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Nutrient uptake and availability in rice with phosphorus management (*Oryza sativa* (L.)

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Abstract

A study was conducted during *kharif* 2016-17 and 2017-18 to assess the impact of phosphorus management *i.e.,* the influence of source and levels of phosphorus on nutrient uptake and availability of rice in Agricultural College Farm, Bapatla. The results inferred that significant improvement in nutrient uptake and availability (NPK) of rice was observed with the treatment received green manuring *insitu* with dhaincha along with PSB. Availability of NPK was enhanced with increased rate of P_2O_5 application upto some extent but optimum grain yield, nutrient uptake and availability after harvest of rice crop was observed with the 50% RDP than 100 and 150% RDP.

Keywords: Rice, phosphorus source, levels of phosphorus, nutrient uptake and nutrient availability

Introduction

Phosphorus is an essential component of all living things, without phosphorus, there is no cell, no plant and no grain… and without adequate phosphorus there is a lot of hunger… India's demand and need for P is high. The inherent supply is insufficient to meet production goals. In view of this, the research step was forward with respect to the progressive and efficient use of land and nutrients is required. More effort need to be extended towards testing viable agronomic, economic and environmental limits in high yielding crop production-experimentation with adequate P along with balanced levels of other nutrients and using best management technologies crucial in determining these limits. The phosphorus deficiency is common in almost all the soils and crops (Raju *et al.,* 2005) [1]. and it reacts with oxides /hydroxides to form stable forms that may not be available to the plant, resulting in low recovery and accumulation in soils. All indications are that the P removal will continue to exceed net P additions and P deficiency will accentuate further with time. Information on P fertility status of soils is of great importance since it helps to determine the level of P fertilizer to be applied to crops. The information is equally important for deciding P fertilizer distribution and planning at both macro and micro levels. The vast alluvial tract of northern, southern, eastern and western parts of the country is usually low or medium in available P content. Phosphorus application is needed in soils testing both medium and low in available P status. Accordingly about 80% of the samples in India need P application at the recommended rates.

Phosphorus is reported to be a critical factor of many crop production systems due to its limited availability in soluble forms. The other side of the coin is, in high P soils, considering the P removal by crops, application of some quantity of P fertilizer would be essential to arrest P mining from the soils so as to sustain high yield agriculture with the inclusion of organic manures for improving soil fertility, crop yields and biological status of soil. By taking all these considerations incorporation of green manure crop like dhaincha (*Sesbania aculeata*) and bio-fertilizer, phosphorus solubilizing bacteria were used to enhance the productivity of rice cropping systems.

Material and Methods

The experiment was laid out in a split plot design with 12 treatments in *kharif* with three replications. The main plot includes sources of phosphorus *viz.,* inorganic fertilizer phosphorus through SSP, green manuring *in-situ* with dhaincha @ 25 kg ha^{-1}, phosphorus solubilizing bacteria bio-fertilizer @ 750 ml ha^{-1} and green manuring *in-situ* with dhaincha @ 25 kg ha^{-1} + phosphorus solubilizing bacteria bio-fertilizer @ 750 ml ha^{-1} and levels of phosphorus *viz.,* 50%, 100% and 150% RDP were allotted to sub plots during *kharif* season of 2016-17 and 2017-18. Soil samples from 0-30 cm depth were collected at random from the experimental site before layout of the experiment. A composite soil sample was analyzed for physical and physico-chemical properties by following standard methods. The results of analysis indicated.

that the experimental soil was clay loam in texture, slightly alkaline in reaction with pH 7.6 and 7.4 with an electrical conductivity of 0.26, 0.30 dS m^{-1} at 25^o C and low in organic carbon (0.41 and 0.43%), low in available nitrogen (234, 251 kg ha^{-1}), medium in available phosphorus (19.0, 21.4 kg ha^{-1}) and high in potassium (554, 572 kg ha^{-1}) during 2016-17 and 2017-18 respectively. Green manuring crop of dhaincha at 45 DAS was incorporated fifteen days prior to transplanting of rice in the respective treatments during both the years of study. The most popular and fine grain quality rice variety *i.e.,* BPT-5204 was used for this experiment. Data regarding nutrient uptake and availability of rice were subjected to standard statistical procedures.

