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INTEGRATED NUTRIENT MANAGEMENT IN RICE (*Oryza sativa* L.) UNDER WATERLOGGED CONDITION

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ABSTRACT

Present investigation was conducted during the *kharif* seasons of 2020 and 2021 at new alluvial zone of West Bengal to evaluate the effect of integrated application of NPK, Zn and biofertilizer on the changes in P content and P uptake and yield under water logged soil in relation to rice in an inceptisol using rice cultivar IET-4786 as a test crop with six different treatment combinations in a randomised block design (RBD) replicated four times. For this purpose integrated application of NPK, Zn, organic matter and PSB was done with different doses in different treatments. The amount of P content in rice biomass was recorded highest (9.32 g kg^{-1}) at 45 days of crop growth in the treatment T_3 [50% NPK Recommended+ FYM @ 5 t ha^{-1} + Zn at 5 kg ha^{-1}+ PSB (@ 10 kg ha^{-1}]. Grain P content was recorded highest in same treatment where as straw P content was found highest in treatment T_4 [50% NPK Recommended + FYM @10 t ha^{-1} + PSB(@10kg ha^{-1})]. The results showed that the amount of P content in rice without husk and boiled rice during both the years were recorded highest in T_4 [50% NPK Recommended + FYM @ 10 t ha^{-1} + PSB(@10kg ha^{-1})] and T_3 [50% NPK Recommended + FYM @ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@10kg ha^{-1})] treatments respectively. From the present study it was found that the amount of P uptake by rice grain and straw during both the years (2020-2021) have been found to be increased with different treatments over control, being highest pooled uptake of P by rice grain (61.17 kg ha^{-1}) and straw (35.05 kg ha^{-1}) in the treatment T_3 [50% NPK Recommended + FYM @ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@10kg ha^{-1})] and T_5 [50% NPK Recommended + FYM @ 10 t ha^{-1} + Zn at 5 kg ha^{-1} +PSB (@10kg ha^{-1})] respectively. Treatment T_3 was found the best treatment as it produced the highest yield of grain and straw.

(Key words: Phosphorus content, phosphorus uptake, rice biomass, grain, straw, yield)

INTRODUCTION

Rice is the premier food grain crops of the India. There has been a phenomenal increase in their production after mid-sixties with the introduction of high yielding varieties. Due to inadequate and imbalanced fertilizer application, farmers are not able to harness the full yield potential of rice crop. The organic matters being the storehouses of nutrients, combined application of organic and inorganic fertilizer can increase the yield, improve the fertility status of soil, improve the input-use efficiency by the crop and can certainly cut down the expenditure on costly fertilizers (Laxminarayana and Patiram, 2006). Soil organic matter plays a significant role for regulating energy and nutrients for soil organisms. It has effect in stabilizing enzyme activities and making available nutrients for plant growth through mineralization (Bhakare *et al.,*2018). The balance fertilization through integrated use of manure, fertilizer and biofertilizer along with micronutrients has been found useful in rice crop. Use of organic manure, green manuring, green leaf manuring, crop residues along with inorganic fertilizers not only reduces the demand for inorganic fertilizers, but also increases the efficiency of applied nutrients due to their favorable effect on physical, chemical and biological properties of soil (Meshram *et al.,*2018). Nutrient management in rice under submerged condition is a difficult practice. Phosphorus (P) is the second most important macro-nutrient reported to be a critical factor of many crop production systems, due to its limited availability in soluble forms (Xiao *et al.,* 2011). It reacts with oxides/ hydroxides to form stable forms that may not be available to plants, resulting low recovery and accumulation in soils (Halajnia *et al.,* 2009). In the form of phosphate fertilizers, phosphorus are added to the soil, a significant part of the phosphatic fertilizer is lost through different mechanisms, of which both chemical and biological transformations into insoluble and unavailable forms play an important role. In order to maximize the fertilizer P use efficiency and to know the mechanism of P solubility and insolubility, P transformation study is must. Integrated nutrient management in wetland rice is a needed strategy involving

