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EFFECT OF PHOSPHORUS AND POTASSIUM ON YIELD AND NUTRIENT UPTAKE OF RICE UNDER IPNS IN AN INCEPTISOL OF ASSAM

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ABSTRACT

*A soil test crop response based field experiment was conducted in an Inceptisols (Aeric Endoaquepts) of Assam during Kharif season of 2011 following Ramamoorthy's Inductive-cum-targeted yield model to explicate the relationship between soil tests and response of winter rice to applied fertilizers under integrated plant nutrition system (IPNS). The nutrient requirement for producing one quintal of rice grain on an average was 1.75, 0.65 and 1.83 kg N, P and K, respectively. The results also indicated that integrated application of chemical fertilizers and FYM increased the grain and straw yield, and N, P and K uptake in rice as well as enhanced organic-C and available N, P and K in soil. Omission of nutrients caused yield loss between 18% (- P) and 15.3 % (- K) and uptake decreased by 44.0 and 28.9 %, respectively. Conversely, plots receiving P and K fertilizers alone could significantly increase grain yield by 4.7% and 10.2%, respectively over control. The P and K uptake were increased by 36.9 and 33.2 % respectively, over control due to individual addition of P and K with respective apparent recovery of 6.1 and 14.2 %. Apparent recovery increased by 21.3 and 74.9% for P and K, respectively with application of NPK together. Uptake of all the nutrients was significantly correlated with yield (r= 0.935**, 0.825** and 0.326** for N, P and K, respectively), suggesting interdependence of nutrient uptake that influenced yield. Build up of organic-C and available NPK was more pronounced in chemical fertilizer treated plots.*

Key words: Phosphorus, potassium, winter rice, soil test crop response, IPNS, nutrient uptake

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food grain in India contributing 41.5% to the total food grain production. *Sali* or winter rice is the dominant crop of Assam covering 17.73 lakh hectares out of the total rice area of 24.84 lakh hectare with a productivity of 1674 kg ha^{-1} as against the national average of 2240 kg ha^{-1}. Phosphorus (P) and potassium (K) along with N are essential macronutrients that must often be applied to maintain the productivity of cropped soils and prevent deficiencies of these nutrients from limiting crop yields. Deficiencies of P and K are sporadically but frequently observed in rice fields in Assam. Generally, rice grown on acid soils is susceptible to P-deficiency and shows symptoms during the seedling to maximum tillering stages. In contrast, K-deficiency symptoms typically appear during the seedling and boot stage. Potassium deficiency in rice has been documented on soils with a wide range of chemical properties in Assam, while deficiencies are most common on soils with pH <5.0 that have low soil K concentrations. Although P and K deficiencies of rice occur every year, they are relatively uncommon and research studies have seldom shown significant rice yield increase from P and K fertilization. Inceptisols occupy about 49.3% of the total area of Assam and are mostly acidic in reaction and contain high amounts of Fe and Al oxides and hydroxides. Fixation of applied P by such oxides and hydroxides is a common problem that hinders uptake of P by crops. Awareness about appropriate P and K application rates for rice in such soils among the farmers is critical to improve productivity. One of the reasons for lower productivity of rice in the state is the imbalanced fertilization of N, P and K nutrients. High cost of fertilizers is remaining constraint for the farmers to apply adequate amount of fertilizers to crop. Accurate fertilizer recommendations require fertilization trials to be conducted routinely to account for changes in production systems, cultivars, crop-nutrient removal due to increasing crop yields, and changes in soil fertility. Soil test based application of plant nutrient helps to realize higher response ratio and benefit: cost ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and the correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization (Rao and Srivastava, 2000). In Assam, works on soil test crop response correlation under integrated plant nutrition system (STCR-IPNS) has not yet been initiated. Hence an effort was made to study the influence of integrated nutrient management on rice yield and tissue concentration of P and K in response to fertilizers application under IPNS in STCR experiment on acidic Inceptisols of Assam.

