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Study on Integrated Effect of Inorganic Fertilizers and Organic Manure on Available Nutrients, Yield and Nutrient Uptake in Scented Rice

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Field experiments were conducted at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat during the year 2017 and 2018 to study the integrated effect of inorganic fertilizers and organic manure on available nutrients, yield and nutrient uptake in scented rice. Before the test crop experiment, fertility gradient experiment was conducted by using *kharif* rice (cv. Ranjit) as an exhaust crop to create three fertility gradient strips. After harvesting the gradient crop, test crop experiment was conducted in the same field with scented rice (cv. Keteki joha) by superimposing 24 combination treatments consisting of five levels of N (0, 10, 20, 40 and 60 kg ha^{-1}), four levels of P_2O_5 (0, 5, 10 and 20 kg ha^{-1}), three levels of K_2O (0, 10 and 20 kg ha^{-1}) and three levels of vermicompost (0, 2 and 3 t ha^{-1}) in each of these fertility gradient strips. Results show that application of integrated nutrient management approach brought about a positive influence on organic carbon, nutrient availability, crop yield and nutrients uptake by scented rice. Combined application of 60 kg N, 10 kg P_2O_5 and 10 kg K_2O per hectare along with 3 tons of vermicompost per hectare resulted in the highest concentration of available NPK in soils, the highest crop yield and uptake of nitrogen, phosphorus and potassium by rice.

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1. INTRODUCTION

Rice is the major cereal crop playing significant role in diet, culture and economy of millions of people across the world. It is the leading food source in terms of calories being consumed for mankind and feeds about 60% of the world's population [1]. It is the principal food crop of the NE India and is extensively cultivated in upland, lowland and deepwater conditions. Total rice coverage in Assam is about 25.3 million hectares while production and productivity are about 3.8 million tons and 1540 $kgha^{-1}$ respectively [2]. Aromatic rice, such as Keteki Joha, Kola Joha, Tulsi Joha, Kunkuni Joha etc. constitutes a small but special group of rice which is considered the best in quality. These rice varieties have long been popular in the orient, and are now becoming more popular in Middle East, Europe and the United States. Most of the trade in aromatic rice is from India, Pakistan and Thailand.

The scented rice (e.g., Joha rice) cultivars are known for its unique aroma, superfine kernel, good cooking qualities and excellent palatability. It is very popular due to its inherent scent and its demand has recently increased. However, these varieties are rarely grown by the farmers for commercial purpose mainly due to very low productivity [3]. Productivity of Joha cultivars is not more than 1.0 ton/ha. Joha rice cultivation constitutes only 5% out of total 17 lakh hectares of *sali* rice area in the state. However, there is immense export potential of Joha rice like that of basmati rice due to characteristic of grain quality.

The low production of improved scented rice is mainly attributed to inadequate nutrient balance applied in the state. Fertilizer application is one of the most efficient means of increasing agricultural profitability. Soils tend to decline in productivity when it is continuously planted without adopting adequate restorative practice. Application of imbalance nutrient contain in fertilizers resulted in multiple nutrient deficiencies particularly in the rice growing areas. The integrated use of organic and mineral nutrition for rice can meet the economic benefit for farmers as well as for sustainability of the production system. Therefore, integration of fertilizers with organic resources becomes eventually necessary. Keeping the above in view, a field experiment was conducted to study the integrated effect of inorganic fertilizers and organic manure on nutrient uptake, yield and available nutrients after harvest in scented rice.

2. MATERIALS AND METHODS

Field experiments were carried out in 2017 and 2018 at Instructional-cum-Research Farm of Assam Agricultural University, Jorhat. The experimental design adopted was Factorial Randomized Block Design. The meteorological data regarding mean monthly maximum and minimum temperature, mean relative humidity (%) at morning and evening, rainfall (mm) and bright sunshine hours (BSSH) per day of the crop season 2017 and 2018 are presented in Figs 1 & 2. Surface soil samples were collected randomly from 0-15 cm depth before sowing of exhaustive crop and estimated for various soil parameters. The pH of the soil was measured in soil water (1: 2.5) suspension using Glass Electrode pH meter [4]. CEC was determined by Ammonia Distillation Method [4]. Available N in soil was determined by Alkaline Potassium Permanganate Method [5]. Available P content of the soil was determined by Bray and Kurtz No. 1 Method [4]. Available K content of the soil sample was extracted by neutral normal ammonium acetate (pH 7.0) and determined by Flame Photometric Method [4] while organic carbon (%) was determined by Walkey and Black's method [4]. The soils of the experimental site was sandy clay loam in texture and acidic in reaction having pH value of 5.14. The soil organic carbon content was 0.64% with cation exchange capacity of 7.24 [cmol (p+) kg^{-1}] and base saturation of 40.55%. The soil contained lower amount of available N (232.46 $kgha^{-1}$) and K_2O (128.64 $kgha^{-1}$) while medium in available P_2O_5 (31.45 $kgha^{-1}$). It exhibited medium fixation capacity of both P and K with 159.44 kg P ha^{-1} and 214.78 kg K ha^{-1} respectively.