Nitrogen, phosphorus and potassium content and uptake at different stages of growth *viz.,* 30, 60, 90 DAS and at maturity and analysis of soil after harvest of rice for NPK were estimated by following methods detailed below (Table.1 and 2).

Table 1: Methods adopted for plant analysis

Element	Method adopted	Reference
Nitrogen	Microkjeldahl distillation method	(Bremner, 1965) [2]
Phosphorus	Vanado molybdo phosphoric yellow colour method	(Koeing and Johnson, 1942) [3]
Potassium	Flame photometer method	Jackson (1973) [4]

Table 2: Methods adopted for soil analysis

Element	Method adopted	Reference
Nitrogen	Alkaline permanganate method	(Subbiah and Asija, 1956) [5]
Phosphorus	Olsen's method	(Olsen *et al*., 1954) [6]
Potassium	Neutral normal ammonium acetate method	(Muhr *et al.,* 1963) [7]

Nutrient Uptake

From the results of plant analysis, nitrogen, phosphorus and potassium uptake was calculated as indicated below.

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Nutrient concentration (\%)} \times \text{Weight of drymatter (kg ha}^{-1})}{100}$$

Before the incorporation of the green manure (dhaincha), NPK content was estimated and results are furnished in Table 3.

Table 3: Quantity of biomass and nutrient concentration of green manure (dhaincha) on dry weight basis

Year	Fresh biomass of dhaincha (t ha^{-1})	Dry Matter (t ha^{-1})	Nutrient concentration (%)			Nutrient Accumulation (kg ha^{-1})		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
2016-17	19.6	2.8	3.0	0.46	1.09	84	12.8	30.5
2017-18	21.4	3.0	3.1	0.50	1.10	93	15.0	33.0

Results and Discussion

From the result of the field experiment, the uptake, availability of nutrients and yield response of rice crop to different applied phosphorus treatments for optimum production has been compiled. Data (Table 4, 5, 6) revealed that variation in nitrogen, phosphorus and potassium content was not affected by different sources and levels of phosphorus and also by their interaction at maturity in grain and straw during both the years of study and also in pooled data.

A perusal of the data presented in Table 4 showed significant differences in nitrogen uptake in plant at maturity (grain and straw) due to different sources of phosphorus, while there was no significant variation in nitrogen uptake due to different levels of phosphorus. The interaction effect was found to be non-significant during both the years of study except in pooled data.

During both the years of study, among the source of phosphorus, it was observed that significantly higher nitrogen uptake was observed with treatment that received green manuring + PSB, which was statistically on a par with green manuring alone but proved significantly superior to soil application of PSB and application of inorganic phosphorus through SSP. The increased N uptake was due to sufficient and continued availability of N from inorganic and organic source in the soil favouring the efficient use of major and micro nutrients due to accumulation and solubilization of nitrogen (Dixit and Gupta, 2000) [8]. The uptake being the product of nutrient content and drymatter accumulation, the increase in N uptake by the crop might be due to increased availability of nitrogen and higher grain and straw yields. Similar results were reported by Patro *et al.* (2005) [9], Vinay Singh (2006) [10]. and Vijay Pooniya and Shivay (2011) [11].

Among the levels of phosphorus a progressive increase in nitrogen uptake was observed with increasing levels of phosphorus but these differences were not significant.

It was found that there was no significant difference in N uptake (kg ha^{-1}) of grain with levels of phosphorus across the main plot treatments (Phosphorus sources) throughout the crop growth period, however application of 50% RDP found significantly inferior over other treatment combinations when it was combined with green manures and PSB found at par with 150% RDP.

The increased N uptake in grain was due to adequate supply of phosphorus in soil favouring the efficient use of major and minor nutrient elements. The uptake being the product of nutrient content and drymatter accumulation, the increase in N uptake by the crop due to increased availability of phosphorus. In addition to this green manure accumulates the phosphorus @ 13.9 kg ha^{-1} as well as nitrogen @ 88.5 kg ha^{-1} further enhances the nitrogen uptake by crop (Table 4a).

Phosphorus uptake (Table 5 and Fig. 1) By rice significantly differed at maturity (grain and straw) by the application of different sources of phosphorus, while there was no significant variation with P levels for phosphorus uptake by rice during both the years of study and in pooled data. The interaction was found to be non-significant.