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conjunctive use of chemical fertilizers and bio-organic sources for realization of potential yield on sustained basis. Farmyard manure or compost and use of phosphate solubilizing bacteria in wetland rice are the common practices. Organic matter content through its microbial decomposed products influences the availability of P content in soil (Sarir *et al.,* 2006). INM is a holistic approach that helps in minimizing the use of chemicals by maximum utilization of biological inputs. INM is a feasible option for maintaining a higher level of soil fertility and productivity. The use of organic manures with optimum doses of fertilizers under intensive farming system increases the turn of nutrient in soil plant system (Jadhav *et al.,* 2018). Biofertilzers help in improving soil fertility by the way of accelerating biological nitrogen fixation from atmosphere solubilization of the insoluble nutrients in soil, generate little quantity of PGRs decomposing plant residues and stimulate plant growth and production. The inoculation of bio-fertilizers increases the yield of crops by 10 to 30 per cent (Mahala *et al.,* 2019). Phosphate Solubilising Bacteria (PSB) are a group of beneficial bacteria capable of hydrolyzing organic and inorganic phosphorus from insoluble compounds. The metabolic activities of microorganisms solubilize phosphate from insoluble calcium, iron and aluminium phosphates (Bhoyar *et al.,* 2018). Among nutrient deficiencies, Zn deficiency has been identified as a most serious agricultural issue in world which is a well known nutritional and health problem in human populations where rice is the dominating staple food. Zinc is involved in growth, enzyme activation, metabolism of carbohydrate, lipids, nucleic acids, gene expression, regulation, protein synthesis and reproductive development of plants (Jondhale *et al*., 2021). Phosphorus and Zinc shows antagonism (Kamath and Sarkar, 1990) and their interaction may take place in the soil as well as in the plant. But in zinc deficient soil it shows synergistic relation with P. With an increasing demand of food and the introduction of high yielding crop varieties, the dependence on the use of high analysis chemical fertilizers are increasing day-by-day. It is also evident that the soil fertility and soil quality especially the soil organic matter content are declining continually overtime due to imbalance fertilizer use and little or no use of farm inputs (organic manures). Use of organic manure in various cropping sequence is pre-requisite to maintain the productivity of crops, but use of only organic manure cannot provide food forever growing population. Rice is the most important staple food in the South-East Asian countries which mostly grown under waterlogged puddle condition resulting in release in available P which may be further increased when the soil is being treated FYM and phosphate solubilizing bacteria (PSB). With these in view, the present research programme was undertaken.

MATERIALS AND METHODS

An experiment was conducted during the *kharif* seasons of 2020 and 2021 at new alluvial zone of West Bengal to evaluate the effect of integrated nutrient management on the yield and nutrition of rice in an inceptisol using rice cultivar IET-4786 as a test crop with six different treatment combinations in a randomized block design (RBD) replicated four times. The physico-chemical properties of the experimental field soil were: pH 6.46, EC: 0.05 dSm^{-1}; Organic Carbon: 0.65%; CEC: 15.76 mol (p+) kg^{-1}; Available N: 250.88 mg kg^{-1}; Available P: 15.33 mg kg^{-1}; Available K: 290.08 mg kg^{-1}; Available Zn: 0.55 mg kg^{-1}. Well rotten farm yard manure containing: Total N– 0.61%, Total P–0.19%, Total K–0.25%, Total Zn– 0.009%.

Treatment details:

T_0 – Control, Recommended NPK (60:30:30)

T_1 – NPK Recommended +Zn at 5 kg ha^{-1}

T_2- 75% NPK Recommended + FYM @ 2.5 t ha^{-1}+Zn at 5 kg ha^{-1}+ PSB (@10 kg ha^{-1})

T_3- 50% NPK Recommended + FYM @ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@10 kg ha^{-1})

T_4- 50% NPK Recommended + FYM@10 t ha^{-1} + PSB (@10 kg ha^{-1})

T_5- 50% NPK Recommended + FYM@10 t ha^{-1} + Zn at 5 kg ha^{-1} +PSB (@10 kg ha^{-1})

