Annals of Plant and Soil Research 20(2): 109–115 (2018)

Individual and combined effect of phosphorus and potassium on yield and nutrient uptake of hybrid rice (*Oryza sativa*) under IPNS in an alluvial soil of Assam

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Received: January, 2018; Revised accepted: April, 2018

ABSTRACT

*A field experiment was conducted based on soil test crop response correlation in an Alluvial soil of Assam during Kharif season of 2016 following Ramamoorthy's Inductive-cum-targeted yield model to elucidate the relationship between soil tests and response of hybrid rice (cv US -382) to applied fertilizers under integrated plant nutrition system (IPNS). For producing one quintal of rice grain, hybrid rice required on an average 2.00, 0.31 and 2.35 kg N, P and K , respectively. The results also indicated that integrated use of chemical fertilizers and vermicompost 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 8.3 % (- P) and 9.7 % (- K) and it has also decreased their uptake. Conversely, plots receiving P and K fertilizers alone could significantly increase grain yield by 9.3 % and 5.2 %, respectively over control. The P and K uptake were increased by 35.8 % and 30.3 % respectively, over control due to individual addition of P and K with respective apparent recovery of 7.3 % and - 21 %. Uptake of all the nutrients was significantly correlated with yield (r= 0.840**, 0.373** and 0.284** 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, hybrid rice, soil test crop response, IPNS, nutrient uptake

INTRODUCTION

In India, rice (*Oryza sativa L.*) is the most important food grain crop contributing about 41.5% to the total food grain production of the country. Rice is the most important and staple food crop for more than two thirds of the population in Assam.The gross and net cropped area for rice in Assam is 3.84 and 2.75 million hectare (Mha), respectively.Winter (*Sali*) rice is the most important variety with productivity of 2.02 t ha^{-1} followed by autumn (*Ahu*) rice with a productivity of 1.36 t ha^{-1}in Assam. The total rice productivity in Assam is 2.11 t ha^{-1}. Rice fulfills 43 per cent of calories requirement of more than 70 per cent of the Indian population. Indeterminate and imbalanced use of high analysis fertilizers resulted in multiple nutrient deficiencies (Das *et al.* 2015, Singh and Kumar 2014) particularly in the rice growing areas. Phosphorus and potassium along with Nitrogen are essential macronutrients that must be applied to maintain the productivity and to prevent deficiencies of these nutrients from limiting crop yields. Deficiencies of P and K are most frequently observed in rice fields of Assam. Generally, rice is susceptible to P-deficiency and its symptoms are shown during the seedling to maximum tillering stages in acid soils of the state. In contrast, K-deficiency symptoms are seen during the seedling and boot stage. Soils with pH <5.0 that have low soil K concentrations show potassium deficiencies in rice. Although P and K deficiencies of rice are observed every year, research studies have occasionally shown significant rice yield increase from P and K fertilization. Alluvial soils are distributed in the Indo – Gangetic Plains and Brahmaputra Valley, and cover an estimated area of 75 Mha. They are variable in physicochemical properties. Depending on the source of parent material and climate, they are either alkaline or acidic in soil reaction. They are inherently rich in plant nutrients but extreme acidity or alkalinity together with resultant soil characteristics affects their availabilities. In general, they are fairly sufficient in phosphorus and potassium, but are deficient in nitrogen and organic matter contents. One of the reasons for lower productivity is imbalanced fertilization of N, P and K nutrients. Replacement of inbred varieties of rice by hybrids could help in improving the productivity