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MATERIALS AND METHODS

A field experiment based on STCR methodology with rice variety Ranjit was conducted at the Assam Agricultural University Experimental Farm, Jorhat located at a latitude of 26°48′N and longitude of 95°50′E during Kharif 2011 in Inceptisols (Aeric Endoaquepts). The soil of the experimental field was sandy clay loam with pH 5.1 and organic carbon 6.0 g kg^{-1}. The amount of available N, P_2O_5 and K_2O were 213, 15 and 90 kg ha^{-1}, respectively. The STCR-test crop experiment (Ramamoorthy *et al.*1967) composed of four gradient strips and four blocks which were fertilized with $N_0P_0K_0$, $N_{1/2}P_{1/2}K_{1/2}$, $N_1P_1K_1$ and $N_2P_2K_2$ levels. The recommended fertilizers ($N_1P_1K_1$) were 60, 20 and 40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Each strip was divided into 24 treatments. Out of which 20 treatments constituted combinations of 5 levels of N (0, 30, 60, 90, 120 kg ha^{-1}), 4 levels of P_2O_5 (0, 30, 60, 90 kg ha^{-1}) and 3 levels of K_2O (0, 60, 120 kg ha^{-1}). Four controls were superimposed to different plots in each strip in a factorial randomized block design (Table 1). As per the treatments N, P and K nutrients were applied through urea, SSP and MOP, respectively. Four levels of FYM (0, 2.5, 5.0 and 10.0 t ha^{-1}) were also included in this study. Rice variety Ranjit was cultivated as a test crop as per the recommended cultural practices. Pre-sowing and post harvest soil samples were collected from each plot and were analysed for organic carbon available N, P and K following standard methods (Jackson, 1973). The plant samples collected at harvest were analysed for NPK contents and computed their respective uptake of nutrients in rice. Grain yield from different treatments, from each strip and from each block was also recorded. At maximum tillering whole plant sample (hill) with roots were collected and used for analysis of various parameters. Management of rice with respect to stand establishment, pest control and other practices closely followed Assam Agricultural University guidelines for transplanted rice production. The effects P and K on crop yield, nutrient uptake, soil organic carbon and available nutrients were evaluated. Apparent recovery also known as fertilizer use efficiency was computed by using the formula (Pillai and Varmadevan 1978).

