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Growth, productivity and nutrient uptake of aerobic rice (*Oryza sativa* L.) as influenced by different nutrient management practices

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ABSTRACT

A field experiment was undertaken to study the effect of nutrient management on rice cv. Puspa (IET-17509) during pre-kharif season of 2013 and 2014. The experiment was conducted at Rice Research Station, Bankura with eleven different nutrient management practices i.e., N_1 = N, P_2O_5, K_2O @ 60, 30, 30 kg ha^{-1} (RDF);N_2 = RDF + Vermicompost @ 2.5 t ha^{-1}; N_3 = RDF + FYM @ 5 t ha^{-1} ; N_4 = FYM @ 5 t ha^{-1}, N_5 = Vermicompost @ 2.5 t ha^{-1} ; N_6 = RDF + glyricidia (well decomposed) as green manure @ 3 t ha^{-1}; N_7 = RDF + $ZnSO_4$ @ 20 kg ha^{-1} N_8 = RDF + borax @ 2 kg ha^{-1} ; N_9 = RDF + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} ; N_{10} = RDF +Vermicompost @ 2.5 t ha^{-1} + borax @ 2 kg ha^{-1} ; N_{11} = RDF + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} respectively in randomized block design comprising of three replications. The result of experiment revealed that rice plot fertilized with the combination of NPK @ 60:30:30 + VC + $ZnSO_4$@ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded the highest grain yield of 4.45 t ha^{-1} which was 56.69 % higher (2.84 t ha^{-1}) than the FYM treated plot. Organic substitution by FYM and vermicompost (VC) had failed to register the significant impact on growth, yield and nutrient uptake. Nutrient uptake and residual nutrient status was also highest in NPK @ 60:30:30 kg ha^{-1} + VC @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1}+ borax @ 2 kg ha^{-1} fertilized plot.

Key words: *Aerobic Rice,integrated nutrient management, yield, nutrient uptake*

INTRODUCTION

Rice (*Oryza sativa* L.) is a principal source of food for more than half of the world's population and also is an important cereal crop next to wheat which accounts for the major dietary energy requirement of Asian rural people as more than 90% of rice is grown and consumed in Asia. It is predicted that a 50 - 60% increase in rice production will be required to meet demand from population growth by 2025. About 75% of the world's rice is produced from 79 million hectares of irrigated lowland fields that together receive an estimated 24-30% of the world's developed freshwater resources (Bouman et al., 2007a). The high productivity of irrigated lowland rice, however, is threatened by increasing water scarcity. Several water-saving technologies have been developed to cope with water scarcity in lowland rice areas, such as alternate wetting and drying (Borell et al., 1997; Bouman and Tuong, 2003; Belder et al., 2004), direct seeded rice (Vijayakumar et al., 2019a), continuous soil saturation (Borell et al., 1997), aerobic rice (Vijayakumar et al., 2019b) and ground cover rice production system, (Lin et al., 2002; Tao et al., 2006). These systems have been developed to mitigate the problem related to water shortage in lowland rice environments. A new system aerobic rice system is the method of cultivation, where the rice crop is established by direct seeding (dry or water-soaked seed) in un-puddle field and non-flooded field condition (Jana, 2012a). The usual way of planting aerobic rice is the same as we would plant the other cereal crops like wheat, oats or maize by direct seeding. There is no need of raising of seedling in nursery bed and puddle operation in the main field (Jana, 2012b).

Proper fertilization is a major factor to improve the rice yield in aerobic condition and this system of rice cultivation also mitigate the water problem. The nutrients, their sources, method and time of application form an important component of fertilizer management strategies (Vijayakumar et al., 2019c). Inorganic fertilizer mainly N, P, K is one of the key factors to increase the rice productivity. Yield and production increased rapidly due to increased use of chemical fertilizers but it is not a solution to continuously increase the yield year after year. It is high time to search for innovative practices, which can guarantee higher yields with minimal deterioration of natural resources. Integrated nutrient management holds promise in sustaining crop yield and improving soil health. In addition to N, P and K, it also supplies considerable amount of secondary and micronutrients, and causes the improved growth and high yield of rice crops (Mondal et al., 2019). Requirement of micronutrients is small compared to macronutrients; nevertheless, micronutrient deficiency can limit crop growth and production but excess use of micronutrients may lead to toxicity that will hamper food safety or quality. Besides major nutrients, Zn is the most important micro-nutrients and also the essential mineral for IAA synthesis. Boron (B) is an also important constituent of cell walls and its deficiency results in reduced pollen viability and pollen tube development (Arif et al., 2012). Borax should be broadcast and incorporated before planting, top-dressed, or as foliar spray during vegetative rice growth. Integrated Nutrient Management (INM) approach is flexible and minimizes use of chemicals but maximize use efficiency and improve the soil health. Using judicious combination of chemical and organics for achieving enhanced and sustainable production by adopting integrated nutrient supply is imperative. Thus, the present experiment was carried out to study the growth, yield performances and nutrient uptake of aerobic rice cv. Puspa under different combination of nutrient management in red and lateritic zone of West Bengal.