Half of the recommended dose of nitrogen [Urea (46% N)] and full dose of potassium [K_2O – Muriate of potash (60% K_2O)] and phosphorus [P_2O_5 – Single super phosphate (16% P_2O_5)] were applied as basal application and remaining half nitrogen was applied in two equal splits at active tillering and panicle initiation stages uniformly to all the treatments. Organic matter was applied basally as per treatments and PSB [*Bacillus polymyxa*] was applied at the rate of 10 kg ha^{-1} at the time of transplanting. Zn [$ZnSO_4$ (21% Zn)] fertilizer was applied after 7 days of transplanting. Samples were collected periodically and analyzed spectrophotometrically by following the vanadomolybdate yellow colour method after oven drying and subsequent digesting plant samples (Jackson, 1973). Phosphorus uptake (kg ha^{-1}) was calculated by multiplying the P contents (%) in plant part (dry matter) with yield (kg ha^{-1}) and then divided by 100.

RESULTS AND DISCUSSION

The pooled results (Table1) showed that the amount of P content in rice biomass has been found to be initially increased up to 45 days of crop growth and thereafter, the amount of the same decreased at the later period of crop growth irrespective of treatments. Such initial increase and decrease at the later period might be attributed to the greater release of soluble P caused by the applied organic matter as well as phosphate solubilising bacteria and also to dilution effect resulting from maximum rice biomass production respectively. From the pooled data, it was found that treatment T_3 [50% NPK Recommended + FYM @ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@10 kg ha^{-1})] resulted significantly higher mean of P content in rice biomass than all other treatments. The second best treatment was T_5 [50% NPK Recommended + FYM @ 10 t ha^{-1} + Zn at 5 kg ha^{-1} +PSB (@10 kg ha^{-1})] though its mean value was significantly less than treatment T_3 but significantly higher than treatments T_4, T_2, T_1 and T_0. The least mean value was observed due to treatment T_0 [Control, Recommended NPK (60:30:30)] which was significantly less than all other treatments. The amount of P content in rice biomass was also recorded highest (9.32 g kg^{-1}) at 45 days of crop growth in the treatment T_3. However, the following trend was found i.e. $T_3 > T_5 > T_2 > T_4 > T_1 > T_0$. Imayavaramban *et al.* (2004) reported similarly in which application of FYM at 12.5 t ha^{-1} green manure at 6.25 t ha^{-1} and 100% of the recommended N, P_2O_5 and K_2O resulted in the highest values of growth parameters such as plant height at harvest, number of tillers and dry matter production.

The pooled results (Table 2) showed that the amount of P content in both grain and straw have been found to be varied with treatments, being highest content in grain was recorded in the treatment T_3 [T_3 = 50% NPK Recommended + FYM@ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@ 10 kg ha^{-1})] while the same content in straw was recorded highest in the treatment T_4 [50% NPK Recommended + FYM@ 10 t ha^{-1} + PSB (@10 kg ha^{-1})] with the per cent increase in P content over control in grain and straw was 29.51 and 17.65 respectively. The organic amendments are the vital sources to sustain the microbial activity and to improve the physical constituents of the soil while they can partly substitute requirement of N, P and K fertilizers. Soil physical properties are important for favorable conditions of crop growth and to maintain soil quality (Raj and Vasanthi, 2019).

The pooled results (Table 2) showed that the amount of P content in rice without husk and boiled rice during both the years were recorded highest in treatment T_4 [50% NPK Recommended + FYM@ 10 t ha^{-1} + PSB(@10 kg ha^{-1})] and treatment T_3 [50% NPK Recommended + FYM@ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@10 kg ha^{-1})] respectively. The results further revealed that the increase of P content over control in rice without husk and boiled rice was recorded as 16.88 and 35.71 respectively. Though the pooled result showed that treatment T_3 was the best but in case of rice without husk treatment T_4 was best, this might be due to the fact that the rice yield is determined by four components including number of panicles $unit^{-1}$ area, spikelet number $panicle^{-1}$, seed setting rate and grain weight. It might also be due to more uptake of P than others. This is due to the fact that the relationship between P and organic matter was found synergistic which releases insoluble P in the soil solution resulting from the solubilizing action of organic acids during decomposition of organic matter.