Table 1: Treatment details for test crop experiment

Strip I	Strip II	Strip III	Strip IV
$N_0\ P_0\ K_0\ OM_0$	$N_0\ P_0\ K_0\ OM_0$	$N_0\ P_0\ K_0\ OM_0$	$N_0\ P_0\ K_0\ OM_0$
$N_0\ P_0\ K_0\ OM_1$	$N_0\ P_0\ K_0\ OM_1$	$N_0\ P_0\ K_0\ OM_1$	$N_0\ P_0\ K_0\ OM_1$
$N_0\ P_0\ K_0\ OM_2$	$N_0\ P_0\ K_0\ OM_2$	$N_0\ P_0\ K_0\ OM_2$	$N_0\ P_0\ K_0\ OM_2$
$N_0\ P_0\ K_0\ OM_3$	$N_0\ P_0\ K_0\ OM_3$	$N_0\ P_0\ K_0\ OM_3$	$N_0\ P_0\ K_0\ OM_3$
$N_0\ P_0\ K_2\ OM_1$	$N_0\ P_0\ K_2\ OM_2$	$N_0\ P_0\ K_2\ OM_3$	$N_0\ P_0\ K_2\ OM_0$
$N_0\ P_3\ K_0\ OM_3$	$N_0\ P_3\ K_0\ OM_0$	$N_0\ P_3\ K_0\ OM_1$	$N_0\ P_3\ K_0\ OM_2$
$N_1\ P_1\ K_0\ OM_3$	$N_1\ P_1\ K_0\ OM_0$	$N_1\ P_1\ K_0\ OM_1$	$N_1\ P_1\ K_0\ OM_2$
$N_1\ P_1\ K_1\ OM_3$	$N_1\ P_1\ K_1\ OM_0$	$N_1\ P_1\ K_1\ OM_1$	$N_1\ P_1\ K_1\ OM_2$
$N_2\ P_0\ K_1\ OM_3$	$N_2\ P_0\ K_1\ OM_0$	$N_2\ P_0\ K_1\ OM_1$	$N_2\ P_0\ K_1\ OM_2$
$N_2\ P_1\ K_0\ OM_2$	$N_2\ P_1\ K_0\ OM_3$	$N_2\ P_1\ K_0\ OM_0$	$N_2\ P_1\ K_0\ OM_1$
$N_2\ P_1\ K_1\ OM_2$	$N_2\ P_1\ K_1\ OM_3$	$N_2\ P_1\ K_1\ OM_0$	$N_2\ P_1\ K_1\ OM_1$
$N_2\ P_2\ K_0\ OM_2$	$N_2\ P_2\ K_0\ OM_3$	$N_2\ P_2\ K_0\ OM_0$	$N_2\ P_2\ K_0\ OM_1$
$N_2\ P_2\ K_1\ OM_2$	$N_2\ P_2\ K_1\ OM_3$	$N_2\ P_2\ K_1\ OM_0$	$N_2\ P_2\ K_1\ OM_1$
$N_2\ P_2\ K_2\ OM_2$	$N_2\ P_2\ K_2\ OM_3$	$N_2\ P_2\ K_2\ OM_0$	$N_2\ P_2\ K_2\ OM_1$
$N_3\ P_1\ K_1\ OM_1$	$N_3\ P_1\ K_1\ OM_2$	$N_3\ P_1\ K_1\ OM_3$	$N_3\ P_1\ K_1\ OM_0$
$N_3\ P_2\ K_2\ OM_1$	$N_3\ P_2\ K_2\ OM_2$	$N_3\ P_2\ K_2\ OM_3$	$N_3\ P_2\ K_2\ OM_0$
$N_3\ P_3\ K_0\ OM_1$	$N_3\ P_3\ K_0\ OM_2$	$N_3\ P_3\ K_0\ OM_3$	$N_3\ P_3\ K_0\ OM_0$
$N_3\ P_3\ K_1\ OM_1$	$N_3\ P_3\ K_1\ OM_5$	$N_3\ P_3\ K_1\ OM_3$	$N_3\ P_3\ K_1\ OM_0$
$N_3\ P_3\ K_2\ OM_0$	$N_3\ P_3\ K_2\ OM_1$	$N_3\ P_3\ K_2\ OM_2$	$N_3\ P_3\ K_2\ OM_3$
$N_4\ P_2\ K_1\ OM_0$	$N_4\ P_2\ K_1\ OM_1$	$N_4\ P_2\ K_1\ OM_2$	$N_4\ P_2\ K_1\ OM_3$
$N_4\ P_2\ K_2\ OM_0$	$N_4\ P_2\ K_2\ OM_1$	$N_4\ P_2\ K_2\ OM_2$	$N_4\ P_2\ K_2\ OM_3$
$N_4\ P_3\ K_1\ OM_0$	$N_4\ P_3\ K_1\ OM_1$	$N_4\ P_3\ K_1\ OM_2$	$N_4\ P_3\ K_1\ OM_3$
$N_4\ P_3\ K_2\ OM_0$	$N_4\ P_3\ K_2\ OM_1$	$N_4\ P_3\ K_2\ OM_2$	$N_4\ P_3\ K_2\ OM_3$
$N_4\ P_0\ K_0\ OM_3$	$N_4\ P_0\ K_0\ OM_0$	$N_4\ P_0\ K_0\ OM_1$	$N_4\ P_0\ K_0\ OM_2$

Where,

N_0 = 0 kg ha^{-1}	P_0 = 0 kg ha^{-1}	K_0 = 0 kg ha^{-1}	FYM (OM_0) = 0.0 t ha^{-1}
N_1 = 30 kg ha^{-1}	P_1 = 30 kg ha^{-1}	K_1 = 60 kg ha^{-1}	FYM (OM_1) = 2.5 t ha^{-1}
N_2 = 60 kg ha^{-1}	P_2 = 60 kg ha^{-1}	K_2 = 120 kg ha^{-1}	FYM (OM_2) = 5.0 t ha^{-1}
N_3 = 90 kg ha^{-1}	P_3 = 90 kg ha^{-1}		FYM (OM_3) = 10.0 t ha^{-1}
N_4 = 120 kg ha^{-1}			

RESULTS AND DISCUSSION

Crop trials were conducted with the basic assumption that fertilizer recommendations typically depend on crop response experiments in which spatial variability has been minimized for every independent variable affecting crop yield except for the nutrient in question, although many non-fertility variables *viz.* WHC, bulk density, soil erosion and other fertility variables significantly impact crop yield (Kastens *et al.* 2003).