MATERIALS AND METHODS

Field experiment was conducted during 2013 and 2014 at the Rice Research Station, Bankura, West Bengal to study the growth, productivity and nutrient uptake of aerobic rice (*Oryza sativa* L.) as influenced by nutrient management practices. The experimental site falls under sub-tropical sub-humid climate. The average rainfall is 1450 mm, 75% of which is received during June to September. During the crop growth period maximum temperature ranged between 32.03^{o}C to 35.5^{o}C and minimum temperature varied between 24.5 to 26.1^{o}C. The maximum relative humidity varied from 86 to 93.0% and minimum relative humidity varied from 43.0 to 74.0%. The total rainfall during the crop growing period was recorded 385.4 mm.The texture of the experimental soil sandy loam with medium fertility and acidic in soil reaction. The experiment was laid down in randomized block design with three replications comprising of eleven combination of nutrient management *viz*., N_1 = N, P_2O_5, K_2O @ 60, 30, 30 kg ha^{-1} (RDF); N_2 = RDF + vermicompost @ 2.5 t ha^{-1}; N_3 = RDF + FYM @ 5 t ha^{-1} ; N_4 = FYM @ 5 t ha^{-1}; N_5 = vermicompost @ 2.5 t ha^{-1} ; N_6 = RDF + glyricidia (well decomposed) as green manure @ 3 t ha^{-1}; N_7 = RDF + $ZnSO_4$ @ 20 kg ha^{-1}; N_8 = RDF + borax @ 2 kg ha^{-1}; N_9 = RDF + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1}; N_{10} = RDF + vermicompost @ 2.5 t ha^{-1} + borax @ 2 kg ha^{-1}; N_{11} = RDF + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} respectively. The gross plot size of individual treatmentwas 5x4 m. Nutrients were applied according to the treatments. The sources of N, P_2O_5 and K_2O were urea, single super phosphate (S.S.P.) and muriate of potash (M.O.P.), respectively. 25% of recommended dose of N and full dose of P_2O_5 and 75% of K_2O was applied as basal. 50% of recommended dose of nitrogen was top dressed at active tillering stage and rest 25% N along with 25% K_2O were applied at panicle initiation stage. The field was drained before application of fertilizers and one week before harvest. In the treatment N_4 and N_5 the full dose of FYM and vermicompost was applied at the time of sowing. Zinc and borax was applied at the time of basal dose. Initial soil samples were collected and analyzed for important properties using standard procedures; like estimation of soil pH with pH meter in 1:2.5 soil water suspension (Jackson, 1973), organic carbon in Walkley and Black's rapid titration method (Jackson, 1973), available nitrogen in Macro Kjeldhal method (Jackson, 1973), available phosphorous in Olsen's method (Jackson, 1973) and available potassium in flame photometer method (Jackson, 1973). The soil was slightly acidic (pH 5.6) in nature, EC: 0.17 dsm^{-1}, organic carbon (%): 0.42, available P_2O_5 35 kg ha^{-1} and K_2O 188 kg ha^{-1}, respectively. The plant height was measured from the base of the plant at ground surface to the tip of the tallest leaf/panicle. Heights of five plants were taken from each replication and the mean values werecomputed and expressed in cm. For dry matter accumulation plants were cut from middle row close to ground from each plot and then samples were oven dried at 65 ±5°C till constant weight was obtained. The dryweight was expressed in g m^{-2}. LAI of the samples were calculated through the area-weight relationships. Yield components namely number of tillers/m^2, number of filled grains/panicle and test weight (1000-seed weight) were recorded at harvest. Finally, at maturity plot wise crop was harvested and sun-dried for three days in the field and thenafter threshing and cleaning grain yield was recorded in t ha^{-1} and reported at 15% moisture content.Statistical analysis was done for determining the standard error of mean (S. Em±) and the value of CD (Critical Difference) at 5% level of significance.

