0.47	2.73	2.00	2.10	2.82	-
Interactions											
SE(m)±	2.25	1.03	1.81	2.00	0.40	0.40	2.58	2.62	2.81	3.37	-
CD(P=0.05)	-	-	-	-	-	-	-	-	-	-	-

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