With regard to sources of phosphorus, significantly the highest phosphorus uptake was noticed with green manuring + PSB application which was statistically at par with green manuring alone and proved significantly superior to the rest of the treatments. The increased P uptake was due to higher drymatter accumulation at different stages of crop growth but not by phosphorus content, as uptake being the product of nutrient content and drymatter accumulation. The present results are in agreement with the findings of Mohammadi (2012) [12]. Salahin *et al.* (2013) [13]. Sarkar *et al.* (2014) [14]. And Sujatha *et al*. (2017) [15].

The lowest phosphorus uptake was observed with the application of inorganic phosphorus through SSP alone at maturity (grain and straw) during both years of study and in pooled data. This might be due to low drymatter accumulation at respective stages of crop growth.

The data on potassium content at maturity both in grain and straw were furnished in Table 6 which showed that there was no significant difference in potassium content with relevance to the effect of source and levels of phosphorus and their interaction as well. However, potassium content of straw in pooled data was significantly influenced by sources of phosphorus. Maximum K content in straw was observed in green manuring + PSB treatment which was statistically on a par with green manuring alone and significantly superior to the other treatments. The lowest K content was observed with the application of phosphorus alone through SSP. This might be due to increase in K content with increasing levels of P_2O_5 stimulated the more vegetative growth by chelation process mainly by the foraging capacity of roots which in turn lead to increased potassium content by straw. These results are in accordance with the findings of Raju and Reddy (2000) [16]. And Patro *et al.* (2005) [9].

A perusal of the data (Table 6) showed significant differences in potassium uptake in plant at maturity (grain and straw) due to different sources of phosphorus, while there was no significant variation in K uptake among the levels of phosphorus and the interaction was found to be non-significant during both the years of study except in pooled data.

Among different sources of phosphorus the highest K uptake was observed with green manuring + PSB which was at par with the green manuring alone and statistically superior to rest of the treatments. The lowest potassium uptake was observed with the inorganic phosphorus through SSP. Potassium uptake followed the similar trend as that was noticed in respect of N and P uptakes at maturity (grain and straw) during both the years of study and in pooled data.

Table 4: Nitrogen content (%) and uptake (kg ha^{-1}) of rice at maturity as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17					2017-18					Pooled data				
	Grain		Straw		Total uptake	Grain		Straw		Total uptake	Grain		Straw		Total uptake
	Content	Uptake	Content	Uptake		Content	Uptake	Content	Uptake		Content	Uptake	Content	Uptake	
Source of phosphorus applied to rice															
M_1-Inorganic P	1.05	48.5	0.63	37.2	85.7	1.08	52.9	0.66	38.6	91.4	1.06	50.4	0.65	39.0	89.4
M_2-Green manuring	1.11	65.7	0.7	46.4	112.1	1.12	69.0	0.74	47.6	116.6	1.12	67.7	0.72	48.3	115.9
M_3- PSB	1.09	59.7	0.67	42.1	101.8	1.1	63.4	0.68	43.4	106.8	1.09	61.3	0.67	42.6	103.9
M_4- GM+PSB	1.11	67.3	0.72	48.7	116.0	1.14	72.4	0.74	49.9	122.4	1.12	69.5	0.73	50.0	119.5
SEm±	0.02	1.06	0.02	1.32	2.12	0.02	1.77	0.02	1.21	2.72	1.02	1.45	0.02	1.25	2.47
CD (p = 0.05)	NS	3.6	NS	4.5	7.3	NS	6.1	NS	4.1	9.4	NS	5.0	NS	4.3	8.5
CV (%)	4.2	5.3	9.4	9.1	6.1	4.3	8.2	8.4	7.8	7.3	4.2	7.0	8.8	8.3	6.9
Levels of phosphorus applied to rice															
S_1- 50% RDP	1.07	56.4	0.64	40.6	97.0	1.10	61.1	0.70	44.8	105.9	1.08	58.5	0.67	42.7	101.2
S_2- 100% RDP	1.09	61.0	0.68	43.4	104.4	1.11	64.6	0.71	46.7	111.3	1.10	62.8	0.69	44.4	107.2
S_3- 150% RDP	1.11	63.2	0.71	45.9	109.1	1.13	67.9	0.71	48.1	116.0	1.12	65.5	0.71	47.0	112.5
SEm±	0.03	1.8	0.03	1.96	3.9	0.02	2.22	0.03	2.24	3.11	0.02	1.61	0.03	2.04	2.87
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.7	9.2	12.4	15.6	11.3	5.8	10.8	13.0	16.0	9.4	5.6	8.4	12.6	15.7	9.3
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**S**	NS	NS	NS