The field experiments were conducted in two phases as follows.

2.1 Fertility Gradient Experiment in the Field

In the first phase, a fertility gradient stabilizing experiment was conducted during *kharif* season of 2016 to minimize the interfering effects of other soil and management factors affecting crop yield. Fertility gradient experiment was established by adopting the Inductive methodology of Ramamoorthy *et al.* [6]. For that, the field was divided into three equal blocks to create fertility gradient strips which was fertilized with $N_0P_0K_0$ (0:0:0 kgha^{-1} N:P_2O_5:K_2O respectively) in strip-I (L_O); $N_1P_1K_1$ (60:20:40 kgha^{-1} N:P_2O_5:K_2O respectively i.e. RDF) in strip-II (L_1), $N_2P_2K_2$ (120:40:80 kgha^{-1} N:P_2O_5:K_2O respectively i.e. Double RDF) in strip-III (L_2) of the exhaustive crop used. Thereafter, rice (cv. Ranjit) was raised as exhaust crop in each fertility strip. The rice crop was transplanted on 15.7.2016 and harvested on 21.11.2016. At the time of transplanting, half of urea, whole of SSP and MOP were broadcasted. The remaining urea was applied as top dressing in one split. After harvesting of the crop, soil samples were collected along with grain and straw samples for chemical analysis.

2.2 Test crop Experiment

In the second phase, each of the previous three strips (L_0, L_1 and L_2) were ploughed and each strip was subdivided into 24 subplots (4 × 3 m each) resulting in 72 (24 × 3) plots. The field experiment was designed as per the ICAR guidelines framed under All India Co-ordinated Research Project on the Soil Test Crop Response Correlation. In the test crop experiments, there were twenty four treatments with N at five levels (0, 10, 20, 40, and 60 kg ha^{-1}), P_2O_5 at four levels (0, 5, 10 and 20 kg ha^{-1}) and K_2O at three levels (0, 10 and 20 kg ha^{-1}) and three levels of vermicompost (0, 2 and 3 t ha^{-1}) and the combination making a total of 72 plots over 3 strips.