Soil characteristics

In general, the soil of the experimental field was sandy clay in texture with pH 5.10, organic carbon 0.60%, CEC 7.8 cmol (p^+) kg^{-1}, available N 213.25 kg ha^{-1}, available P 15.68 kg ha^{-1} and available K 90.27 kg ha^{-1}. Strip wise range and mean values of soil organic carbon, available nutrients and grain yield are furnished in Table 3. The organic-C in treated plots, ranged from 5.6 to 9.6, 6.0 to 9.6, 6.2 to 9.6 and 6.2 to 7.8 g kg^{-1} with mean values of 7.4, 7.5, 7.7 and 7.8 kg^{-1} in strips I, II, III and IV, respectively. In control plots, it ranged from 5.6 to 6.5 with a mean of 6.0 g kg-^{1}. A perusal of the data (Table 2) indicates that the available N, P_2O_5 and K_2O varied from 169.1 to 250.9 kg ha^{-1}, 20.7 to 42.5 and 85.5 to 116.2 kg ha^{-1}, respectively in strip I, 182.5 to 270.5, 24.1 to 59.2 and 90 to 124.5 kg ha^{-1} in strip II , 185.2 to 270.6, 30.6 to 64.1 and 90.2 to 135.8 kg ha^{-1} in strip III and 195.4 to 290.6, 41.8 to 80.8 and 95.6 to 145.2 kg ha^{-1}, respectively in strip IV with a mean of 216.1, 32.4 and 100.7 kg ha^{-1}, 225.5, 42.9 and 108.2, 235.5, 53.1 and 114.0, and 238.0, 65.4 and 123.5 kg ha^{-1} for available NPK, respectively in their respective strips. It was observed that with increasing fertility in the strips, all the soil parameters as well as grain yield increased and the highest content was exhibited in strip L_2. This might be due to better nutrient uptake by the crop which favourably influenced the growth and yield of rice as reported by Santhi and Selvakumari (1999). Similar results were also reported by Srinivas and Angayarkanni (2008). Moreover, the results point out that a considerable variability existed in the soil test values and grain yield, which is a pre-requisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets (Santhi *et al*. 2002 and Chatterjee *et al*. 2010).

Table 2: Range and mean values of soil parameters under different strips

Particulars	Strip L_0	Strip $L_{1/2}$	Strip L_1	Strip L_2
Organic carbon (g kg-^{1})	5.6-9.6 (7.4)	6.0-9.6 (7.5)	6.0-9.6 (7.7)	6.2-7.8 (7.1)
Available N (kg ha^{-1})	169.1-250.9 (216.1)	182.5-270.5 (225.5)	185.2-270.6 (235.5)	195.4-290.6 (238.0)
Available P_2O_5 (kg ha^{-1})	20.7-42.5 (32.4)	24.1-59.2 (42.9)	30.6-64.1 (53.1)	41.8-80.8 (65.4)
Available K_2O (kg ha^{-1})	85.5-116.2 (100.7)	90-124.5 (108.2)	90.2-135.8 (114.0)	95.6-145.2 (123.5)
Grain yield (q ha^{-1})	30.0-48.0 (40.42)	32.5-50.7 (42.58)	34-50.8 (44.1)	38.5-50.8 (44.8)

Figures in parentheses indicate mean value

Yield

A perusal of the data (Table 2) exhibited that grain yield of rice ranged from 30.0 to 48.0, 32.5 to 50.75, 34 to 50.85 and 38.5 to 50.85 kg ha^{-1} with mean values of 40.42, 42.58, 44.12 and 44.8 kg ha^{-1} in strips I, II, III and IV, respectively. In control plots, it ranged from 30 to 38.5 with a mean of 33.8 kg ha^{-1}. Individual effect of the treatments showed that the highest grain and straw yield of 41.9 and 54.6 q ha^{-1} was recorded with application of FYM @ 5 t ha^{-1}, respectively (Table 4). However, it was comparable with the yield obtained with application of FYM @ 2.5 and 10 t ha^{-1}. Both the grain and straw yields obtained with FYM levels were significantly higher over the control. The improvement of soil chemical properties of the FYM treated plots provided environment for the superior growth of rice plants than on the plots without FYM treatments. Specifically the higher organic matter and available N, P and K (Table 3) provided an improved soil quality leading to improved crop productivity. The crop could also have benefited from the changes in soil physical properties as a result of FYM addition, (Ogbodo 2011). On the other hand, application of 5 t FYM ha^{-1} enhanced available N, P, and K status over other treatments and the benefits of this was reflected in yield of rice. Soil productivity is closely linked with soil organic matter status as it plays an important role in the improvement of soil structure and organic matter status.