RESULTS AND DISCUSSION

Effect of nutrient management on growth parameters

The crop growth in terms of plant height of rice cultivated with different nutrient management practices was found significant and the variation in plant height among the treatments ranged from 2.29 to 25.95% at harvest (Table 1). Among the different nutrient management schedules, NPK @ 60:30:30 kg ha^{-1} along with vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded the highest plant height (115.5 cm) followed by the dose of NPK @ 60:30:30 + vermicompost @ 2.5 t ha^{-1}+ $ZnSO_4$ @ 20 kg ha^{-1} (112.9 cm). The lowest plant height (91.7 cm) was recorded in the plot fertilized with only FYM @ 5 t ha^{-1}. Higher plant height obtained with proper combination of nutrient management to rice crop was the indication of better internode elongation and good vegetative growth throughout the crop cycle. The tiller number per hill of aerobicrice at 60 DAS varied significantly (Table 1) with variation of different nutrient management practices. At 60 DAS, the maximum tiller number $hill^{-1}$ (14.2) was obtained in the plot fertilized with combination of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} followed by the NPK @ 60.30:30 + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (13.6 $hill^{-1}$). The lowest tiller number $hill^{-1}$ (8.3) was noticed in the treatment N_4.This might be due to combination of inorganic fertilizers along with organic manure source (vermicompost) and micronutrients application (Zn and

Table. 1. Effect of integrated nutrient management on growth parameters of rice (cv. Puspa)(Pooled value of 2 years)

Treatment	Growth parameters						
	Plant height at harvest (cm)	Tiller $hill^{-1}$ (60 DAS)	Dry matter production at harvest (g m^{-2})	Days to 100% Flowering	LAI (60 DAS)	Root dry Weight (g $hill^{-1}$)	Root length (cm)
N_1	96.7	9.2	642.6	59	3.71	5.26	25.5
N_2	102.6	10.9	712.4	57	4.01	5.44	27.1
N_3	101.2	10.1	704.8	58	3.91	5.35	26.8
N_4	91.7	8.3	574.7	62	3.22	5.01	24.6
N_5	93.8	8.6	599.2	62	3.35	5.12	25.0
N_6	99.4	9.8	689.9	58	3.83	5.31	26.1
N_7	105.4	11.7	732.0	57	4.12	5.67	26.9
N_8	103.5	11.1	721.1	57	4.09	5.59	26.4
N_9	112.9	13.6	792.6	55	4.29	5.89	29.2
N_{10}	111.3	13.1	779.9	56	4.23	5.74	28.6
N_{11}	115.5	14.2	822.6	54	4.44	6.06	30.9
S. Em (+)	2.1	0.27	7.5	0.41	0.07	0.09	0.6
CD (*P* = 0.05)	6.2	0.80	22.3	1.2	0.20	0.26	1.7

N_1 = N, P_2O_5, K_2O @ 60, 30, 30 kg ha^{-1} (RDF); N_2 = RDF + vermicompost @ 2.5 t ha^{-1}; N_3 = RDF + FYM @ 5 t ha^{-1} ; N_4 = FYM @ 5 t ha^{-1}, N_5 = vermicompost @ 2.5 t ha^{-1} ; N_6 = RDF + glyricidia (well decomposed) as green manure @ 3 t ha^{-1}; N_7 = RDF + $ZnSO_4$ @ 20 kg ha^{-1} N_8 = RDF + borax @ 2 kg ha^{-1} ; N_9 = RDF +vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} ; N_{10} = RDF + vermicompost @ 2.5 t ha^{-1} + borax @ 2 kg ha^{-1} ; N_{11} = RDF +vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1}.