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of rice in India. Rice hybrids can yield 10–44 % higher grain than popular high yielding varieties and expect to have higher nutrient requirement as compared to traditional cultivars (Gupta *et al.* 2011).The productivity of hybrid rice in Assam is 65 to 100 q ha^{-1} .The hybrids developed by the Hybrid Rice Research Network and some others developed by IRRI and private sectors are categorized into three maturity groups *i.e*. early (< 120 days) , mid – early (121 to 130 days) and medium (131 – 140 days). The hybrids of these three maturity groups are then evaluated in Initial Hybrid Rice Trail (IHRT) at 25- 30 locations across the country and observed high requirement of balanced nutrition. Therefore, to sustain long term productivity, balanced nutrition to crops is the key factor. If fertilizers are applied under integrated plant nutrition system (IPNS) on the basis of soil test then greater economy in fertilizer use can be made. Soil test based fertilizer recommendations result in efficient fertilizer use and maintenance of soil fertility. Among these, the targeted yield approach (Ramamoorthy *et al.* 1967) gained status and impetus in India. Targeted yield concept is based on quantitative idea of the fertilizer needs based on yield and nutrient requirements of the crop, per cent contribution of the soil available nutrients and that of the applied fertilizers. This method not only estimates soil test based fertilizer dose but also the level of yield the farmer can achieve with that particular dose. Targeted yield approach also provides scientific basis for balanced fertilization of crop by creating the balance among the nutrients from the external sources and that from the soil. This practice ensures balanced fertilization, higher yield and more profitability.

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) on hybrid rice has not yet been initiated. In the present investigation, 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 alluvial soils of Assam.

MATERIALS AND METHODS

A field experiment was conducted based on STCR approach with hybrid rice variety (US – 382) in Assam Agricultural University Experimental Farm, Jorhat located at a latitude of 26°48' N and longitude of 95°50' E during Kharif season of 2016 in an acidic Alluvial soils.The soils of experimental site was sandy clay loam in texture and acidic in reaction having pH value of 5.10 and organic carbon of 6.0 g kg^{-1}. The amount of available N, P_2O_5 and K_2O were 212.66, 32.95 and 118.47 kg ha^{-1}, respectively. A STCR-test crop experiment (Ramamoorthy*et al.*1967) composed of three gradient strips and four blocks which were fertilized with $N_0P_0K_0$,$N_1P_1K_1$ and $N_2P_2K_2$ levels.

Table 1: Treatment details for test crop experiment

Strip I	Strip II	Strip III
$N_4P_0 K_0 OM_3$	$N_0 P_0 K_2 OM_3$	$N_3 P_3 K_2 OM_3$
$N_1 P_1 K_0 OM_3$	$N_3 P_1 K_1 OM_3$	$N_4 P_2 K_1 OM_3$
$N_1 P_1 K_1 OM_3$	$N_3 P_1 K_2 OM_3$	$N_4 P_2 K_2 OM_3$
$N_0 P_3 K_0 OM_3$	$N_3P_3K_0OM_3$	$N_4 P_3 K_1 OM_3$
$N_2P_0 K_2OM_3$	$N_3 P_3 K_1 OM_3$	$N_4 P_3 K_2 OM_3$
$N_0 P_0K_0 OM_3$	$N_0 P_0 K_0 OM_3$	$N_0 P_0 K_0 OM_3$
$N_2 P_1 K_0 OM_3$	$N_3 P_3 K_2 OM_3$	$N_4 P_0 K_0 OM_3$
$N_2P_1K_1 OM_3$	$N_4 P_2 K_1 OM_3$	$N_1 P_1 K_0 OM_3$
$N_2 P_2 K_0 OM_2$	$N_4 P_2 K_2 OM_2$	$N_1 P_1 K_1 OM_2$
$N_2 P_2 K_1 OM_2$	$N_4P_3 K_1 OM_2$	$N_0 P_3 K_0 OM_2$
$N_2 P_2K_2 OM_2$	$N_4 P_3 K_2 OM_2$	$N_2 P_0 K_1 OM_2$
$N_0 P_0 K_0 OM_2$	$N_0 P_0 K_0 OM_2$	$N_0 P_0 K_0 OM_2$
$N_0 P_0 K_2 OM_2$	$N_4 P_0 K_0 OM_2$	$N_2 P_1 K_0 OM_2$
$N_3 P_1 K_1 OM_2$	$N_1 P_1 K_0 OM_2$	$N_2 P_1 K_1 OM_2$
$N_3 P_2 K_2 OM_2$	$N_1 P_1 K_1 OM_2$	$N_2 P_2 K_0 OM_2$
$N_3P_3 K_0 OM_2$	$N_0 P_3 K_0 OM_2$	$N_2 P_2 K_1 OM_2$
$N_3 P_3 K_1 OM_1$	$N_2 P_0 K_1 OM_1$	$N_2 P_2 K_2 OM_1$
$N_0 P_0 K_0 OM_1$	$N_2 P_1 K_0 OM_1$	$N_0 P_0 K_0 OM_1$
$N_3P_3K_2 OM_1$	$N_2P_1 K_1 OM_1$	$N_0 P_0 K_2 OM_1$
$N_4 P_2 K_2 OM_1$	$N_2 P_2 K_0 OM_1$	$N_3 P_1 K_1 OM_1$
$N_4 P_3 K_1 OM_1$	$N_2 P_2 K_1 OM_1$	$N_3P_2 K_2 OM_1$
$N_4 P_3 K_2 OM_1$	$N_0 P_0 K_0 OM_1$	$N_3P_3 K_0 OM_1$
$N_0 P_0 K_0 OM_1$	$N_0 P_0 K_2 OM_3$	$N_3 P_3K_1OM_1$
$N_4P_0 K_0 OM_3$	$N_0 P_0 K_2 OM_3$	$N_0 P_0K_0 OM_1$