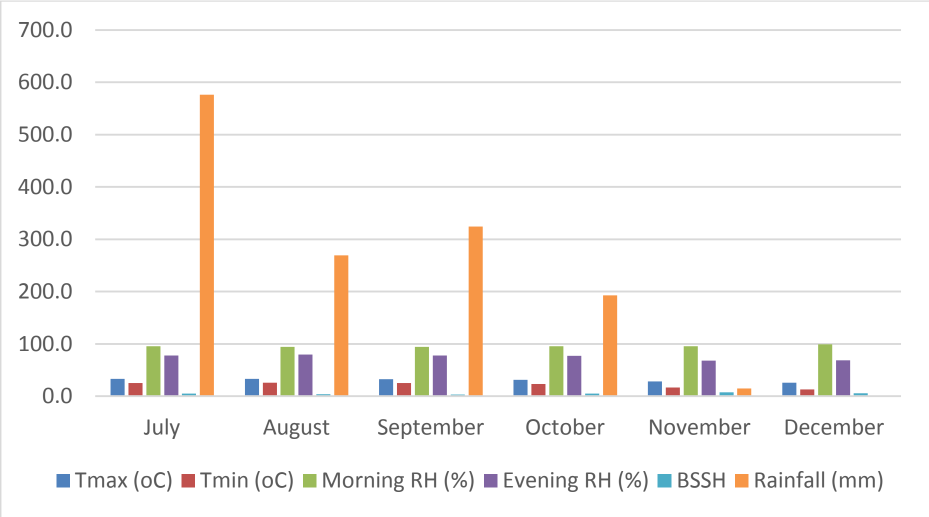

Fig. 1. Meteorological data during crop growing season, 2017

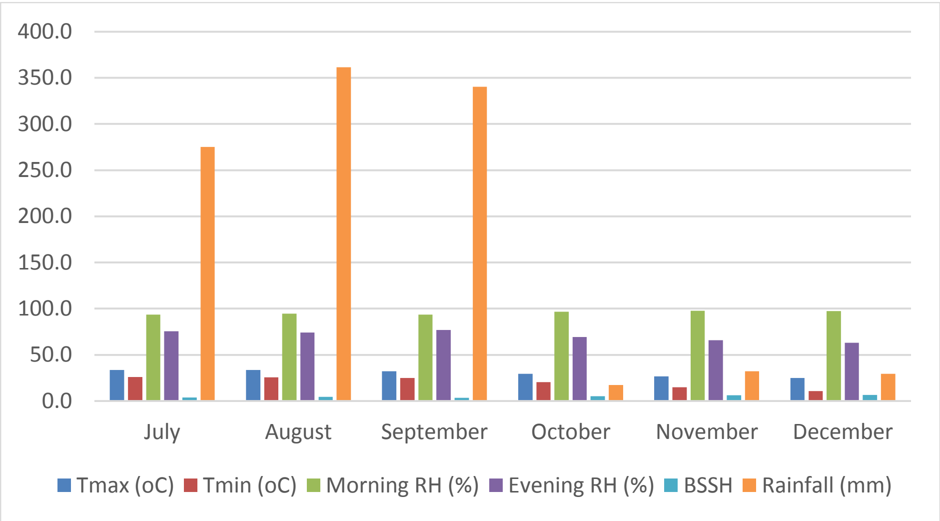

Fig. 2. Meteorological data during crop growing season, 2018

The graded doses of N, P_2O_5 and K_2O were applied in the form of urea, single superphosphate and muriate of potash, respectively in each strip as per treatment combination. Vermicompost was incorporated in the soil 2 days prior to transplanting of rice. The moisture and N, P and K content of vermicompost were 17 per cent, 1.10 per cent, 0.76 per cent and 0.71 per cent, respectively. Whole of SSP and MOP were applied by broadcasting at the time of transplanting whereas, urea was applied in 2 splits, *viz.* as basal application, and panicle initiation stage. The treatment details of test cross experiment are presented in Table 1.

Scented rice (cv. Keteki joha) was taken as test crop and was transplanted on 3rd August in 2017 and 16th July in 2018 and harvested on 15th December in 2017 and 5th December in 2018.

Plant samples were collected plot-wise after harvesting of the crop. Grain and straw samples were separated and fresh weight were taken, oven dried at a temperature of 70-80°C and again dry weight were taken to determine the moisture content. Finally, the oven dried grain and straw samples were ground in a mechanical grinder and used for analysis of various parameters.

After harvesting of exhaust crop and test crop respectively, soil samples were collected from each plot from the surface (0-15 cm). The soils were used for analysis for available N, P, K and organic- C following the above mentioned standard procedure and are presented in Table 2 for exhaust crop and table 5 for test crop analysis.

Grain and straw samples of rice collected respectively from fertility gradient experiment and test crop experiment (scented rice) for each treatment were used for determination of total nitrogen content (modified Kjeldahl's method, [4] phosphorus content (Di-acid digestion and vanadomolybdate method, [4] and potassium content (Flame photometric method, [4]. The respective per cent content of different nutrients was multiplied by the corresponding dry matter yield to estimate the nutrient uptake.

The crop under net area for each treatment was harvested and threshed separately. Grain and straw samples were sun dried to reduce the moisture level to 14% and then weighed and the yield per plot was expressed in terms of kg ha^{-1}. The data recorded in 2017 and 2018 were statistically analyzed and results of two years pooled data are discussed.

3. RESULTS AND DISCUSSION

3.1 Fertility Gradient Experiment

3.1.1 Grain and straw yield

Experimental data on yield of gradient crop are presented in Table 2. It was found that the grain yield of rice crop (cv. Ranjit) ranged from 4450 to 5440 kg ha^{-1} and straw yield from 5820 to 12280 kg ha^{-1}. In gradient III where double recommended dose of fertilizer was applied the highest grain and straw yield was observed. Increase of grain yield of rice from 11.7 per cent to 22.3 per cent over control strip was recorded and also straw increment ranged from 88.7 to 110.90 per cent as compared to the control due to the effect of increased dose of fertilizers.