Table 4a: Interaction between sources and levels of phosphorus on N uptake (kg ha^{-1}) in grain of rice at maturity as influenced by phosphorus management - pooled data

Source of phosphorus applied to rice	Levels of Phosphorus applied to rice			Mean
	S_1 - 50% RDP	S_2 - 100% RDP	S_3 - 150% RDP	
M_1- Inorganic phosphorus	38.0	53.2	60.0	50.4
M_2- Green manuring	67.1	67.8	68.1	67.7
M_3- Soil application of PSB	60.2	60.2	63.6	61.3
M_4- Green manuring + PSB	68.5	69.8	70.2	69.5
Mean	58.5	62.8	65.5	
	SEm±	**CD (p = 0.05)**	**CV (%)**	
Source of phosphorus applied to rice (M)	1.45	5.0	7.0	
Levels of Phosphorus applied to rice (S)	1.51	NS	8.4	
Interaction				
M*S	3.02	9.0		
S*M	2.86	8.9		

Table 5: Phosphorus content (%) and uptake (kg ha^{-1}) of rice at maturity as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17					2017-18					Pooled data				
	Grain		Straw		Total uptake	Grain		Straw		Total uptake	Grain		Straw		Total uptake
	Content	Uptake	Content	Uptake		Content	Uptake	Content	Uptake		Content	Uptake	Content	Uptake	
Source of phosphorus applied to rice															
M_1- Inorganic P	0.36	16.6	0.12	7.1	23.7	0.38	18.6	0.14	8.6	27.2	0.37	17.6	0.13	7.8	25.4
M_2-Green manuring	0.40	23.7	0.16	10.6	34.3	0.42	25.9	0.16	10.9	36.8	0.41	24.8	0.16	10.7	35.5

M_3- PSB	0.38	20.8	0.15	9.4	30.2	0.39	22.5	0.15	9.7	32.2	0.38	21.4	0.15	9.50	30.9
M_4-GM+PSB	0.42	25.4	0.17	11.5	37.0	0.44	27.9	0.16	11.1	39.0	0.43	26.7	0.16	11.0	37.6
SEm±	0.02	0.97	0.01	0.47	1.20	0.01	1.02	0.01	0.45	1.15	0.01	0.97	0.01	0.42	1.15
CD (p = 0.05)	NS	3.3	NS	1.6	4.1	NS	3.5	NS	1.5	3.9	NS	3.3	NS	1.45	3.9
CV (%)	11.8	13.5	18.7	14.7	11.6	9.6	12.9	15.5	13.3	10.2	9.5	12.9	16.3	12.9	10.6
Levels of phosphorus applied to rice															
S_1- 50% RDP	0.38	20.0	0.14	8.9	28.9	0.39	21.7	0.15	9.6	31.3	0.38	20.6	0.14	8.9	29.5
S_2- 100% RDP	0.38	21.3	0.15	9.6	30.8	0.41	23.8	0.15	9.9	33.7	0.4	22.8	0.15	9.7	32.5
S_3- 150% RDP	0.41	23.3	0.15	9.7	33.0	0.42	25.2	0.16	10.8	36.1	0.42	24.6	0.16	10.6	35.2
SEm±	0.02	1.19	0.01	0.41	1.40	0.02	1.42	0.02	1.00	1.72	0.02	1.20	0.01	0.58	1.46
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	19.8	19.1	15.1	14.9	15.7	14.7	20.6	15.7	13.8	17.6	16.6	18.3	20.9	20.5	10.6
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

The higher K uptake recorded by green manuring + PSB might be due to improvement in the physico-chemical properties of soil by incorporating the green manures which might have increased the supply of nutrients with increasing levels of phosphorus resulting in better growth and yield of rice. The phosphorus solubilizing bacteria plays a major role in solubilization of native and applied phosphorus in soil and further enhances the uptake of potassium due to synergistic effect of potassium with nitrogen and phosphorus. The results are in close conformity with those of Vinay Singh (2006) [10]. Jana *et al.* (2009) [17]. and Meena *et al.* (2015) [18].

