Original Research Article

Nutrients accumulation and partitioning pattern of rice grown in vertisol under IPNS-STCR based nutrient management

Abstract

Rice is the indispensable grain in the Indian food basket and contributes about 45 percent to India's foodgrain production. Nutrients are essential for the higher growth and productivity of plants. Post-green revolution, fertilizer applications played a pivotal role in increasing food grain production, especially in rice and wheat. Nutrient distribution and accumulation patterns in different plant parts are important to design sustainable fertilizer schedules. The present investigation was conducted in *Kharif* season 2017 at the JNKVV research field, aimed to analyze nutrient accumulation and partitioning patterns under IPNS-STCR based nutrient application. There were six treatment combinations including an absolute control, replicated four times in a Randomised Complete Block Design. Results revealed that the higher level of nutrient *viz.* nitrogen, phosphorus and potassium were accumulated in the shoot as compared to root at all the stages of rice, however, nutrient content and total uptake increased with the increased growth stage of the plant. Among the different nutrient management, treatment having 158:107:69 kg N:P_2O_5:K_2O with 5 t FYM ha^{-1} performed better than all the others.

Keywords: STCR, Rice, Nutrient accumulation, partitioning

Introduction

Rice (*Oryza sativa* L.) is the most important extensively cultivated food crop that has been referred as "Global Grain" because of its use as a prime staple food in about 100 countries of the world. It is the backbone of Indian Agriculture. Its cultivation is of immense importance to food security of Asia, where more than 90 % of the global rice is produced and consumed. It is a staple food for more than 60% of the world population (Parthipan and Ravi, 2016) and it contributes 45 % to the total food grain production in India (Ram *et al*. 2013). Nutrients are one of the most important inputs, required by the plants for their growth and yield. The N, P, and K are major nutrients and are supplied through fertilizers and manures. At present, the increasing cost of fertilizers, growing ecological concern, and conservation of energy have created considerable interest for the use of organics as a source of plant nutrients with the blending of chemical fertilizer to reduce losses of nutrients as the integrated nutrient management system. The use of both organic and inorganic fertilizer by farmers has been reported to increase yield and sustain soil productivity (Chukwu *et al*., 2012). Integrated nutrient management, which includes potential sources of nutrients like chemical fertilizer, bulky manures could help in mitigating the problems to some extent (Dhaliwal *et al*., 2007).

Integrated nutrient management can play a vital role in balancing the soil fertility and plant nutrient supply to an optimum level through the judicious and efficient use of chemical fertilizers, along with green manure, FYM, and biofertilizers leading to an eco-friendly approach and economically viable solution for this problem. The use of green manure, FYM, or biofertilizer not only helps in supplementing requirements but also improves soil physical, chemical, and biological properties (Yadav *et al*., 2009).

One of the reasons for the lower production of rice is the imbalanced fertilization of N, P, and K nutrients. The targeted yield approach (Ramamoorthy *et al*., 1967) has been found beneficial which recommends balanced fertilization considering the soil available nutrient status and the crop need.

The soil test-based fertilizer application based on nutrient required by the crop produce sustainable yield, provides balanced nutrition to the crop and soil fertility conditions. The targeted yield approach is unique in providing fertilizer required for desired targeted yield as per the farmers' resource availability as this practice leads to balanced use of fertilizer for better crop yield and sustainable soil health, which is possible only through the Soil Test Crop Response approach.

The present investigation mainly focused on the nutrient particularly primary NPK nutrients uptake and accumulation in different parts of rice plant and the overall nutrient uptake by the rice crop per hectare.

Materials and methods

Experimental site

The study was conducted at the JNKVV research field, Department of Soil Science and Agricultural Chemistry, AICRP on STCR, Jabalpur (M.P.), situated in the South-Eastern part of Madhya Pradesh at 23^0 13’ North latitude, 79^0 57’ East longitudes, and at an elevation of 393 meters above mean sea level. The soil of the experimental site was Vertisol (medium black) belongs to *Kheri s*eries of fine montmorillonitic *hyperthermic* family of *Typic Haplusterts.* Based on the analytical report, the soil was slightly alkaline in reaction and safe in salt content and medium in organic carbon. The soil was low in available nitrogen, medium in available phosphorus and medium in available potassium having 215.83, 21.67 and 319.25 kg ha^{-1}, respectively.