B), which favoured the growth and development of tiller of rice, resulted increase in number of tillers per hill. This result corroborated with the results obtained by Jat et al., 2011 and reported that tiller increased with zinc fertilization in rice crop. Dry matter accumulation varies with crops and treatments. Here in this experiment different levels of nutrient management practices also influenced the dry matter accumulation of the crop (Table 1). The plot fertilized with the NPK @ 60:30:30 kg ha^{-1}+ Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded highest dry matter accumulation (822.6 g m^{-2}). The lowest dry matter accumulation (574.7 g m^{-2}) was recorded in only FYM treated plot. The requirement of days after sowing to 100% flowering of rice with different nutrient management varied from 54 to 62 days (Table 1). Earliest 100% flowering *i.e.*, (54 DAS) was observed in the treatment N_{11} and N_9 were statistically at par. Leaf Area Index (LAI) is a key bio-physical and structural parameter which is crucial for understanding canopy interception, ET and net photosynthesis etc. that varied with different treatments. In general LAI increased with the advancement of crop growth stages. At 60 DAS, highest LAI (4.44) was recorded in N_{11} treatment *i.e.*, 37.88% more than that of only FYM treated plot (N4). N_9 treatment *i.e.*, combined application of NPK @ 60.30:30 + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (4.29) was statistically at par with the plot fertilized with combined application of *i.e.*, NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1}. A considerable effect of varying fertilizer treatments was noted in the root growth (Table 1) and at 60 DAS the root dry weight of the crop was found to vary between 5.01 to 6.06 g $hill^{-1}$ with the variation of 20.95%. Amongst all treatments, the application of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded higher value of root dry mass (6.06 g $hill^{-1}$) and the least value of root dry matter accumulation (5.01 g $hill^{-1}$) was recorded in the treatment N_4. The root length of rice at 60 DAS varied significantly with diversified nutrient management practices (Table 1). A considerable effect of varying treatments was noted in the root length at 60 DAS and the root length of the crop was found to vary between 24.6 to 30.9 cm with the variation of 25.60%. Amongst all treatments, the combined application of NPK @ 60:30:30 kg ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + ZnSO4 @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1} recorded higher value of root length (30.9 cm) and the least value of root length was recorded in the treatment N_4 *i.e.*, only FYM applied plot.

Effect of nutrient management onyield attributes and yield

The yield components of rice in terms of panicle m^{-2} area was found statistically significant as influenced by nutrient management practices (Table 2). It has been observed that the number of panicles m^{-2} was between 277.4 to 405.5 with a variation of 46.17%. Among the treatments, the rice plot fertilized with the combination of NPK @ 60:30:30 kg ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded the highest number of panicles m^{-2} (405.5 m-2) followed by the treatment N_9 (397.2 m^{-2}). The lowest number of panicle m^{-2} was recorded in only FYM @ 5 t ha^{-1} treated plot (277.4). Similar observation of increasing the number of spikelets was observed by Qadir et al., 2013 and they reported that boron was applied along with Zn and Fe resulted in the production of higher number of spikelets $panicle^{-1}$ and grains with higher test grain weight. However, the average panicle weight of rice increased from 1.09 to 2.26 g with diversified nutrient management with increment of 107.3% over only FYM treated plot (Table 2). Among the nutrient management practices,treatment N_{11} recorded highest panicle weight (2.26g) and it was statistically at par with N_9 treatment (2.10g). This is in conformity with the findings of Arif et al. (2012) which revealed that application of B and Zn enhanced the panicle m^{-2} and panicle weight of rice. Panicle length of rice was also significantly influenced by different nutrient management practices (Table 2). The highest panicle length (25.9 cm) was recorded in the treatment N_{11} and second highest panicle length (25.6 cm) obtained with treatment N_9. Lowest value was recorded in the plot fertilized with only FYM @ 5 t ha^{-1}. Filled grain panicle-1 was significantly influenced by nutrient management practices. However, the number of filled grains $panicle^{-1}$ varied from 90.5 to 134.9 and the variation was recorded at 49.06%. The highest number of filled grain panicle-1(134.9) was achieved in plot fertilized with the combination of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} which was significantly superior to all the other treatments and the least number of filled grain panicle^{-1} (90.5) was recorded in the only FYM treated plot. The increase in the number of filled grains panicles^{-1} might have been owing to enhancing effect on the physiological activities, photo synthesis and translocation and assimilation of photosynthates and formation of higher number of spikelets during the spikelet initiation process which ultimately resulted higher number of filled grains panicles^{-1}. The findings are in line with those of Hussain (2006). The plumpness or boldness of seed in terms of test weight (1000-grain weight) of rice grown under diversified nutrient management was found non-significant. The highest test weight was recorded in the treatment N_{11} (23.7g). The land productivity in terms of grain yield of rice was significantly influenced by the nutrient management practices in the red and laterite soils of West Bengal (Table 2). Differential fertility gradient created in riceby the application of different combination of macro and micro-nutrients had resulted significant grain yield variation of rice cv. *Puspa* ranging from 2.84 to 4.45 t ha^{-1} and the yield increase was to tune of 2.46 to 56.69%. In this experiment, plot fertilized with the combination of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded the highest grain yield (4.45 t ha^{-1}) followed by the dose of NPK @ 60:30:30 + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} (4.32 t ha^{-1}) and the lowest grain yield (2.84 t ha^{-1}) was recorded from the treatment N_4 *i.e.*, FYM @ 5 t ha^{-1} applied. Application of Zn and B, when used alone as well as when applied in combination, resulted in significantly higher grain yield. The beneficial effect of B on enhancement of crop yield has been reported by Sarker et al., 2019. Similarly, the favourable effect of Zn on grain yield of rice has also been well documented by Mondal et al., 2019. The straw yield of rice varied significantly with variation of nutrient management practices. The straw yield of rice significantly increased from 5.05 to 6.20 t ha^{-1} and the variation was recorded by 22.77%. Among the treatments, the rice plot fertilized with NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded the maximum straw yield of 6.20 t ha^{-1} followed by NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1}+ $ZnSO_4$ @ 20 kg ha^{-1} (6.18 t ha^{-1}) and the lowest straw yield of 5.05 t ha^{-1} was recorded in the only FYM @ 5 t ha^{-1} treated plot where no chemical fertilizer was given. Superiority of this treatment might be due to application of proper combination of chemical as well as organic source of nutrient supply on time to rice crop. In addition, HI show significant variation due to different nutrient