The pooled results (Table 3) showed that the amount of P uptake by rice grain and straw have been found to be increased with different treatments over control, being highest pooled uptake of P by rice grain (61.17 kg ha^{-1}) and straw (35.05 kg ha^{-1}) in the treatments T_3 [50% NPK Recommended + FYM @ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@10 kg ha^{-1})] and T_5 [50% NPK Recommended + FYM@ 10 t ha^{-1} + Zn at 5 kg ha^{-1} +PSB (@10 kg ha^{-1})] respectively. However, the pooled uptake of P by rice grain and straw was found in the following order: P uptake by grain: $T_3 > T_2 > T_1 > T_4 > T_5 > T_0$. P uptake by straw: $T_5 > T_4 > T_3 > T_2 > T_1 > T_0$. Due to water logging in rice field there might be release of phosphorus more. The solubilizing action of organic acids produced during decomposition of organic manures or green manure might have increased the release of native P, stimulated microbial growth in soil, and favoured root growth which had finally led to increased P uptake by rice. (Meshram *et al.,*2018). Thakur *et al.* (2011) also recorded higher P uptake due to combined application of inorganic fertilizers with organic manure (FYM) under soybean-wheat cropping sequence in a Vertisol. Sharma *et al.* (2013) also confirms the results of the present study, who reported that the maximum P and Zn content and uptake by crops where the combined application of NPK + 5 kg Zn ha^{-1} + PSB + *Azotobacter* was applied. The results of the present study also find support from the results reported by Dadlich and Somani (2007) that the combined application of P, FYM and biofertilizers (PSB and VAM) significantly increased the P content and uptake by rice grain and straw.

The pooled data showed that (Table 3) the yields of both rice grain and straw were found to be increased with different treatment combinations. The amount of such increase in grain and straw yields have been recorded to be highest 7.77 (20.65% over control) and 9.45 t ha^{-1} (14.82% over control) respectively in the treatment T_3 where 50% NPK as recommended + FYM @ 5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB at 10 kg ha^{-1} was applied. Pandey *et al.* (2016) also reported that the combined application of biofertilizer (Phosphate Solubilizing Bacteria) through seed inoculation and inorganic fertilizers including 20 kg ha^{-1} of S substantially increased the yield of rice. Yaduvanshi (2003) also reported that the application of NPK and its combination with green manure and FYM increased the rice yield significantly. Dadlich and Somani (2007) reported that the application of increasing level of P, FYM and biofertilizers significantly enhanced the yield of crops. Yashona *et al.*(2018) also stated that the combined mode of zinc application involving soil zinc along with organic manures and foliar applications proved more beneficial among any sole mode of application with respect to increment in plant growth, yield and produce quality.

Relationships among different P content, grain and straw yield

From the present study it was found that phosphorus content in rice biomass showed the highly significant positive correlations with grain and straw yield of rice irrespective of days. P uptake in grain and straw also showed the significant positive correlations with grain and straw yield of rice but P content in rice without husk showed the non-significant negative correlations with both the grain and straw yield. P content in boiled rice highly positively correlated with grain and straw yield.

Results of multiple stepwise linear regression analyses of P content on grain and straw yield

Grain yield = 3.38 + 0.21 P_75** + 0.23 P_15** + 0.18 P_60* ….Eq (i)

R^2 = 0.96, Adj R^2 = 0.92, SE(est) = 0.14

From Eq. (i), it was found that phosphorus in rice biomass at 15 days and 75 days enhanced the grain yield and both were the highly and positively significant predictors to explain the grain yield at 1% level of significance. Again P in rice biomass at 60 days also enhanced the grain yield and also positively significant predictor to explain grain yield at 5% level of significance. This equation can explain 96% of total variability of grain yield.

Straw yield = 5.58 + 0.37 P_15** + 0.21 P_75** …..Eq. (ii)

R^2 = 0.91, Adj R^2 = 0.82, SE(est) = 0.19

Again, from Eq.(ii), it was found that Phosphorus in rice biomass at 15 days and 75 days enhanced the straw yield and both were the highly and positively significant predictors to explain the straw yield at 1% level of significance. This equation can explain 91% of total variability of straw yield.