The grain and straw yield of scented rice cv. Keteki joha in fertility gradient experiment increased with increasing fertility levels. The highest yield was recorded with highest fertility level *i.e.* gradient III and the lowest in control or lowest fertility level *i.e.* gradient I. In gradient III, the highest value is observed which might be due to better assimilation of nutrients by the crop which resulted in luxuriant crop growth with higher grain formation. Similar findings were also reported by Kadam and Sonar [7-9] and Kashyap *et al.* [10] in rice.

3.1.2 Available nutrients in soil after harvest of the exhaust crop

Results (Table 2) revealed that after harvest of exhaust crop the available N content in soil ranged from 225.6 to 351.2 kg ha^{-1}, available P_2O_5 from 14.9 to 22.8 kg ha^{-1} and available K_2O ranged from 156.4 to 229.8 kg ha^{-1}. The available N, P_2O_5 and K_2O were found to be highest in gradient III. The organic carbon content in soil was also found to be highest in gradient III i.e. 3.1 mg kg^{-1} and lowest in control plot (2.2 mg kg^{-1}) that is in gradient I. The results also revealed that for all the major nutrients a desired gradient in their status has been effectively created.

Table 1. Treatment details for test crop experiment

Strip \ Treatments	Strip I	Strip \ Treatments	Strip II	Strip \ Treatments	Strip III
T_1L_O	N_4P_0 K_0 OM_3	T_1L_1	N_0 P_0 K_2 OM_3	T_1L_2	N_0 P_0 K_1 OM_3
T_2L_O	N_1 P_1 K_0 OM_3	T_2L_1	N_3 P_1 K_1 OM_3	T_2L_2	N_3 P_1 K_1 OM_3
T_3L_O	N_1 P_1 K_1 OM_3	T_3L_1	N_3 P_2 K_2 OM_3	T_3L_2	N_3 P_2 K_2 OM_3
T_4L_O	N_0 P_3 K_0 OM_3	T_4L_1	N_3 P_3 K_0 OM_3	T_4L_2	N_3 P_3 K_0 OM_3
T_5L_O	N_2 P_0 K_1OM_3	T_5L_1	N_3 P_3 K_1 OM_3	T_5L_2	N_3 P_3 K_1 OM_3
T_6L_O	N_0 P_0K_0 OM_3	T_6L_1	N_0 P_0 K_0 OM_3	T_6L_2	N_0 P_0 K_0 OM_3
T_7L_O	N_2 P_1 K_0 OM_3	T_7L_1	N_3 P_3K_2 OM_3	T_7L_2	N_3 P_3 K_2 OM_3
T_8L_O	$N_2P_1K_1$ OM_3	T_8L_1	N_4 P_2 K_1 OM_3	T_8L_2	N_4 P_2 K_1 OM_3
T_9L_O	N_2 P_2 K_0 OM_2	T_9L_1	N_4 P_2 K_2 OM_2	T_9L_2	N_4 P_2 K_2 OM_2
$T_{10}L_O$	N_2 P_2 K_1 OM_2	$T_{10}L_1$	N_4 P_3 K_1 OM_2	$T_{10}L_2$	N_4 P_3 K_1 OM_2
$T_{11}L_O$	N_2 P_2 K_2 OM_2	$T_{11}L_1$	N_4 P_3 K_2 OM_2	$T_{11}L_2$	N_4 P_3 K_2 OM_2
$T_{12}L_O$	N_0 P_0 K_0 OM_2	$T_{12}L_1$	N_0 P_0 K_0 OM_2	$T_{12}L_2$	N_0 P_0 K_0 OM_2
$T_{13}L_O$	N_0 P_0 K_{20} OM_2	$T_{13}L_1$	N_4 P_0 K_0 OM_2	$T_{13}L_2$	N_4 P_0 K_0 OM_2
$T_{14}L_O$	N_3 P_1 K_1 OM_2	$T_{14}L_1$	N_1 P_1 K_0 OM_2	$T_{14}L_2$	N_1 P_1 K_0 OM_2
$T_{15}L_O$	N_3P_2 K_2 OM_2	$T_{15}L_1$	N_1 P_1 K_1 OM_2	$T_{15}L_2$	N_1 P_1 K_1 OM_2
$T_{16}L_O$	N_3P_3 K_0 OM_2	$T_{16}L_1$	N_0 P_3K_0 OM_2	$T_{16}L_2$	N_0 P_3K_0 OM_2
$T_{17}L_O$	N_3 P_3 K_1 OM_0	$T_{17}L_1$	N_2 P_0 K_1 OM_0	$T_{17}L_2$	N_2 P_0 K_1 OM_0
$T_{18}L_O$	N_0 P_0 K_1OM_0	$T_{18}L_1$	N_0 P_0 K_1OM_0	$T_{18}L_2$	N_0 P_0 K_1 OM_0
$T_{19}L_O$	$N_3P_3K_2$ OM_0	$T_{19}L_1$	N_2 P_1K_0 OM_0	$T_{19}L_2$	N_0 P_1 K_0 OM_0
$T_{20}L_O$	N_4 P_2 K_1 OM_0	$T_{20}L_1$	N_2 P_1 K_1 OM_0	$T_{20}L_2$	N_2 P_1 K_1 OM_0
$T_{21}L_O$	N_4 P_2 K_2 OM_0	$T_{21}L_1$	N_2 P_2 K_0 OM_0	$T_{21}L_2$	N_2 P_2 K OM_0
$T_{22}L_O$	N_4 P_3 K_1OM_0	$T_{22}L_1$	N_2 P_2 K_1 OM_0	$T_{22}L_2$	N_2 P_2 K_1 OM_0
$T_{23}L_O$	N_4 P_3 K_2OM_0	$T_{23}L_1$	N_2 P_2 K_2 OM_0	$T_{23}L_2$	N_2 P_2 K_2 OM_0
$T_{24}L_O$	N_0P_0 K_0 OM_0	$T_{24}L_1$	N_0 P_0 K_0 OM_0	$T_{24}L_2$	N_0 P_0K_0 OM_0

