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Yield, grain quality and soil microbial activity as influenced by phosphorus management in rice (*Oryza sativa* L.) under acidic *Alfisols*

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ABSTRACT

Field experiment was carried out during 2018 and 2019 in a rice-green gram cropping system to study the effect of phosphorus (P) management in kharif rice under acidic Alfisols of Odisha, India. The experiment was conducted in split-plot design with three replications. Four main plots viz., P_1-100% of soil test dose (STD) for P as basal to rice, P_2- 100% of STD for P to both the crops, P_3-50 % of STD for P to rice and 100% of STD for P to green gram, P_4 -100% of STD for P to both the crops applied to green gram were allotted to the main plots and three rice varieties viz., V_1-Mandakini, V_2-Lalat and V_3- Pratikhya were considered in the sub plots. Application of 100% STD for P to both the crops (P_2) resulted in the highest grain and straw yield (3981 and 4715 kg ha^{-1}, respectively). Rice variety Pratikshya maturing in 145 days produced the highest grain and straw yields of 3808 and 4399 kg ha^{-1}, respectively. The grain quality parameters of rice like protein content (6.75 %), amylose content (20.36 %) and alkali value (4.60) were found highest in P_2 which was significantly different from other P management practices. Rice variety Pratikshya produced a better quality grain like protein (6.63 %), amylose (20.28 %) and alkali value (4.56). Significantly highest total chlorophyll content (4.61 mg g^{-1} fresh leaves) was also observed with P_2 among the P management practices and a value of 4.46 mg g^{-1} fresh leaves chlorophyll content was recorded in rice variety Pratikhya. Microbial biomass carbon increased up to 30 days after transplanting (DAT) and decreased thereafter up to 45 DAT irrespective of phosphorus doses and rice varieties. The soil dehydrogenase activity was increased due to application of different doses of phosphorus and rice variety irrespective of growth stages. P uptake by rice was estimated highest with P_2 (100% of STD for P to both the crops) and cv. Pratikhya responded better among the varieties.

Keywords*:* Rice, yield, grain quality, microbial activities, phosphorous uptake, *Alfisols*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops in India. Rice is also the principal crop of Odisha grown over an area of 4.4 million hectares and the average productivity of rice is low (2475 kg ha^{-1}) as compared to the national average of 2754 kg ha^{-1} due to various reasons such as cultivation of long duration varieties, lack of life saving irrigation, non-availability of good quality seeds, natural calamities, etc. (Panda *et al.,* 2009). As horizontal expansion of *kharif* rice area may not be possible under present scenario, the only way to enhance rice production is by vertical means through introduction of high yielding varieties and appropriate agronomic management practices. Phosphorus (P) is the second most important macronutrient and a major component of ATP that provides energy to the plant for such processes as photosynthesis, protein synthesis, nutrient translocation, nutrient uptake and respiration. Slow mobility of applied phosphorus and its marked fixation results in low crop recoveries in the order of 20-25% (Allipuram *et al.,* 2018). For optimum production of rice crop, judicious application of phosphorus is highly essential which underlines the significance of P management taking into consideration of native supplies and crop demands. Fertilizer P management in rice -wheat cropping systems is of particular significance because of distinct growing condition of rice and wheat that lead to alternative anaerobic and aerobic soil environment. In rice, submergence creates reducing condition of ferric phosphate to ferrous phosphate resulting in a greater availability of P in the soil. Again organic acids formed under submerged condition also solubilize phosphates (Sanyal *et al*., 2015). Within the crop, selection of promising nutrient efficient cultivars and its response towards nutrient management practices are two important factors governing crop productivity and grain quality. Crop

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cultivars respond differently to applied nutrients due to the differences in nutrient absorption, translocation, shoot demands and biomass production, owing to their diverse genetic and physiological mechanisms. Therefore, an attempt was made to study the effect of phosphorus management in rice-green gram cropping system on yield, grain quality, soil microbial activity and P uptake by *kharif* rice in acidic *Alfisols* of Odisha, India.