Experimental details

The experiment was laid out in *Kharif* season of 2017 under the on-going research programme of AICRP on STCR. The present study has consisted of six treatments of nutrient management to achieve the targeted yield of rice which were replicated four times in a randomized block design with gross plot size 5 x 5 m having 1.0 m spacing between plots and 1.0 m spacing between the replications. All the standard agronomic practices were followed for raising the rice crop except the nutrient management which was applied as per the treatments.

Treatment details

T_1 : Control

T_2 : General recommended dose (120:60:40 kg N, P_2O_5 and K_2O ha^{-1})

T_3 : T. Y. 50 q ha^{-1} (115:72:48 kg N, P_2O_5 and K_2O ha^{-1})

T_4 : T. Y. 60 q ha^{-1} (158:107:69 kg N, P_2O_5 and K_2O ha^{-1})

T_5 : T.Y. 50 q + 5 t FYM ha^{-1} (115:72:48 kg N, P_2O_5 and K_2O ha^{-1})

T_6 : T.Y. 60 q + 5 t FYM ha^{-1} (158:107:69 kg N, P_2O_5 and K_2O ha^{-1})

Fertilizer Adjustment Equations:

Following STCR based fertilizer adjustment equation of rice has been used to calculate the required fertilizer doses as per the target yield.

$$FN = 4.25\ T - 0.45\ SN$$

$$FP_2O_5 = 3.55\ T - 4.09\ SP$$

$$FK_2O = 2.10\ T - 0.18\ SK$$

Whereas, FN - Fertilizer nitrogen (kg ha^{-1}), FP_2O_5 - Fertilizer phosphorus (kg ha^{-1}), FK_2O - Fertilizer potassium (kg ha^{-1}), T - Desired yield target (q ha^{-1}) SN - Available soil nitrogen (kg ha^{-1}), SP - Available soil phosphorus (kg ha^{-1}) and SK - Available soil potassium (kg ha^{-1}).

Based on the targeted yield fertilizers were applied as per the established equation for rice. The organic manure (FYM), available locally in plenty was utilized as per treatment in well-prepared plots one month before sowing and were well mixed in top 20 cm soil with the help of spade. The NPK fertilizers were supplied through urea, single super phosphate and muriate of potash. Full doses of phosphorus, potassium and half dose of nitrogen as per treatment were applied as basal. The remaining half amount of nitrogen was top-dressed in two split doses at 30 and 60 DAS. Crop management practices were performed as per the standard recommendation for this region.

Nutrient content and their uptakes

Nutrient content of rice *i.e.* nitrogen, phosphorus and potassium, were analyzed on dry weight basis as per standard procedures as given in Table 1.

Table 1. Methods of plant chemical analysis

Particulars	**Analytical method**	**Method employed**
Nitrogen (%)	Micro-Kjeldahl method	AOAC (1995)
Phosphorus (%)	Vanado molybdate yellow colour method	Bhargava & Raghupathi (1984)
Potassium (%)	Flame-photometric method	Bhargava & Raghupathi (1984)

Nutrient uptake by rice was calculated in kg ha^{-1} in relation to yield ha^{-1} by using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{grain/straw yield (kg ha}^{-1}\text{)}}{}$$

Statistical analysis

Analysis of variance (ANOVA) for randomized block design was worked out and the significance of treatments was tested to draw valid conclusions as described by Gomez and Gomez (1984). The differences of treatments mean were tested by ‘F’ test of significance based on the null hypothesis. Critical differences were worked out at 5 percent level of probability where ‘F’ test was significant. If the variance ratios (F-test) were found significant at 5% level of significance, the standard error of the mean (SE m) and critical differences (CD) were calculated accordingly.