Where,

N_0 = 0 kg ha^{-1} P_0 = 0 kg ha^{-1} K_0 = 0 kg ha^{-1}
Vermicompost (OM_0) = 0.0 ha^{-1}
N_1 = 30 kg ha^{-1} P_1 = 20 kg ha^{-1} K_1 = 40 kg ha^{-1}
Vermicompost (OM_1) = 2 t ha^{-1}
N_2 = 60 kg ha^{-1} P_2 = 40 kg ha^{-1} K_2 = 80 kg ha^{-1}
Vermicompost (OM_2) = 3 t ha^{-1}
N_3 = 90 kg ha^{-1} P_3 = 80 kg ha^{-1}
N_4 = 120 kg ha^{-1}

The recommended fertilizers ($N_1P_1K_1$) were 60, 20 and 40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Altogether 24 treatments involving various selected combination levels of nitrogen (0, 30, 60, 90 and 120 N kg ha^{-1}), phosphorus (0, 20, 40, 80 kg P_2O_5 ha^{-1}), potassium (0, 40 and 80 kg K_2O ha^{-1}) and vermicompost (0, 2 and 3 t ha^{-1}) were made. Three strips were superimposed to different plots in each strip in a fractional factorial design (Table 1). Hybrid rice variety (US-382) was grown 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 which were collected at harvest were analysed for NPK contents and their respective uptake of nutrients in rice were also figured out. Grain yield from different treatments, from each strip and from each block was also recorded. The whole plant sample with roots were collected and used for analysis of numerous parameters at maximum tillering stage. The effects P and K on crop yield, nutrient uptake, soil organic carbon and available nutrients were also estimated. Apparent recovery also known as fertilizer use efficiency was calculated by using the formula (Pillai and Varmadevan 1978, Das *et al.* 2015).

RESULTS AND DISCUSSION

Crop trials were conducted with the assumption that recommendations of fertilizers 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