Potassium uptake was found to be non-significant due to different levels of phosphorus. However, the maximum K uptake was observed with the application of 150% RDP followed by 100% and 50% in both the years of study and in pooled data (Fig. 1).

Higher grain yield was obtained with increased uptake of nutrients and the interaction was found to be significant in both the years of study and in pooled data (Table 7 and 7a).

Nutrient Availability (N, P and K) in soil after harvest of rice

Data pertaining to the soil available N at harvest are presented in the Table 8 which revealed that available N in the soil did not differ significantly due to levels of phosphorus except in pooled data, but source of phosphorus had a significant effect on soil available N but not by their interaction during both the years of study and in pooled data. Similar trend of response as that of soil available nitrogen was observed with soil available phosphorus and potassium.

Among the different sources of phosphorus, the higher soil available N was observed with the incorporation of green manure *in-situ* + PSB treatment which was at par with the application of green manuring alone and found significantly superior to soil application of PSB This might be due to positive response of green manuring with bio-fertilizers on soil N status and may be attributed to N mineralization from organic sources or by retaining N in labile microbial pool with the changing microbial flush. The most suitable soil conditions might have helped the mineralization of soil N and greater multiplication of soil microbes, which could convert organically bound nitrogen into readily available form leading to building up of higher available N. Similar results were observed in the findings of Swarup and Yaduvanshi (2000)[19]. Sharma *et al.* (2001) [20]. Chettri *et al.* (2017) [21]. And Roy *et al.* (2017) [22].

Nitrogen availability in soil after rice crop was not significantly influenced by levels of phosphorus from 50% RDP to 150% RDP. However, the availability of nitrogen was increased with increasing application of phosphorus from 50% to 150% RDP.

Among the source of phosphorus, green manuring + PSB recorded the highest available phosphorus which was at par with the green manuring alone and significantly superior to other treatments. The lowest phosphorus availability was observed with the application of inorganic phosphorus through SSP.

Table 6: Potassium content (%) and uptake (kg ha^{-1}) of rice at maturity as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17					2017-18					Pooled data				
	Grain		Straw		Total uptake	Grain		Straw		Total uptake	Grain		Straw		Total uptake
	Content	Uptake	Content	Uptake		Content	Uptake	Content	Uptake		Content	Uptake	Content	Uptake	
Source of phosphorus applied to rice															
M_1-Inorganic P	0.37	17.1	1.10	64.9	84.3	0.40	19.6	1.18	72.2	91.8	0.39	18.6	1.16	69.5	88.1
M_2-Green manuring	0.42	24.9	1.20	79.6	105.1	0.44	27.1	1.25	85.1	112.2	0.43	26.0	1.23	82.4	108.4
M_3- PSB	0.40	21.9	1.10	69.1	95.5	0.41	23.6	1.23	79.6	103.2	0.41	23.1	1.20	76.3	99.4
M_4-GM+PSB	0.42	25.4	1.20	81.2	107.8	0.45	28.6	1.32	91.6	120.1	0.43	26.7	1.27	86.9	113.6
SEm±	0.01	0.32	0.02	1.48	1.57	0.02	0.57	0.03	2.99	2.91	0.02	0.38	0.02	2.04	2.12
CD (p = 0.05)	NS	1.0	NS	5.1	5.4	NS	1.9	NS	10.3	10.0	NS	1.3	0.07	7.0	7.3
CV (%)	9.5	4.2	5.4	5.8	4.8	7.6	7.0	7.5	11.0	8.2	8.3	4.8	4.9	7.8	6.2
Levels of phosphorus applied to rice															

S_1- 50% RDP	0.40	21.1	1.10	69.7	90.8	0.42	23.3	1.23	78.7	102.1	0.41	22.2	1.20	76.4	98.6
S_2- 100% RDP	0.40	22.4	1.10	70.2	92.6	0.42	24.4	1.25	81.2	106.6	0.41	23.4	1.22	78.5	101.9
S_3- 150% RDP	0.41	23.3	1.20	77.6	101.0	0.43	25.8	1.26	85.3	111.2	0.42	24.6	1.24	82.1	106.7
SEm±	0.02	0.64	0.02	2.37	2.62	0.01	0.94	0.03	2.50	2.69	0.02	0.66	0.02	2.09	2.20
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	9.5	9.9	7.1	10.8	9.2	11.8	13.2	9.5	10.6	8.7	10.1	9.7	6.4	9.1	7.5
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