MATERIALS AND METHODS

The field experiment was conducted at farmers' field,Village Gajamara, Sadar Block of Dhenkanal district, Odisha, India during *kharif* 2018 and 2019. It comes under Mid Central Table Land Agro Ecological Zone of Odisha, India. The GPS location of the experimental site is 20^0 06' 18.37" N longitude and $85^0$59' 83.07"Elatitude. The initial soil sample collected before transplanting of rice from experimental plots were analysed by adopting standard methods (Panda, 2019). The texture of the soil was sandy loam (70.4% sand, 14.5% silt and 15.1% clay). The soil was acidic in reaction (pH 5.83), non-hazardous with electrical conductivity of 0.04 dSm^{-1}, medium in organic carbon (6.7 g kg^{-1}), low in available nitrogen (264 kg N ha^{-1}), phosphorus (11.7 kg P ha^{-1}) and potassium content (171.0 kg K ha^{-1}). The investigation was laid out in split-plot design with three replications and 12 treatments. The four main-plot treatments were P_1-100% of STD for P as basal to rice, P_2- 100% of STD for P to both the crops, P_3-50 % of STD for P to rice and 100% of STD for P to green gram, P_4-100% of STD for P of both the crops applied to green gram, whereas sub-plot treatments were three rice varieties viz., V_1-*Mandakini*, V_2-*Lalat* and V_3-*Pratikshya*. The recommended dose of fertilizers for the rice crop was 80-40-40 kg N-P_2O_5-K_2O ha^{-1}. The nitrogen was applied in three splits i.e., 25% basal, 50% at active tillering stage and 25% at panicle initiation (PI) stage. Phosphorus was applied as 100% basal in form of DAP as per the treatment scheduled. Potassium was applied in the form of muriate of potash (MOP) in two splits *i.e.*, 50% basal and 50% at PI stage. Rice seedlings of 25 days old were transplanted at a spacing of 25 cm x 10 cm in plots of 6 m x 3m size. Plant protection measures were taken as and when required. Mature grains were collected after harvest of the crop for grain yield and its quality analysis. Grain protein content was analysed using Folin Ciocalteau reagent and amylose content of milled rice was estimated by using colorimetric iodine assay method (Using UV-VIS Spectrophotometer) where as dilute KOH was used to estimate alkali value of milled rice grains (Sadasivam and Manickam, 2011). The soil microbial parameter like MBC was determined by fumigation extraction method (Vance *et al*., 1987) and dehydrogenase activity was determined by monitoring the production of triphenyl formazan (Tabatabai, 1982). The grains and straws after harvest were dried in hot air oven at 60ºC and grinded for analysis of phosphorous content (Panda, 2019). Phosphorous (P) uptake was calculated by multiplying the phosphorous content in grain and straw with the respective yields. The pooled data of two years on different parameters recorded was statistically analyzed to correlate the findings. The analysis of variance (ANOVA) of different variables of different treatments was statistically calculated at $p=0.05$ level of significance (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

Grain and Straw Yield

Data pertaining to grain yield, straw yield and the harvest index are presented in Table 1. The results indicated that among the P management practices, application of 100% STD of P to both the crops (P_2) recorded highest grain (3981 kg ha^{-1}) and straw (4715 kg ha^{-1}) yield, which was at par with P_1 (100% STD of P as basal to rice) with respect to grain yield, but was significantly different from all other P management practices such as P_3 (50% STD of P to rice and 100% STD of P to green gram) and P_4 (100% STD of P of both the crops applied to green gram). The lowest grain yield of 3439 kg $ha^{-1}$and straw yield of 3869 kg ha^{-1}were obtained due to application of 100% STD of P of both the crops to green gram (P_4) closely followed by P_3(50% STD of P to rice and 100% STD of P to green gram). This result was corroborated with the findings of Singh *et al.* 2018. Higher grain yield due to phosphorus application might be due to more availability as well as uptake of phosphorus by plant, which could provide a conducive situation for better utilisation of photosynthates. Availability of more phosphorus helps more root and shoot growth, which was attributed to increase grain yield of rice. However, rice cv. '*Pratikshya*' produced the highest grain yield of 3808 kg $ha^{-1}$and straw yield of 4399 kg ha^{-1}, which was at par with cv. *Lalat*, but was 8.4 and 6.0% higher than cv. *Mandakini*. Maximum harvest index of 47.0 % was recorded with P_4 (100% STD of P of both the crops applied to green gram), which was significantly different from all other P management practices. Increase in harvest index with phosphorus application indicates better translocation of photosynthates from source to sink (Singh *et al.,* 2018). However a non significant effect of varietal performance was recorded on harvest index that may be due to similarity in morphological aspects and vegetative growth among rice cultivars (Elkheir *et al.,* 2018).