Table 2. Effect of integrated nutrient management on yield attributes and grain yieldof rice (cv. *Puspa*) (Pooled value of 2 years).

Treatment	Yield attributes and yield							
	Panicle m^{-2}	Panicle weight(g)	Panicle Length (cm)	Filled grains panicle^{-1}	1000-seed weight(g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
N_1	315.7	1.21	23.7	104.8	22.1	3.25	5.29	38.06
N_2	339.4	1.43	24.0	115.4	22.7	3.50	5.41	39.28
N_3	330.0	1.39	23.9	111.9	22.4	3.39	5.33	38.88
N_4	277.4	1.09	22.0	90.5	21.7	2.84	5.05	35.99
N_5	299.9	1.19	23.2	93.1	21.9	2.91	5.12	36.24
N_6	321.5	1.28	23.3	109.3	22.4	3.31	5.30	38.44
N_7	352.1	1.61	24.6	119.9	23.1	3.89	5.82	40.06
N_8	342.2	1.50	24.4	116.5	22.9	3.72	5.79	39.12
N_9	397.2	2.10	25.6	130.1	23.6	4.32	6.18	41.14
N_{10}	381.6	1.95	25.2	125.2	23.4	4.07	5.93	40.70
N_{11}	405.5	2.26	25.9	134.9	23.7	4.45	6.20	41.78
S. Em (+)	2.6	0.08	0.8	2.2	0.9	0.11	0.07	0.31
CD (P = 0.05)	7.7	0.23	2.3	6.5	NS	0.32	0.20	0.92

N_1 = N, P_2O_5, K_2O @ 60, 30, 30 kg ha^{-1} (RDF); N_2 = RDF + vermicompost @ 2.5 t ha^{-1}; N_3 = RDF + FYM @ 5 t ha^{-1} ; N_4 = FYM @ 5 t ha^{-1}, N_5 = vermicompost @ 2.5 t ha^{-1} ; N_6 = RDF + glyricidia (well decomposed) as green manure @ 3 t ha^{-1}; N_7 = RDF + $ZnSO_4$ @ 20 kg ha^{-1} N_8 = RDF + borax @ 2 kg ha^{-1} ; N_9 = RDF +vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} ; N_{10} = RDF + vermicompost @ 2.5 t ha^{-1} + borax @ 2 kg ha^{-1} ; N_{11} = RDF +vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1}.

management practices (Table 2). The harvest index of rice increased from 35.99 to 41.78 and the increment was noted up to 16.08 %. Among the different treatment, the rice plot fertilized with the combination of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded the highest harvest index of 41.78 followed by the treatment N_9 *i.e.*, NPK @ 60.30:30 + Vermicompost @ 2.5 t ha^{-1} +$ZnSO_4$ @ 20 kg ha^{-1} (41.14). The lowest harvest index of 35.99 was recorded in the plot where only FYM was added. The higher value of harvest index attributed to the more economic yield.