Where,

N_0 = 0 kg ha^{-1}; N_1 = 10 kg ha^{-1}; N_2 = 20 kg ha^{-1}; N_3 = 40 kg ha^{-1}; N_4 = 60 kg ha^{-1}

P_0 = 0 kg ha^{-1}; P_1 = 5 kg ha^{-1}; P_2 = 10 kg ha^{-1}; P_3 = 20 kg ha^{-1}

K_0 = 0 kg ha^{-1}; K_1 =10 kg ha^{-1}; K_2 = 20 kg ha^{-1}

FYM (OM_0) = 0.0 t ha^{-1}; FYM (OM_1) = 2 t ha^{-1}; FYM (OM_2) = 3 t ha^{-1}

With increasing fertility strips the average content of soil available nutrients and organic carbon were found to be increased. The highest content was recorded in gradient III. This increase in availability of nutrients and organic carbon could be ascribed to graded dose of fertilizer application in order to create fertility gradient in the same field. Similar findings were reported by Chatterjee *et al*. [11] Basumatary *et al.* [12] Ahmed *et al.* [13] and Kashyap *et al.* [10]

3.2 Test Crop Experiment

3.2.1 Grain and straw yield

Details of the strip wise grain and straw yields are presented in Table 3. Perusal of pooled data exhibited that maximum grain yield was obtained in strip L_2 (2567 kg ha^{-1}) followed by strip L_1 (2513 kg ha^{-1}) and was lowest in strip L_0 (1824 kg ha^{-1}). It was found that the treatments where vermicompost was applied along with inorganic fertilizers exhibited higher grain yield than that of chemical fertilizer alone and also grain yield of rice was greatly influenced by integrated nutrient management. The overall average yield of straw in the three fertility gradient strips *viz*. L_0, L_1 and L_2 were 3958, 4708 and 5087 kg ha^{-1} respectively (Table 3). Data showed that integration of inorganic and organic manure had stimulatory effect on straw yield in every strip. Among all the treatment combinations, T_8L_2 recorded the highest grain yield (3690 kg ha^{-1}) and straw yield (5750 kg ha^{-1}) where N, P_2O_5 and K_2O was applied @ 60:10:10 kg ha^{-1} along with 3 t ha^{-1} of vermicompost.

The maximum crop yields were obtained in strip L_2, followed by strip L_1 and lowest in strip L_0 corresponding to fertility gradient III, II and I respectively. Integrated nutrient management greatly influenced the grain yield of scented rice. The increase in crop yield resulted from higher nutrient concentration as well as dry matter production in the treatments, where combined uses of organic and inorganic fertilizers were applied [9]. This might encouraged better root proliferation and higher amount of nutrient uptake. The increase in crop yield were also recorded by Kumar *et al.* [14] Mahajan *et al.* [15] Chaubey *et al.* [16] Kashyap *et al.* [10] and Sekaran *et al*. [17].