Table 1: Effect of phosphorous management on yield, LAI and grain quality of *kharif* rice

Particulars	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	HI (%)	Total chlorophyll 45 DAT (mg g^{-1} fresh leaves)	LAI	Grain length (mm)	Kernel elongation (mm)	Protein (%)	Amylose (%)	Alkali value
P Management										
P_1	3811	4429	46.2	4.45	4.45	4.85	6.66	6.63	19.90	4.54
P_2	3981	4715	45.7	4.61	4.52	5.06	6.79	6.75	20.36	4.60
P_3	3465	4103	45.8	4.23	4.26	4.41	6.47	6.40	19.12	4.39
P_4	3439	3869	47.0	4.21	4.25	4.40	6.41	6.38	19.08	4.37
SEm±	60.2	66.2	0.25	0.016	0.012	0.008	0.01	0.007	0.064	0.008
LSD (p = 0.05)	198	204	0.8	0.05	0.04	0.03	0.03	0.02	0.20	0.02
Varieties										
Mandakini	3513	4151	45.9	4.28	4.30	4.60	6.50	6.40	18.90	4.40
Lalat	3701	4287	46.3	4.38	4.36	4.70	6.58	6.53	19.64	4.48
Pratikshya	3808	4399	46.4	4.46	4.46	4.79	6.69	6.63	20.28	4.56
SEm±	48.1	50.1	0.20	0.016	0.007	0.008	0.006	0.006	0.063	0.06
LSD (p = 0.05)	140	144	0.6	0.02	0.02	0.02	0.04	0.02	0.18	0.02

P_1-100% of STD for P as basal to rice, P_2- 100% of STD for P to both the crops, P_3-50 % of STD for P to rice and 100% of STD for P to green gram, P_4-100% of STD for P of both the crops applied to green gram

Photosynthetic Activity

The total chlorophyll content of rice leaves and LAI values are depicted in Table 1. Highest total chlorophyll content of 4.61 mg g^{-1} of fresh leaves was recorded at 45 days after transplanting (DAT) with P_2 (100% of STD for P to both the crops) which was at par with P_1 (100% of STD for P as basal to rice only). Lowest total chlorophyll content was recorded at P_4 (100% of STD for P of both the crops applied to green gram). This photosynthetic activity of rice leaf was increased up to 45 DAT in all the treatments, thereafter the content was decreased due to advancement of growth stages of rice. This result is associated with the utilization of nutrients in vegetative stage for production of photosynthetic pigment as well as total chlorophyll content but during reproductive stages nutrients are utilized for production of grain (Monica *et al.,* 2020b). Highest total chlorophyll content of 4.46 mg g^{-1} of fresh leaves was recorded with rice variety *Pratikshya* which was significantly different that of variety *Lalat* and *Mandakini*. Similar trend was also recorded to leaf area index (LAI) where highest value of 4.52 was recorded with P_2 (100% of STD for P to both the crops) and was significantly different from all other treatments. Among the rice varieties significantly highest LAI value of 4.46 was recorded with cv. *Pratikshya* followed by *Lalat* (4.38) and *Mandakini* (4.28).

Grain quality

Highest grain length of (5.06 mm) and kernel elongation (6.79 mm) was recorded at P_2 (100% of STD for P to both the crops) which significantly differed from all other treatments (Table 1). Highest grain length of (4.79 mm) and kernel elongation (6.69 mm) was recorded with rice variety *Pratikshya* which was significantly different that of variety *Lalat* and *Mandakini*. It was observed that protein content of grain varieed from 6.38 to 6.75 % with P management practices and highest was recorded at P_2 (100% of STD for P to both the crops). Among the rice varieties, cv. *Pratikshya* recorded highest protein content of 6.63 % which was significantly higher from other varieties. The increase in protein content of rice grain may be due to a synergistic effect of P management on N uptake and its translocation in grains (Monica *et al.,* 2020a). Similar observations were also found in case of amylose content in grains and it was found highest (20.36 %) with P_2 (100% of STD for P to both the crops) whereas lowest value (19.08 %) was recorded with P_4 (100% of STD for P of both the crops applied to green gram). Application of dilute KOH to rice grains degraded the starch molecules and the shape of the grain was changed to a dispersed grain which resulted in the alkali value of rice grain varied from 4.37 to 4.60 among P management practices and 4.4 to 4.56 in rice varieties.