Results and Discussion

Effect of different treatments on Nitrogen, phosphorus and potassium partitioning in rice

Nitrogen partitioning

Data pertaining to nitrogen partitioning plant^{-1} at 40, 80 DAS, and at harvest of rice were significantly affected by various treatments (Fig.1). It is evident from the data on nitrogen partitioning plant^{-1} was increased with increasing levels of NPK with and without FYM but decreased gradually at the harvest stage. Data further revealed that nitrogen partitioning plant^{-1} at 80 DAS was higher than 40 DAS and at harvest of the crop. It was also evident from the data on nitrogen partitioning plant^{-1} significantly increased with highest nitrogen content (0.95, 1.07, 0.66 % in shoot and 0.83, 1.18, 0.76% in roots at 40, 80 DAS and at harvest, respectively) were obtained under T_6 (158:107:69 kg $N:P_2O_5:K_2O$ + 5 t FYM ha^{-1}) over rest the treatments. However, the minimum values of N content of shoot and roots were obtained in control at all the stages of the rice crop, respectively. Similar results have been reported by Qiao-gang *et al* (2013); Kafle and Sharma (2015); Senthilvalavan and Ravichandran (2016); Singh (2017). Earlier, Quingling *et al* (2000) reported that higher N significantly increased by dry matter partitioning of the leaf at the vegetative stage. Partitioning of dry matter to leaves decreased as the nitrogen concentration in the leaves decreased. Leaf partitioning of absorbed nitrogen compared to dry matter was higher and varied little during early vegetative growth but varied from panicle initiation onwards probably due to competition for nitrogen among leaves, steam and the developing panicle.

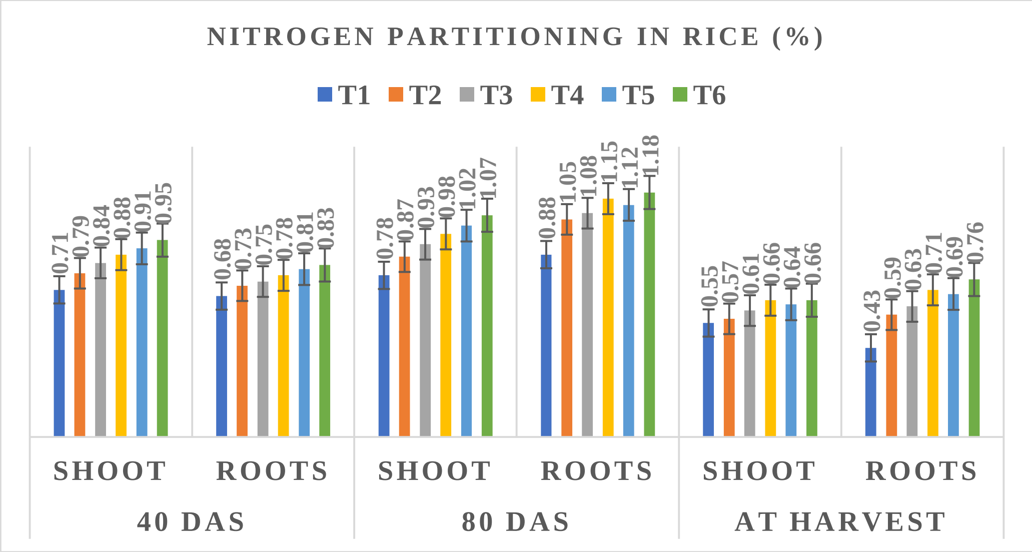

Figure. 1 Nitrogen partitioning in different parts of rice at different stages of growth