3.2.2 Nutrient Uptake

The strip-wise average nutrient uptake of N, P and K was in the order of strip L_2> L_1> L_0, respectively (Table 4). Results showed that N, P and K uptake in rice increased with increasing level of N, P_2O_5 and K_2O. Pooled analysis of data showed that the highest uptake of nitrogen (143.02 kg ha^{-1}), phosphorus (7.70 kg ha^{-1}) and potassium (112.14 kg ha^{-1}) was found in the treatment T_8L_2 that is comprised of 60: 10: 10 kg ha^{-1} N: P_2O_5: K_2O + 3 t ha^{-1} vermicompost.

Results also showed that the uptake of N and K was significantly affected by N-levels while uptake of P was statistically significant under P-level only. On the other hand, K-uptake of scented rice was not affected significantly by K_2O-level whereas, it was significant under P_2O_5 level. The uptake of phosphorus was significantly affected by vermicompost level. Interaction of nitrogen and vermicompost shows significant effect in yield, uptake of nitrogen and phosphorus.

It was seen that N@ 60 kg ha^{-1}, P_2O_5@ 10 kg ha^{-1}, K_2O@ 10 kg ha^{-1} and vermicompost @ 3 t ha^{-1} recorded the highest values for all the three nutrients uptake. This is because of higher dry matter production where combined uses of organic and inorganic fertilizers were applied. Due to possible favourable effect of combined application of fertilizers on soil environment, better performance, better root proliferation, higher amount of nutrient uptake was observed. Similar increase in nutrient uptake by rice due to application of organic and inorganic fertilizers in acid soils of Assam was recorded by Singh *et al*. [18], Basuamatary *et al.* [12] Das *et al.* [9] and Kashyap *et al.* [10].

3.3 Soil Test Values after Harvest of Test Crop

3.3.1 Available nitrogen

The average available N ranged from 210.17 to 271.38 kg ha^{-1} in pooled analysis that is from low to medium after harvest of the test crop (Table 5). The highest mean value of available nitrogen was recorded in Strip L_2 (271.38 kg ha^{-1}) while the lowest value was observed in control that in Strip L_0 (210.17 kg ha^{-1}). Among the treatment combinations, the highest available N (349.31 kg ha^{-1}) was recorded in the treatment T_8L_2. Similar trend of available N in soil was recorded after harvest of the gradient experiment.

The increase in the available N in the soil could be mainly due to the release of ammonical and nitrate-nitrogen because of interaction of

Table 2. Grain yield, straw yield and soil properties after harvest of exhaust crop (Gradient experiment)

Character	Av-N (kg ha^{-1})	Av-P_2O_5 (kg ha^{-1})	Av-K_2O (kg ha^{-1})	OC (mg kg^{-1})	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Increase in yield over control (%)	
							Grain	Straw
Gradient-I								
Mean	225.6	14.9	156.4	2.2	4450	5820	-	-
Gradient-II								
Mean	292.8	18.6	186.7	2.7	4970	10980	11.7	88.7
Gradient-III								
Mean	351.2	22.8	229.8	3.1	5440	12280	22.3	110.9

Table 3. Effect of INM on seed and straw yield of scented rice

Treatments / Strips	Seed yield (Kg/ha)			Straw yield (Kg/ha)		
	Strip I (L_O)	**Strip II (L_1)**	**Strip III (L_2)**	**Strip I (L_O)**	**Strip II (L_1)**	**Strip III (L_2)**
T_1	2023	2648	2440	4833	5104	5167
T_2	1190	2440	2023	3000	4942	4875
T_3	1190	2648	2440	3084	5125	5308
T_4	982	2023	3490	2508	4058	5230
T_5	1190	2398	2223	2259	4896	4959
T_6	1523	2023	2440	3042	4292	4938
T_7	2273	2373	2857	5084	4771	5188
T_8	2023	3590	3690	5167	5208	5750
T_9	2023	2440	2023	5000	5125	5208
T_{10}	2023	2857	2023	4183	4896	5104
T_{11}	1607	2440	2440	3167	4834	4667
T_{12}	1607	2640	2523	3313	4708	5104
T_{13}	2357	3490	2023	4792	4813	5167
T_{14}	2023	2440	3065	4667	4834	5142
T_{15}	2023	3273	1623	3958	5104	5546
T_{16}	1190	2440	2232	2667	5000	4980
T_{17}	1190	2023	3273	2283	4063	5671
T_{18}	2023	2440	2648	3900	4500	5167
T_{19}	2440	2315	2607	4813	5000	4188
T_{20}	2023	2857	3065	4958	5208	5167
T_{21}	2357	2023	3273	5292	4042	4538
T_{22}	2023	2857	2232	4271	5021	5084
T_{23}	2440	1607	2523	4917	3208	5042
T_{24}	2023	2023	2440	3850	4250	4917
Mean	1824	2513	2567	3958	4708	5087
	SEm±	SEd±	CD-5%	SEm±	SEd±	CD-5%
Strip (L)	7.68	10.86	21.7	54.52	77.11	154.09
Treatment (T)	21.71	30.72	61.4	154.23	218.11	435.83
L X T	37.63	53.22	206.34	267.13	377.78	754.88