Among the NPK fertilizer treated soils (Table 4), the grain and straw yields of rice cv. Ranjit were significantly higher in plots where fertilizers were applied either alone or in combination with each other than that where NPK were omitted (control). The highest yield of grain (48.4 q ha^{-1}) and straw (62.8 q ha^{-1}) were recorded in plots receiving all NPK fertilizers. Plots receiving P and K fertilizers alone showed significant yield increase over control and the magnitudes of increase were 4.7 and 10.2%, respectively. Conversely, omission of nutrients caused yield loss between 18% (- P) and 15.3 % (- K). These results were supported by the findings of Channabasavanna and Biradar (2001), Ebaid *et al*. (2007), Mukhopadhyay *et al.* (2008) and Siavoshi *et al.* (2011). The increase in grain and straw yield in NPK fertilized plots could be due to enhanced nutrient availability which improved nitrogen and other macro- and micro-elements absorption as well as enhancing the production and translocation of the dry matter content from source to sink. Based on the experimental data, the nutrient requirement (NR) for producing one quintal of rice grain on an average was calculated to be 1.75, 0.65 and 1.83 kg N, P and K respectively.

Table 4: Effect on P and K on grain and straw yield of rice (cv. Ranjit), nutrient uptake, organic-C and available nutrient in soil under different treatments

Treatments	Grain Yield (q ha^{-1})	Straw Yield (q ha^{-1})	Δ Yield (q ha^{-1})	Nutrient uptake (kg ha^{-1})			Apparent Recovery (%)		OC (g kg^{-1})	Available nutrient in soil (kg ha^{-1})		
				N	P	K	P	K		N	P_2O_5	K_2O
FYM (t ha^{-1})												
0	39.1	50.8	2.4 (5.8)	66.9	19.1	69.1	-	-	6.7	212.9	43.6	101.0
2.5	40.6	52.6	0.9 (2.2)	69.6	22.6	70.5	22.5	1.6	6.8	209.5	48.6	104.8
5	41.9	54.6	-0.4 (1.0)	72.7	22.2	68.8	19. 5	-0.3	7.1	224.5	55.0	109.2
10	41.5	54.4	-	72.5	21.2	69.4	13.3	0.40	7.4	215.2	46.8	103.3
SEm±	1.6	2.0		3.4	3.1	6.6	-	-	0.27	12.2	7.5	10.5
LSD5%	1.8	2.3		3.9	NS	NS	-	-	0.4	10.2	NS	NS
NPK fertilizers												
(-) NPK	36.4	47.6	12.0 (24.8)	55.0	14.8	51.5	-	-	6.5	189.9	34.9	95.4
(-)NK	38.1	49.2	10.3 (21.3)	64.7	20.2	53.7	6.1	-	6.3	199.5	57.1	101.5
(-) NP	40	51.9	8.4 (17.4)	69.1	16.6	68.5	-	14.2	6.4	201.0	47.6	100.7
(-) P	39.7	52.9	8.7 (18.0)	72.0	17.8	75.0	-	39.1	6.8	218.9	47.0	106.2
(-) K	41	53.4	7.4 (15.3)	74.7	27.4	81.3	21.3	-	7.3	225.0	49.7	107.8
(-) PK	41.8	53.9	6.6 (13.6)	69.8	16.1	59.7	-	-	7.6	218.5	40.0	97.4
(+) NPK	48.4	62.8	-	87.8	36.1	96.4	35.6	74.9	8.1	256.1	63.3	123.1
SEm±	1.6	2.0		3.4	3.1	6.6	-	-	0.5	12.2	7.5	10.5
LSD 5%	4.2	3.0		5.1	4.6	9.9	-	-	0.7	18.	11.2	14.6
CV%	4	3.8		4.9	14.5	9.6	-	-	6.8	5.7	15.5	10

Δ Yield = Yield of FYM10- yield of respective treatments for levels of FYM and Yield of NPK - yield of omitted nutrient treatment for NPK fertilizers; Data in parentheses are percent yield loss.