The soils of the experimental field was sandy clay loam in texture with pH 5.13, organic carbon 6.0 g kg^{-1}, CEC 7.22 cmol (p+) kg^{-1}, available N 212.66 kg ha^{-1}, available P_2O_5 32.95 kg ha^{-1} and available K_2O 112.95 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 3.40 to 13.70 and 4.00 to 14.90g kg^{-1} with mean values of 8.60 and 9.00 kg^{-1} in strips L_1 and L_2, respectively. In control plots, it ranged from 3.10 to 11.20 with a mean of 7.70 g kg^{-1}. A perusal of the data (Table 2) indicates that the available N, P_2O_5 and K_2O varied from 115.08to 312.74 kg ha^{-1}, 8.26 to 24.11 and 111.20 to 234.60 kg ha^{1}, respectively in strip L_0 , 140.31 to 362.91 , 14.40 to 32.37 and 142.22 to 269.40 kg ha^{-1} in strip L_1 , 243.35 to 477.46, 20.99 to 41.81 and 158.45 to 301.42 kg ha^{-1} in strip L_2 with a mean of 183.13, 14.73 and 172.14 kg ha^{-1}, 271.00, 25.32 and 219.97, 356.62, 29.97 and 237.58 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 (Kumar *et al.* 2017, Das *et al.* 2015). 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	Strip L_2
Organic carbon (g kg^{-1})	3.10 – 11.20 (7.70)	3.40 – 13.70 (8.60)	4.00 – 14.90 (9.00)
Available N (kg ha^{-1})	115.08 – 312.74 (183.13)	140.31 – 362.91 (271.00)	243.35 – 477.46 (356.62)
Available P_2O_5 (kg ha^{-1})	8.26 – 24.11 (14.73)	14.40 – 32.37 (25.32)	20.99 – 41.81 (29.77)
Available K_2O (kg ha^{-1})	111.20 – 234.60 (172.14)	142.22 – 269.40 (219.97)	158.45 – 301.42 (237.58)
Grain yield (q ha^{-1})	35.30 – 67.90 (50.92)	34.92 – 74.05 (53.77)	37.90 – 74.70 (57.31)

Figures in parentheses indicate mean values

Yield

A perusal of the data (Table 2) exhibited that grain yield of rice ranged from 35.30 to 67.90, 34.92 to 74.05 and 37.90 to 74.70with mean values of 50.92, 53.77 and 57.31 kg ha^{-1} in strips L_0, L_1 and L_2respectively. Highest grain and straw yield of 58.30 and 68.50 q ha^{-1} was recorded with application of vermicompost @ 3 t ha^{-1}, respectively (Table 3). However, it was comparable with the yield obtained with application of vermicompost @ 0 and 2 t ha^{-1}. Both the grain and straw yields obtained with vermicompost levels were significantly higher over the control. 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 vermicompost addition, (Ogbodo 2011). Application of 3 t vermicompost ha^{-1} improved 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 helps in the improvement of soil structure and organic matter status. Among the NPK fertilizer treated soils (Table 3), the grain and straw yields of hybrid rice cv. (US – 382) 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 (61.60 q ha^{-1}) and straw (70.60 q ha^{-1}) were recorded in plots receiving all NPK fertilizers. Plots receiving P and K fertilizers alone showed significant increase in yield over control and the magnitudes of increase were 22.20 and 11.07 %, respectively. Conversely, omission of nutrients caused yield loss between 8.3% (- P) and 9.7 % (- K). These results were supported by the findings of Channabasavanna and Biradar (2001),

Table 3: Effect on P and K on grain and straw yield of hybrid rice (cv. US-382), 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
Vermicompost (t ha^{-1})												
0	53.2	57.2	5.1 (8.7)	103.2	15.4	125.1	23.5	30.3	6.8	272.4	21.5	178.3
2	54.7	64.6	3.6 6.2)	108.7	15.6	96.8	25.4	-35.3	8.3	273.3	24.0	213.5
3	58.3	68.5	-	110.2	16.5	102.1	30.8	-20.1	10.0	273.4	23.7	216.2
SEM±	3.6	4.0	-	7.9	1.5	8.3	-	-	0.7	32.5	2.6	14.1
$LSD_{5\%}$	NS	6.9	-	NS	NS	14.4	-	-	1.3	NS	NS	24.3
NPK Fertilizers												
(-) NPK	40.6	48.0	21.0 (34.1)	81.3	13.1	135.8	-	-	5.3	252.3	23.6	222.8
(-) NK	44.4	52.6	17.2 (27.9)	98.6	17.8	96.5	7.3	-	5.8	354.3	33.6	209.0
(-) NP	42.7	50.5	18.9 (30.7)	85.1	18.2	104.2	-	-21	6.8	255.9	17.2	181.8
(-) N	43.4	51.6	18.2 (29.5)	91.6	18.0	92.7	43.0	-67.8	6.8	255.4	20.4	181.9
(-) P	56.5	68.5	5.1 (8.3)	104.8	16.5	142.4	-	63.9	8.4	227.4	21.4	209.0
(-) K	55.6	68.9	6 (9.7)	107.9	17.8	144.7	33.3	-	8.6	137.5	22.9	212.6
(+) NPK	61.6	70.6	-	118.7	16.6	128.5	22.4	24.6	9.5	274.6	24.4	219.2
SEM ±	2.8	2.8	-	7.4	1.3	8.5	-	-	0.7	31.8	42.2	12.9
$LSD_{5\%}$	7.2	7.5	-	19.2	3.4	NS	-		1.7	NS	5.7	33.5