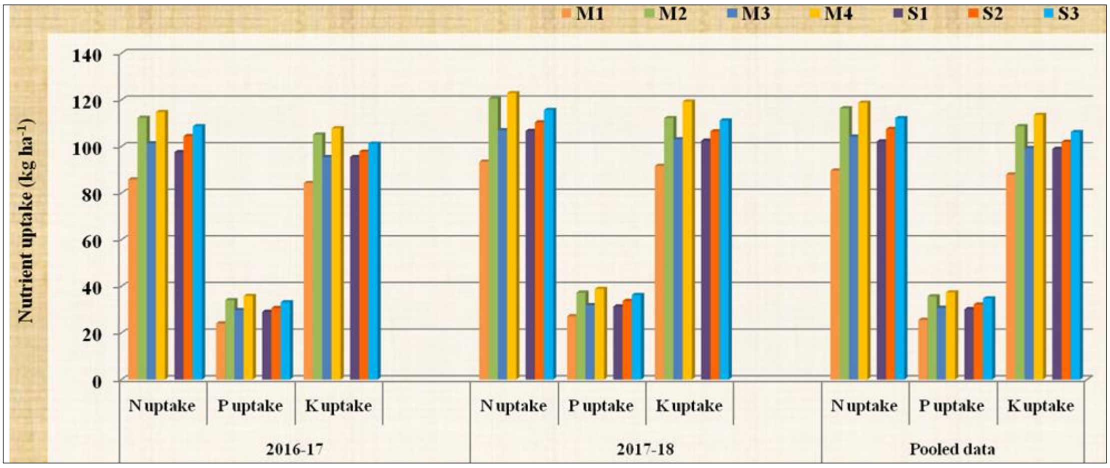

Fig 1: Nitrogen, phosphorus and potassium uptake (kg ha^{-1}) of rice at maturity as influenced by phosphorus management during 2016-17, 2017-18 and pooled data

Table 7: Grain yield (kg ha^{-1}) of rice as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17	2017-18	Pooled data
	Grain yield	**Grain yield**	**Grain yield**
Source of phosphorus applied to rice			
M_1- Inorganic phosphorus	4623	4896	4759
M_2- Green manuring	5920	6162	6041
M_3- Soil application of PSB	5477	5767	5622
M_4- Green manuring + PSB	6059	6352	6206
SEm±	99.5	134.1	108.4
CD (p = 0.05)	344	464	375
CV (%)	5.4	6.9	5.7
Levels of phosphorus applied to rice			
S_1 - 50% RDP	5273	5555	5414
S_2 - 100% RDP	5593	5817	5705
S_3 - 150% RDP	5693	6010	5852
SEm±	126.9	119.9	134.2
CD (p = 0.05)	NS	NS	NS
CV (%)	8.0	7.2	4.1
Interaction	**S**	**S**	**S**

Table 7a: Interaction between sources and levels of phosphorus on grain yield (kg ha^{-1}) of rice as influenced by phosphorus management during 2016-17, 2017-18 and pooled data

Source of phosphorus applied to rice	Levels of Phosphorus applied to rice (2016-17)			Mean	Levels of Phosphorus applied to rice (2017-18)			Mean	Levels of Phosphorus applied to rice (Pooled data)			Mean
	S_1 - 50% RDP	**S_2 - 100% RDP**	**S_3 - 150% RDP**		**S_1 - 50% RDP**	**S_2 - 100% RDP**	**S_3 - 150% RDP**		**S_1 - 50% RDP**	**S_2 - 100% RDP**	**S_3 - 150% RDP**	
M_1- Inorganic phosphorus	3661	4926	5282	4623	4019	4980	5689	4896	3840	4953	5485	4759
M_2- Green manuring	5910	5912	5937	5920	6151	6164	6170	6162	6031	6038	6054	6041
M_3- Soil application of PSB	5470	5470	5491	5477	5764	5766	5771	5767	5617	5618	5631	5622
M_4- Green manuring + PSB	6052	6062	6063	6059	6286	6358	6412	6352	6169	6210	6237	6206
Mean	5273	5593	5693		5555	5817	6010		5414	5705	5852	
	SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
Source of phosphorus	99.5	344	5.4		134.1	464	6.9		108.4	375	5.7	