Effect of nutrient management on plant nutrient uptake

Total nutrient uptake by rice crop varied significantly with different nutrient management practices (Table 3). The N, P and K uptake varied from 60.5 to 98.9 kg ha^{-1} with the increment of 63.47 %, 8.2 to 15.2 kg ha^{-1} with the variation of 85.36 % and 82.4 to 155.5 kg ha^{-1} with the variation of 88.71 % respectively. Maximum N, P and K uptake of nutrients were observed in the plot fertilized with NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + ZnSO4 @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1}. The highest N uptake was 98.9 kg ha^{-1} in the treatment N_{11} followed by the N_9 (95.6 kg ha^{-1}) and the lowest nitrogen uptake (60.5 kg ha^{-1}) was recorded in the only FYM treated plot, where no chemical fertilizer was added. In the treatments of organic substitution by FYM and vermicompost recorded small amount of nutrient uptake because of slow decomposition of organic matter. N uptake and grain yield show positive correlation between them (R^2 = 0.9817) (Fig. 1). Same trend was observed in case of P uptake. The highest P uptake was 15.2 kg ha^{-1} in the N_{11} treatment followed by the N_9 treatment (14.7 kg ha^{-1}) and the lowest P uptake was recorded in the only FYM treated plot (8.2 kg ha^{-1}). P uptake and grain yield show positive and highly correlation between them (R^2 = 0.993) (Fig. 2). In case of K uptake, treatment N_{11} *i.e.*, NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} recorded highest uptake (155.5 kg ha^{-1}) followed by the N_9 treatment (149.2 kg ha^{-1}) and the lowest K uptake was recorded in the control plot, where no chemical fertilizer was applied (N_4). K uptake and grain yield show positive and high correlation between them (R^2 = 0.837) (Fig. 3).

Effect of nutrient management on nutrient status of post-harvest soil

After harvest of rice, available soil nitrogen, phosphorus and potassium varied significantly with different nutrient

Table 3. Effect of integrated nutrient management on plant nutrient uptake and nutrient status in post-harvest soil (Pooled value of 2 years).

Treatment	Plant nutrient uptake (kg ha^{-1})			Nutrient status in post-harvest soil (kg ha^{-1})		
	N	P	K	N	P	K
N1	73.3	10.4	122.3	194.4	21.2	177.7
N2	79.1	11.0	131.3	199.2	21.9	180.2
N3	78.9	10.7	129.0	197.3	21.5	179.0
N4	60.5	8.2	82.4	172.5	18.1	166.8
N5	63.2	8.6	85.7	174.6	18.8	167.3
N6	74.6	10.5	126.5	191.4	19.0	175.5
N7	86.0	12.5	136.1	206.1	24.5	182.2
N8	82.3	11.9	132.9	200.9	21.3	180.9
N9	95.6	14.7	149.2	228.4	28.6	200.9
N10	89.5	13.3	141.3	222.6	26.0	191.9
N11	98.9	15.2	155.5	232.2	29.9	203.8
S. Em (+)	2.6	0.93	3.8	3.2	1.6	3.5
CD (*P* = 0.05)	7.4	2.7	11.3	9.5	4.7	10.4

N_1 = N, P_2O_5, K_2O @ 60, 30, 30 kg ha^{-1} (RDF); N_2 = RDF + vermicompost @ 2.5 t ha^{-1}; N_3 = RDF + FYM @ 5 t ha^{-1} ; N_4 = FYM @ 5 t ha^{-1}, N_5 = vermicompost @ 2.5 t ha^{-1} ; N_6 = RDF + glyricidia (well decomposed) as green manure @ 3 t ha^{-1}; N_7 = RDF + $ZnSO_4$ @ 20 kg ha^{-1} N_8 = RDF + borax @ 2 kg ha^{-1} ; N_9 = RDF +vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} ; N_{10} = RDF + vermicompost @ 2.5 t ha^{-1} + borax @ 2 kg ha^{-1} ; N_{11} = RDF +vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1}.

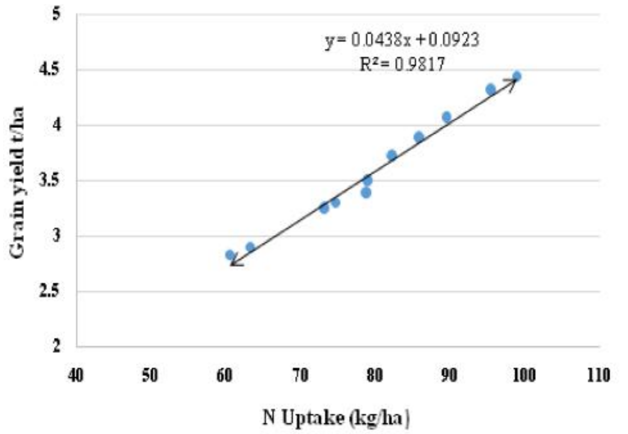

Fig. 1. Correlation between N uptake (kg/ha)and grain yield (t/ha).