Table 4. Effect of INM on total nutrient uptake of scented rice

Treatments / Strips	N (Kg/ha)			P (Kg/ha)			K (Kg/ha)		
	Strip I (L_O)	Strip II (L_1)	Strip III (L_2)	Strip I (L_O)	Strip II (L_1)	Strip III (L_2)	Strip I (L_O)	Strip II (L_1)	Strip III (L_2)
T_1	30.15	61.65	86.73	3.48	5.84	5.84	41.14	82.64	73.48
T_2	68.36	50.86	103.65	3.80	5.66	5.66	13.48	67.48	80.48
T_3	89.65	86.15	79.15	2.88	4.73	4.73	25.48	58.81	68.41
T_4	42.11	101.02	53.77	4.30	5.66	5.66	9.48	59.48	99.48
T_5	47.36	68.36	70.75	4.70	5.19	5.19	20.48	62.24	93.48
T_6	63.98	68.65	50.86	3.69	5.42	4.42	26.21	56.14	77.98
T_7	72.15	108.60	66.55	4.00	5.53	5.53	63.48	69.74	68.01
T_8	69.81	114.14	143.02	3.07	6.70	7.70	51.14	101.47	112.14
T_9	72.73	65.44	80.90	3.38	5.10	5.10	69.48	69.48	73.48
T_{10}	53.77	69.81	102.48	4.53	5.84	5.84	32.81	80.48	106.48
T_{11}	41.81	84.40	66.90	4.88	5.14	5.14	17.48	61.48	75.48
T_{12}	49.98	65.91	45.90	3.80	4.04	4.04	25.48	63.48	89.48
T_{13}	98.10	47.94	111.52	4.95	4.09	4.09	57.14	97.48	39.48
T_{14}	45.02	66.90	66.90	3.69	4.25	4.25	57.81	73.48	69.48
T_{15}	68.36	52.43	111.81	5.38	4.82	4.82	74.48	90.81	78.14
T_{16}	25.77	73.17	86.15	3.80	6.33	6.33	28.48	77.48	47.81
T_{17}	43.56	72.15	65.44	2.96	3.90	3.90	23.48	66.14	61.14
T_{18}	18.77	69.67	72.15	1.44	4.09	4.09	64.48	63.48	54.48
T_{19}	19.65	77.75	62.96	1.88	4.99	4.99	69.48	67.38	77.48
T_{20}	18.77	86.58	61.65	1.77	5.49	5.49	49.48	80.48	72.14
T_{21}	27.52	65.15	47.94	2.57	3.84	3.84	43.61	61.14	61.14
T_{22}	46.89	49.11	82.06	2.88	6.72	6.72	42.81	59.48	109.48
T_{23}	81.25	51.44	40.65	5.00	2.80	2.80	41.48	42.81	45.21
T_{24}	72.36	56.40	50.86	2.69	4.16	5.45	57.48	78.14	104.81
Mean	52.83	71.40	75.45	3.56	5.01	5.06	41.93	70.46	76.63
	SEm±	SEd±	CD-5%	SEm±	SEd±	CD-5%	SEm±	SEd±	CD-5%
Strip (L)	0.126	0.178	0.355	0.107	0.152	0.303	0.291	0.412	0.822
Treatment (T)	0.356	0.503	1.005	0.303	0.429	0.857	0.823	1.164	2.326
L X T	0.616	0.871	1.741	0.525	0.743	1.484	1.426	2.016	4.029