From the above investigation, it can be concluded that application of NPK, Zn, organic matter and PSB proved effective in significantly enhanced the P content in rice biomass, grain and straw as well as this treatments helped to uptake of P in grain and straw and increased the yield of rice. It is stated from the present study that P content was found lesser in boiled rice. The enhanced microbial activity through P solubilizing inoculants may contribute considerably in plant P uptake. PSBs mainly *Bacillus polymyxa* proved very effective for increasing plant available P in soil as well as the growth and yield of various crop plants. Integrated nutrient management as well as organic manure applied generally improved soil heath and availability of NPK after harvest. It is clear from the results that application of 50% NPK Recommended + FYM@5 t ha^{-1} + Zn at 5 kg ha^{-1} + PSB (@10 kg ha^{-1} can produced more yields of rice by the farmers.

Table 1. Amount of phosphorus content (g kg^{-1}) in rice biomass (pooled mean of 2020-2021)

Treatments	Days after transplanting (mean values of 4 replications)					% over control
	15 days	30 days	45 days	60 days	75 days	
T0	4.53	5.10	5.87	5.27	5.16	
T1	4.95	5.57	6.83	5.83	5.21	9.44
T2	5.19	6.38	8.05	6.53	6.30	25.05
T3	6.21	7.47	9.32	7.75	7.53	47.59
T4	5.00	6.21	7.57	6.90	6.46	23.89
T5	5.41	6.56	8.00	7.27	7.08	32.18
SE (m)±	0.137	0.052	0.005	0.006	0.002	
C D (P=0.05)	0.411	0.157	0.015	0.018	0.006	

Table 2. Amount of phosphorus content (%) in rice grain, straw, rice without husk and boiled rice after harvesting of *kharif* rice growing under waterlogged condition (Pooled mean of 2020-2021)

Treatments	Grain P content (%)		Straw P content (%)		P content in rice without husk (%)		P content in boiled rice (%)	
	Pooled	% over control	Pooled	% over control	Pooled	% over control	Pooled	% over control
T0	0.61		0.34		0.77		0.56	
T1	0.69	13.11	0.37	8.82	0.76	-1.30	0.64	14.29
T2	0.76	24.59	0.38	11.76	0.88	14.29	0.71	26.79
T3	0.79	29.51	0.36	5.88	0.73	-5.19	0.76	35.71
T4	0.62	1.64	0.40	17.65	0.90	16.88	0.65	16.07
T5	0.61	0	0.38	11.76	0.66	-14.28	0.64	14.29
SE (m)±	0.007	0.00	0.004		0.006		0.010	
C.D (P=0.05)	0.022		0.012		0.018		0.030	

Table 3. Amount of phosphorus uptake (kg ha^{-1}) in rice grain and straw, grain and straw yield of rice (t ha^{-1}) (Pooled mean of 2020-2021)

Treatments	P uptake in grain (kg ha^{-1})		P uptake in straw (kg ha^{-1})		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	Pooled	% over control	Pooled	% over control	Pooled	% over control	Pooled	% over control
T0	38.96		27.98		6.44		8.23	
T1	46.50	19.35	31.64	13.08	6.72	4.35	8.67	5.35
T2	53.00	36.04	33.68	20.37	6.99	8.54	8.86	7.65
T3	61.17	57.01	33.77	20.69	7.77	20.65	9.45	14.82
T4	44.18	13.40	34.74	24.16	7.14	10.87	8.79	6.80
T5	40.61	4.24	35.05	25.27	7.48	16.15	9.19	11.66
SE(m)±	2.303		0.439		0.083		0.148	
C D (P=0.05)	6.909		1.317		0.249		0.444	

Table 4. Correlation coefficients (r) between different P content with grain and straw yield

	Straw yield	Grain yield		Straw yield	Grain yield
P at 15 days	0.864**	.852**	P uptake in straw	0.791**	0.791**
P at 30 days	0.851**	.897**	P content in rice without husk	-0.349	-0.319
P at 45days	0.860**	.883**	P content in boiled rice	0.829**	0.763**
P at 60 days	0.849**	.929**	Grain P content	0.521**	0.402
P at 75days	0.850**	.931**	Straw P content	0.328	0.344
P uptake in grain	0.656**	0.580**			

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