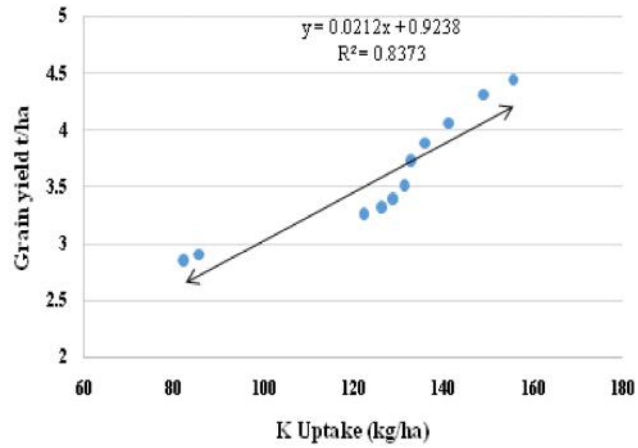

Fig. 3. Correlation between K uptake (kg/ha)and grain yield (t/ha).

management practices (Table 3). The available nitrogen in the post-harvest soil varied from 172.5 to 232.2 kg ha^{-1} with the variation of 34.60 %. The available nitrogen status was more (232.2 kg ha^{-1}) in the plot fertilized with the combined application of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} followed by the plot fertilized as NPK @ 60:30:30kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} +$ZnSO_4$ @ 20 kg ha^{-1} (228.4 kg ha^{-1}). The lowest available nitrogen (172.5 kg ha^{-1}) was recorded in the FYM @ 5 t ha^{-1} treated plot because decomposition of FYM was very slow. So, plant utilized the native soil nutrient.Phosphorus availability in the soil varied from 18.1 to 29.9 kg ha^{-1} with the variation of 65.19%. The highest available phosphorus recorded in the same treatment *i.e.*, N_{11} (29.9 kg ha^{-1}) followed by the N_9 treatment (28.6 kg ha^{-1}) and lowest available phosphorus was recorded in the FYM treated plot. The available potassium in soil varied from 166.8 to 203.8 kg ha^{-1} with the variation of 22.18 %. The highest available potassium obtained from the combined application of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} (203.8 kg ha^{-1}) and the lowest value was obtained in only FYM @ 5 t ha^{-1} treated plot where no chemical fertilizer was applied.

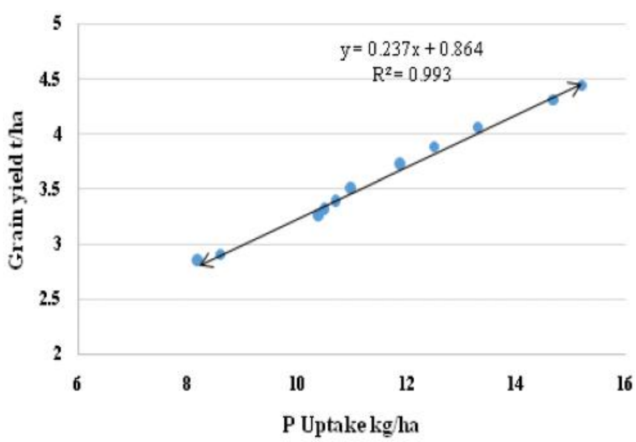

Fig. 2. Correlation between P uptake (kg/ha) and grain yield (t/ha).

CONCLUSION

From the experimental results, it was concluded that a significant yield response was obtained with the combined application of NPK @ 60:30:30 kg ha^{-1} + vermicompost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1}. Organic substitution by FYM and vermicompost had failed to register the significant impact on growth and yield. The integrated nutrient management had also improved the post-harvest nutrient status of soil and nutrient concentration in grain. Combined application of NPK @ 60:30:30 kg ha^{-1} + vermi-compost @ 2.5 t ha^{-1} + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 2 kg ha^{-1} can be recommended for cultivation of rice to obtained good yield and superior quality.

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