Phosphorous partitioning

Data about phosphorous partitioning plant^{-1} at 40, 80 DAS and at harvest of rice as significantly affected by different treatments of NPK levels with and without FYM (Fig 2). It is also evident from the data on phosphorous partitioning plant^{-1} was increased at 80 DAS but decreased gradually at harvest of crop. The maximum phosphorous content (0.079, 0.108, 0.103 in shoot and 0.047, 0.059, 0.051 in roots at 40, 80 DAS, and at harvest, respectively) were obtained under T_6 having 158:107:69 kg $N:P_2O_5:K_2O$ with 5 t FYM ha^{-1}, over rest of treatments. However, the minimum values of P-contents in shoot and roots were obtained in control at all three stages of rice crop, respectively. The findings are in good agreement and well supported by Julia *et al* (2016), Earlier, Naphade *et al* (1993) have also reported that integrated use of FYM along with RDF proved significantly better than RDF alone and there was an increase in the uptake of N, P, and K when compared to the application of inorganic fertilizers alone. Jacqueline *et al* (2008) have also reported that the P uptake by rice grain and straw increased significantly with the combined application of organic manure and chemical fertilizers. Results revealed that the application of compost in combination with fertilizers significantly increased the P uptake by rice over control. Similarly, results obtained by Singh (2017) revealed that the effect of organic manures and chemical fertilizers was significant on the uptake of N, P, and K by the grain and straw ranged from 43.8 to 81.2 kg ha^{-1} and 11.4 to 23.7 kg ha^{-1}. The combined application of organic manures along with 50% NPK recorded a comparatively lower uptake of N, P, and K as compared to the integrated use of organic manures and 75% NPK.

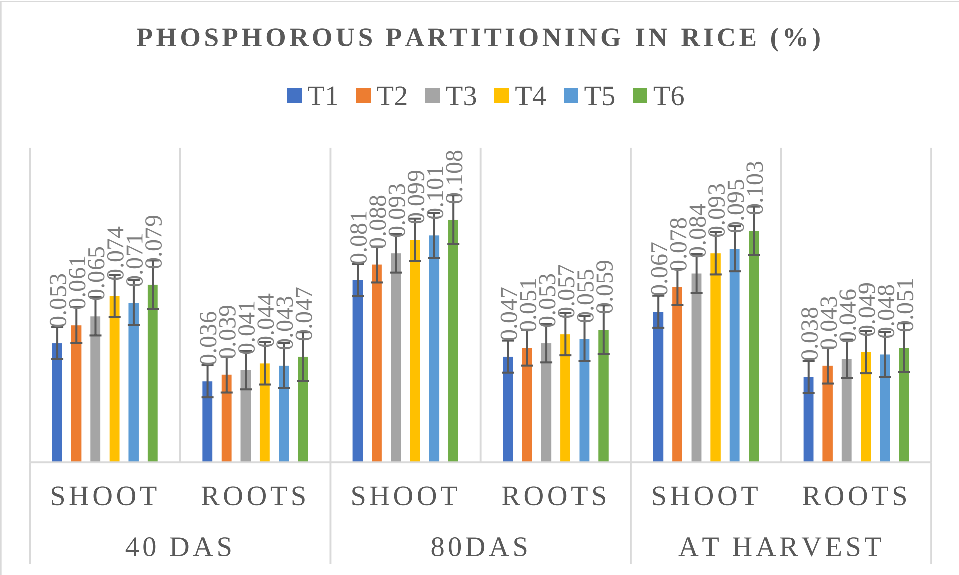

Figure.2 Phosphorus partitioning in different parts of rice at different stages of growth

Potassium partitioning

Potassium partitioning (shoot and root) at 40, 80 DAS and at harvest of rice crop as affected by various treatments (Fig 3). The potassium content increased significantly with increasing levels of NPK with and without FYM in T_6 treatment (1.330, 1.470, 1.525 in shoot and 0.410, 0.500, 0.370 in roots at 40, 80 DAS and at harvest) while minimum values were recorded under control. It might be due to the fact that the balanced use of various fertilizers and manure results in proper absorption, translocation, and assimilation of nutrients, ultimately increasing the dry-matter accumulation and nutrient contents of the crop. These results are in agreement with the findings of Singh and Agarwal (2004); Mukherjee and Sen (2005); Kevin *et al* (2007); Hana *et al* (2011); Challa Venureddy (2014).