Δ Yield = Yield of vermicompost 3 - yield of respective treatments for levels of vermicompost and Yield of NPK - yield of omitted nutrient treatment for NPK fertilizers; Data in parentheses are percent yield loss

Ebaid *et al.* (2007), Mukhopadhyay *et al.* (2008), Siavoshi *et al.* (2011) and Das *et al* (2015) for high yielding rice. 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 2.00, 0.31 and 2.35 kg N, P and K respectively.

Nutrient Uptake

Uptake of N by rice ranged from 103.20 kg ha^{-1} in control to 110.20 kg ha^{-1} in plots receiving 3t vermicompost ha^{-1} and the uptake was superior at 5% level of significance. Nitrogen uptake was decreased by 16.93 and 28.30 % with single application of P and K, respectively over combined application of N, P and K. Uptake of P and K ranged from 15.40 to 16.50 kg ha^{-1} and 96.80 to 102.10 kg ha^{-1}, respectively and were not significantly affected by vermicompost. 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. The relative absorption of P was found to be significant in plots where only P was applied over that of no NPK (control). The P uptake in this plot was increased by 35.80 per cent more over control with an apparent recovery of 7.30 per cent (Table 3) and it rose to 85.10 % in plots receiving N and P together so did the apparent recovery percentage to 33.30.The relative use efficiency of P enhanced to 22.40 per cent by combined application of NPK fertilizers and remaining 77.60 per cent of applied P was left in the soil which was either 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 (24.60 kg ha^{-1}) and the effect of different combination of N, P and K was statistically significant over control (Table 3). The efficiency of K absorption evaluated as apparent recovery was -21.00 and 63.90 per cent , respectively with application of K alone and N and P together. Apparent recovery was improved to 24.60 per cent by combined application of NPK fertilizers. The K uptake was considerably higher in most of the treatments receiving K fertilizer compared to N and P (Table 3).The yields have markedly increased with improved crop management practices such as use of N and P fertilizers, resulting in higher K removal owing to higher biomass production (Kumar *et al.*, 2017). Uptake of all the nutrients significantly correlated with yield (r = 0.840**, 0.373** and 0.284** 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 vermicompost @ 2 and 3 t ha^{-1} over control. It was observed that organic carbon content was higher in the treatments where chemical fertilizers were integrated with vermicompost (interaction effect not given here). There was 24.62 % increase of organic carbon content in plot receiving NPK fertilizer together over that of the control plot. 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 vermicompost 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 3). This might be due to presence of very negligible amount of P and K in vermicompost 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 vermicompost 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 (22.40 and 6.81 % N, 27.30 and 29.50 % P_2O_5 and 4.65 and 17.06 % K_2O, respectively) as compared to plots receiving NPK 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 vermicompost 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 L_0 to strip L_2. Application of P and K fertilizers alone could significantly increase the grain yield by 22.20 and 11.07%, respectively over control. But omission of P and K caused yield loss by 8.30 per cent and 9.70 per cent and uptake decreased by 7.22 and 18.90 per cent, respectively over NPK fertilizers together. The respective apparent recovery of P and K was 7.10 and – 21.00 per cent only in individual application which increased to 33.30 and 24.60 per cent by collective application of NPK. Results suggest that combined application of N, P and K fertilizers is inevitable for better performance of hybrid rice. This envisages the importance of balanced fertilization of hybrid rice with respect to N, P and K fertilizers.

Acknowledgement

The authors duly acknowledge Indian Council of Agricultural Research (ICAR) for providing financial support under AICRP on Soil Test Crop Response Correlation (STCR).

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