Soil microbial activity

Microbial biomass carbon (MBC), one important soil health indicator increased with increase in crop growth irrespective of treatments up to 30 DAT thereafter it declined (Table 2). Among different P management practices, the rate of stimulation pertaining to MBC (mg g^{-1} soil) was highest at P_2 (100% of STD for P to both the crops) and it varied significantly from 144.2 to 177.6 mg g^{-1} of soil at different growth stages. The lowest MBC (mg g^{-1} soil) was noticed at P_4 (100% of STD for P of both the crops applied to green gram) which was at par with P_3 (50% STD of P to rice and 100% STD of P to green gram). Among different rice cultivars cv. *Pratikshya* responded better towards MBC up to 30 DAT compared to other two cultivars. Interestingly, a stimulatory response on dehydrogenase activity (DHA) was noticed with respect to different crop growth stages. Among different P management practices in *kharif* rice, DHA (mg TPF g^{-1} soil day^{-1}) was highest with P_2 (100% of STD for P to both the crops) which varied from 14.9 to 18.7 mg TPF g^{-1} soil day^{-1} at different growth stages. Among the rice cultivars cv. *Pratikshya* responded better towards DHA up to 30 DAT compared to other two cultivars. Stimulating effect of MBC and DHA with respect to *cv. Pratikshya* may be due to its better genetic and physiological characteristics over other two cultivars. This genetic and physiological variation leads to release of more root exudates and secondary plant metabolites near rhizospheric zone which accelerated microbial diversity. This result was in conformity with that of Purohit *et al*., 2019.

Table 2: Effect of phosphorous management on soil microbial activities at different growth stages and P uptake by *kharif* rice

Particulars	MBC (mg g^{-1} soil) DAT				DHA (mg TPF g^{-1} soil day^{-1}) DAT				P uptake (kg ha^{-1})		
	0	15	30	45	0	15	30	45	Grain	Straw	Total
P Management											
P_1	143.1	157.2	173.9	152.8	14.7	16.6	17.7	16.7	14.1	10.2	24.3
P_2	144.2	159.5	177.6	156.4	14.9	17.7	18.7	17.6	15.6	11.6	27.2
P_3	141.5	152.3	169.2	147.2	13.7	15.1	16.2	15.2	9.8	6.9	16.4
P_4	141.5	152.0	169.0	147.0	13.6	14.9	15.9	15.0	9.6	6.8	16.5
SEm±	0.096	0.80	0.13	0.11	0.068	0.05	0.053	0.05	0.38	0.31	0.53
LSD (p = 0.05)	0.30	0.25	0.39	0.34	0.21	0.15	0.16	0.15	1.18	0.94	1.6
Varieties											
Mandakini	141.5	153.8	171.3	149.5	14.0	15.8	16.9	15.9	10.0	7.5	17.6
Lalat	142.6	155.3	172.5	150.9	14.2	16.2	17.2	16.2	12.5	9.0	21.4
Pratikshya	143.6	156.7	173.5	152.2	14.4	16.4	17.4	16.4	14.3	10.0	24.3
SEm±	0.064	0.103	0.89	0.73	0.049	0.053	0.04	0.046	0.21	0.23	0.34
LSD (p = 0.05)	0.18	0.30	0.25	0.21	0.14	0.15	0.12	0.13	0.63	0.65	1.0

P uptake

Result pertaining to P uptake of rice crop as affected by the different phosphorous management practices and varieties are presented in Table 2. Application of 100% STD for P to both the crops (P_2) resulted in highest P uptake in grain (15.6 kg ha^{-1}) and straw (11.6 kg ha^{-1}) with a total P uptake of 27.2 kg ha^{-1}, whereas the lowest total P uptake (16.4 kg ha^{-1}) was estimated with P_3 (50% STD of P to rice and 100% STD of P to green gram). However, this response of rice to P uptake was at par to that of P_4 (100% of STD for P of both the crops applied to green gram). When 100% STD for P was applied to both the crops in a rice-green gram cropping system, uptake of total P in *kharif* rice was the highest (Allipuram *et al.* 2018). Total P uptake of 24.3 kg ha^{-1} was recorded as maximum with rice cv. *Pratikshya*, being significantly different from the other two that might be due to their diverse genetic and physiological characteristics. Lowest P uptake of 17.6 kg ha^{-1} was recorded with cv *Mandakini*.

From the present study it may be concluded that application of 100% STD of P to both the crops (P_2) resulted in the highest grain and straw yield of rice. Other parameters like total chlorophyll content, LAI and different cooking quality parameters like grain length, kernel elongation, protein content, amylase content and alkali value were recorded highest at P_2 (100% STD for P to both the crops). Among the rice cultivars, *cv. Pratikshya* responded better to P management (P_2) with respect to yield, P uptake and other cooking quality parameters. Interestingly, the soil microbial activities like MBC and DHA were recorded better with respect to P management practices (100% STD of P to both the crops) and rice *cv. Pratikshya.*

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