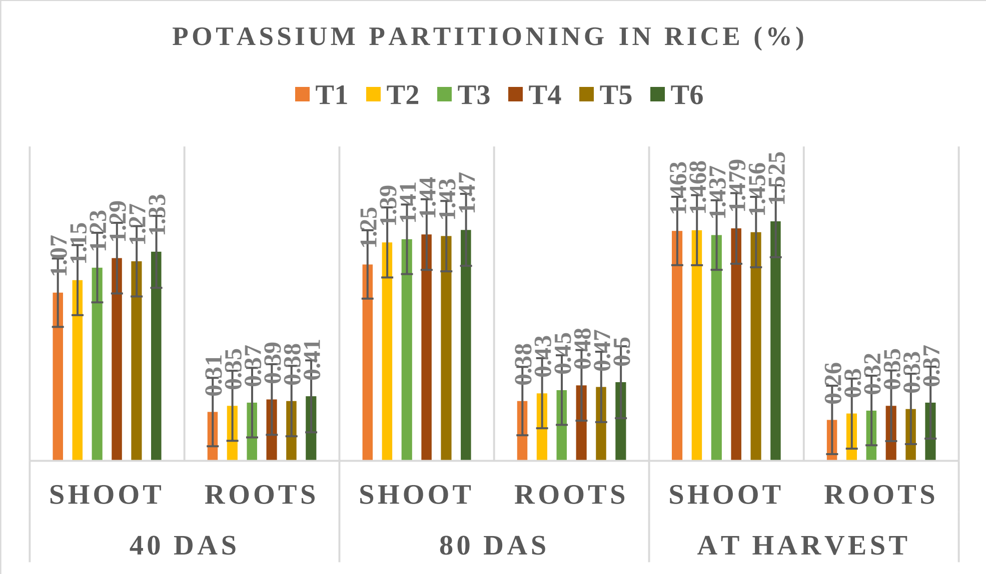

Figure. 3 Potassium partitioning in different parts of rice at different stages of growth

Effect of different treatments on Nitrogen, phosphorus and potassium uptakes

Nitrogen uptake

Data pertaining to nitrogen uptake by rice grain, straw and total uptake by biological produce are presented in Table 2. Data indicated that increasing NPK levels with and without FYM significantly increased the nitrogen uptake and the highest nitrogen uptake by grain, straw and total uptake (61.89, 49.92 and 111.81 kg ha^{-1}) were associated with the application of 158:107:69 kg N:P_2O_5:K_2O + 5 t FYM ha^{-1} (T_6) over rest of the treatments except T_4 (57.13, 46.64 and 103.77 kg ha^{-1}) with respect to grain, straw and total uptake, T_5 (56.74, and 101.13 kg ha^{-1}) with respect to nitrogen uptake by grain and total uptake. However, the nitrogen uptake by grain, straw and total uptake (28.75, 23.82 and 52.57 kg ha^{-1}) under treatment T_1 having control had significantly lower as compared to other treatments.

Phosphorous uptake

Data on phosphorous uptake by rice grain, straw and total uptake revealed that it was significantly affected by all different levels of inorganic fertilizers with and without FYM (Table 2). The application of inorganic fertilizer along with organic manure brought about significant increased in phosphorous uptake as compared to without fertilizers. The results clearly indicated that higher level of NPK along with FYM having T_6 was recorded significantly maximum phosphorous uptake by grain, straw and total uptake (12.49, 6.88 and

19.37 kg ha^{-1}), which was statistically at par with T_4 and T_5 with respect to grain, whereas minimum uptakes of phosphorous by grain, straw and total uptake of 5.53, 2.90 and 8.43 kg ha^{-1}, respectively were obtained under without applied fertilizers having control.