(M)												
Levels of phosphorus (S)	126.9	NS	8.0		119.9	NS	7.2		134.2	NS	4.1	
Interaction												
M*S	253.8	761			239.7	719			235.5	706		
S*M	229.9	709			237.2	746			214.9	769		

Since, phosphorus fertilizers are not subjected to leaching losses in soil unlike nitrogen, higher levels of phosphorus might have left higher residual phosphorus in soil. The higher availability of soil phosphorus in the treatment green manure *insitu* + PSB might be due to coating of sesquioxides by organic materials and thus reduced the phosphorus fixation by soil (Bharadwaj and Omanwar, 1994) [23]. and also release of carbon dioxide and organic acids in solubilizing the native soil phosphorus (Singh *et al*., 2008) [24]. The maximum available P recorded in treatments with PSB may be due to the mobilization of soil P by the acidification of soil and the release of enzymes such as phosphatases and phytases of carboxylates such as gluconates and oxalates (Jones and Oburger, 2011) [25]. Which dissociates the bound form of phosphates like $Ca_3 (PO_4)_2$. Hence, the findings of the study highlight the possibility of reduction of P fertilizer use with the application of PSB's and also under high status of total P in wetland rice cultivation. Similar results were observed by Hossain *et al*. (2008) [26]. And Jemila *et al*. (2017) [27].

The available potassium status of the soil increased with increasing rates of phosphorus application. This may be due to release of potassium from decaying roots and the continuous replenishment of the potassium containing minerals in the soil.

The beneficial effect of green manuring and PSB on available potassium might be due to the reduction of potassium fixation, solubilisation and release due to the interaction of organic matter with clay besides the direct potassium addition to the potassium pool of soil. Similar results were also observed by Sarkar *et al.* (2014) [14]. And Chettri *et al*. (2017) [21].

Potassium availability was increased with the application of 150% RDP followed by 100% and 50% RDP during both the years of study and in pooled data, these differences were not statistically significant.

Conclusion

The maximum nutrient uptake and availability after harvest of rice was observed with the incorporation of green manuring @ 25 kg ha^{-1} + soil application of PSB @ 750 ml ha^{-1}. Use of higher dose of phosphatic fertilizers does not result in significant marginal increase in the nutrient uptake besides it results in increasing the cost of cultivation and creating adverse effects on other nutrients. Hence, it can be concluded that among the levels of phosphorus optimal uptake and availability of nutrients were observed with the 50% RDP.

Table 8: NPK availability (kg ha^{-1}) in soil after harvest of rice as influenced by phosphorus management during *kharif* 2016-17, 2017-18 and pooled data

Treatments	2016-17			2017-18			Pooled data		
	N	P	K	N	P	K	N	P	K
Source of phosphorus applied to rice									
M_1- Inorganic phosphorus	179.7	28.5	455.0	194.7	31.3	439.7	187.2	29.9	447.3
M_2- Green manuring	204.5	37.0	543.5	218.4	39.5	507.6	211.5	38.3	525.6
M_3- Soil application of PSB	190.9	34.6	498.9	205.3	35.8	472.4	198.1	35.2	485.7
M_4- Green manuring + PSB	210.4	38.3	548.4	227.0	40.5	514.2	218.7	39.4	531.3
SEm±	2.83	0.65	11.81	1.03	0.91	9.85	1.64	0.35	8.07
CD (p = 0.05)	9.8	2.2	40.8	3.5	3.1	34.0	5.6	1.2	27.9
CV (%)	4.3	6.6	6.9	5.5	7.4	6.1	4.9	7.0	4.9
Levels of phosphorus applied to rice									
S_1 - 50% RDP	192.1	33.9	500.2	209.3	35.7	468.2	200.7	34.8	484.2
S_2 - 100% RDP	197.7	34.7	512.5	211.9	36.9	490.1	204.8	35.8	501.3
S_3 - 150% RDP	199.3	35.2	521.6	212.9	37.6	492.3	206.1	36.4	507.0
SEm±	2.45	0.68	9.44	1.20	0.70	9.85	1.22	0.48	8.54
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	4.3	6.8	6.4	2.0	6.6	7.1	2.1	4.7	6.0
Interaction	NS	NS	NS	NS	NS	NS	NS	NS	NS

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