Nutrient Uptake

Uptake of N by rice ranged from 66.9 kg ha^{-1} in control to 72.7 kg ha^{-1} in plots receiving 5 t FYM ha^{-1} and the uptake was superior at 5% level of significant while, N uptake at 10 t FYM ha^{-1} was statistically at par with that of 5 t FYM ha^{-1} (Table 4). These results corroborate the findings of Singh and kumar *(*2014). Nitrogen uptake was decreased by 26.3 and 21.3 % with single application of P and K, respectively over combined application of N, P and K. Uptake of P and K ranged from 19.1 to 22.6 kg ha^{-1} and 68.9 to 70.5 kg ha^{-1}, respectively and were not significantly affected by FYM. On the other hand, uptake of all the major nutrients was significantly affected by NPK fertilizers alone or in combination with each other over control (Table 3). In all the cases, the highest amount of nutrients was removed by rice treated with all the NPK fertilizers. Similar results were also reported by Porpavai *et al*. (2006). The relative absorption of P was found to be significant in plots where only P was applied over that of no NPK (control). The increase in P uptake in this plot was 36.9% more over control with an apparent recovery of 6.1% (Table 3) which rose to 85.8% in plots receiving N and P together so did the apparent recovery percentage to 21.3. It is interesting to observe that the relative use efficiency of P enhanced to 35.6% by combined application of NPK fertilizers and remaining 64.4% of applied P was left in the soil either as fixed or available as residual P to the follow up crop. The absorption of applied K was the highest with application of NPK fertilizers together (96.4 kg ha^{-1}) and the effect of different combination of N, P and K was statistically significant over control (Table 4). The efficiency of K absorption evaluated as apparent recovery was 14.2 and 39.1 %, respectively with application of K alone and N and P together. Apparent recovery was enhanced to 74.9% by combined application of NPK fertilizers. In general, K uptake was considerably higher in most of the treatments receiving K fertilizer compared to N and P (Table 4). With the improved crop management practices such as use of N and P fertilizers, the yields have markedly increased resulting in higher K removal owing to higher biomass production (Sheeba and Chellamuthu 1999). Uptake of all the nutrients significantly correlated with yield (r = 0.935**, 0.825** and 0.326** for N, P and K, respectively), suggesting interdependence of nutrient uptake that influenced yield.

Organic-C and Available nutrients

The organic-C content in post harvest soil increased significantly due to application of FYM @ 5 and 10 t ha^{-1} over control. It was observed that organic carbon content was higher in the treatments where chemical fertilizers were integrated with farmyard manure (interaction effect not given here). There was an increase of 4.0, 6.7 and 13.5 % of organic carbon in soil over chemical fertilizer when the same was applied in combination with 2.5, 5 and 10 t FYM ha^{-1}, respectively. In contrary, omission of P and K tended to decrease organic carbon over control (no NPK) while other treatments significantly increased soil organic-C in post harvest soil (Table 3). The effect of FYM application in STCR experiment was found to increase significantly only in available N in soil *vis-a-vis* P_2O_5 and K_2O (Table 4). This might be due to presence of very negligible amount of P and K in FYM and in highly complexed organic form. This confronts the findings of Singh *et al*. (2001) and Kaur and Benipal (2006) who reported that use of FYM alone or with fertilizer N increased the available K status of the soil. The effect of various combination of N, P and K fertilizers on their available contents in soil was highly significant ($p<0.01$). Plots receiving P and K alone showed marked reduction in available N, P_2O_5 and K_2O (22.1 and 21.5% N, 9.8 and 24.7 % P_2O_5 and 17.5 and 18.3 % K_2O, respectively) as compared to plots receiving N along with P and K alone or in combination (Table 3). However, application of P and K individually enhanced available P_2O_5 and K_2O remarkably ($p<0.01$) over control. In all the cases, conjoint application of NPK markedly increased their available contents in soil.

From these results, it can be concluded that the integrated application of chemical fertilizers and FYM increased the grain and straw yield, and N, P and K uptake in rice as well as enhanced organic-C and available NPK in soil from strip I to IV. Application of P and K fertilizers alone could significantly increase the grain yield by 4.0 and 10.2%, respectively over control. But omission of P and K caused yield loss by 18 and 15.3 % and uptake decreased by 44.0 and 28.9 %, respectively over NPK fertilizers altogether. The respective apparent recovery of P and K was 6.1 and 14.2 % only in individual application which increased to 21.3 and 74.9% by collective application of NPK. Results suggest that combined application of N, P and K fertilizers is inevitable for better performance of rice.

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