Potassium uptake

The data of potassium uptake (Table 2) showed that it was significantly influenced with the use of increasing levels of inorganic fertilizers with and without FYM. Results clearly indicated that higher doses of 158:107:69 kg $N:P_2O_5:K_2O$ along with 5 t FYM ha^{-1} (T_6) was recorded significantly maximum potassium uptake by grain, straw and total uptake (14.7, 113.5 and 128.2 kg ha^{-1}). Over rest of the treatments except T_4, which was being statistically at par with T_6 with respect to potassium uptake by grain, straw and total uptake and T_5 (102.6 and 115.8 kg ha^{-1}) with respect to potassium uptake by straw and total uptake, respectively. However, the minimum uptakes of potassium by grain, straw and total uptake of 6.91, 61.93 and 68.84 kg ha^{-1}, respectively were recorded under control.

Nitrogen, phosphorus and potassium uptakes by rice increased significantly with increasing levels of NPK with and without FYM (Table 2). Uptake by grain, straw, and total uptakes of nutrients were high in T_6 treatment as compared to control. It might be due to the fact that the balanced use of various plant nutrient sources results in proper absorption, translocation, and assimilation of nutrients, ultimately increasing the dry-matter accumulation and nutrient contents of crop. These results are in agreement with the findings of Gupta *et al* (2006); Kumar *et al* (2006); Singh *et al* (2006); Acharya *et al* (2012); Ranjitha and Reddy (2013); Senthilvalavan and Ravichandran (2016). Earlier, Chesti *et al* (2015) observed that the significantly higher total NPK uptake by rice (96.3, 20.4 and 109.5 kg ha^{-1}, respectively) with the application of 100% NPK+10 t FYM ha^{-1} as compared to the total NPK uptake (86.5,18.1 and 96.8 kg ha^{-1}, respectively) with the 100% NPK alone. The improvement of nutrient uptake could be ascribed to an increase in the available nitrogen, phosphorus and potassium contents in the soil resulting from the added nitrogen levels to the soil. It has been also observed that the application of Inorganic fertilizers contains a higher amount of nitrogen, phosphorus and potassium, nutrient absorption increased resulting in luxuriant growth and accumulation of more nutrients in rice plant that ultimately increased the uptake of nitrogen, phosphorus and potassium.

Table 2: Effect of different treatments under IPNS- STCR approaches on primary nutrients uptake by rice

Treatments	Nutrient uptake (kg ha^{-1})								
	Nitrogen			Phosphorus			Potassium		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1: Control	28.75	23.82	52.57	5.53	2.90	8.43	6.91	61.93	68.84
T_2: GRD	44.21	33.15	77.36	7.81	4.65	12.46	9.90	83.74	93.64
T_3: T.Y. 50 q ha^{-1}	50.27	39.28	89.55	9.78	5.22	14.99	11.18	92.93	104.11
T_4: T.Y. 60 q ha^{-1}	57.13	46.64	103.77	11.53	5.72	17.25	13.62	103.79	117.41
T_5: T.Y. 50 q + 5 t FYM ha^{-1}	56.74	44.39	101.13	11.20	5.62	16.82	13.16	102.64	115.80
T_6: T.Y. 60 q + 5 t FYM ha^{-1}	61.89	49.92	111.81	12.49	6.88	19.37	14.76	113.52	128.28
CD ***(p=0.05)***	**6.88**	**5.26**	**11.53**	**1.32**	**0.68**	**1.91**	**1.56**	**12.19**	**13.54**

Conclusion

The uptake of nitrogen, phosphorus and potassium by rice has gradually increased until the harvest stage with higher content in shoot over the root. The highest uptake of nutrients was in treatment T_6, where integrated fertilizer and FYM (158:107:69 kg $N:P_2O_5:K_2O$ with 5 t FYM ha^{-1}) was applied whereas, the lowest content was in control. Similarly, partitioning of nitrogen, phosphorus and potassium has been influenced by IPNS-STCR based nutrient application. The accumulation of NPK was higher in rice shoot than root, in treatment supplied with fertilizers and FYM conjointly. Based on these findings, we concluded that the IPNS-STCR strategy of nutrients application in Vertisol is performed better than the solo application of chemical fertilizers.

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