Table 5. Effect of INM on soil test values after harvest of scented rice

Treatments / Strips	N (Kg/ha)			P_2O_5 (Kg/ha)			K_2O (Kg/ha)			OC (%)		
	Strip I (L_O)	Strip II (L_1)	Strip III (L_2)	Strip I (L_O)	Strip II (L_1)	Strip III (L_2)	Strip I (L_O)	Strip II (L_1)	Strip III (L_2)	Strip I (L_O)	Strip II (L_1)	Strip III (L_2)
T_1	123.57	233.09	249.13	27.34	33.43	29.95	79.30	320.76	187.30	0.93	1.24	1.20
T_2	136.11	327.17	330.67	26.17	29.17	41.59	63.94	187.32	160.42	0.89	1.10	1.12
T_3	173.75	264.45	299.31	30.04	36.91	40.42	112.42	214.20	220.42	0.87	0.98	1.06
T_4	142.39	182.91	249.13	28.05	36.53	55.92	92.74	227.64	200.74	0.96	0.98	1.20
T_5	192.56	245.63	205.23	18.41	33.82	52.83	119.62	187.32	227.62	0.76	1.16	1.08
T_6	111.38	189.18	211.85	21.53	24.89	32.27	75.94	187.32	183.94	0.95	0.96	0.98
T_7	186.29	289.53	230.31	25.40	37.30	34.21	172.42	200.76	280.42	1.03	1.00	0.90
T_8	242.74	345.81	349.31	28.12	41.49	57.20	130.18	356.76	358.18	0.86	0.86	1.28
T_9	267.83	233.09	286.76	22.99	32.27	27.23	127.30	187.32	235.30	0.79	1.18	0.96
T_{10}	242.74	289.53	324.39	28.90	33.43	53.61	125.86	214.20	233.86	0.94	1.02	1.06
T_{11}	186.29	320.89	236.59	26.95	40.69	29.56	202.18	227.64	310.18	0.93	1.10	1.12
T_{12}	116.47	195.63	203.03	22.30	30.34	33.04	71.62	183.96	179.74	0.98	1.24	1.12
T_{13}	292.91	264.45	186.41	24.62	24.89	28.79	212.74	334.20	320.74	0.93	0.98	1.08
T_{14}	192.56	308.35	299.31	29.66	27.23	34.21	115.30	214.20	223.30	1.07	1.00	0.96
T_{15}	211.38	233.09	249.13	23.43	24.89	43.12	250.18	334.20	238.18	1.07	0.79	0.96
T_{16}	249.01	289.53	330.67	20.04	33.94	41.20	71.62	200.76	179.62	0.85	0.88	1.08
T_{17}	330.55	233.09	299.31	22.76	25.12	44.29	133.06	187.32	241.06	0.87	1.00	1.04
T_{18}	211.38	327.17	249.13	18.85	24.39	33.04	238.18	214.20	346.18	0.87	0.90	0.94
T_{19}	299.19	245.63	330.67	23.88	36.53	36.53	248.74	227.64	356.74	1.05	0.86	1.00
T_{20}	255.28	295.81	318.12	26.45	35.38	32.66	106.18	241.08	214.18	0.96	0.86	0.98
T_{21}	186.29	239.36	286.41	24.27	34.99	42.46	161.86	214.20	269.86	0.89	0.69	0.96
T_{22}	236.47	327.17	299.31	28.42	28.40	41.72	119.62	214.20	227.62	0.88	0.79	0.90
T_{23}	298.73	182.91	330.67	24.89	31.88	40.62	146.50	227.64	254.50	0.79	0.92	1.08
T_{24}	158.39	172.75	158.25	18.53	21.50	33.04	91.54	214.20	198.34	0.86	0.92	1.12
Mean	210.17	259.84	271.38	24.67	31.64	39.15	136.21	229.96	243.68	0.91	0.98	1.05
	SEm±	SEd±	CD-5%	SEm±	SEd±	CD-5%	SEm±	SEd±	CD-5%	SEm±	SEd±	CD-5%
Strip (L)	0.501	0.709	1.416	0.084	0.118	0.236	0.022	0.032	0.064	0.024	0.034	0.068
Treatment (T)	1.418	2.005	4.006	0.236	0.334	0.668	0.064	0.094	0.180	0.068	0.096	NA
L X T	2.456	3.473	6.939	0.409	0.579	1.157	0.110	0.156	0.311	0.117	0.166	NA

nutrients with vermicompost [19] Raju and Reddy [20] also reported the favourable effects of organic sources in conjunction with chemical fertilizers in enhancing the availability of N. These results were supported by Jagtap *et al*. [21] Kashyap *et al.* [10] and Basuamatary *et al.* [4] Harikesh *et al.* [22].

3.3.2 Available phosphorus

The mean available phosphorus increased from 24.67 to 39.15 kg ha^{-1} in pooled analysis after harvest of test crop revealing its low to medium status in soil (Table 5). Among the strips the highest mean value of available phosphorus was recorded in Strip L_2 with 39.15 kg ha^{-1} and the lowest mean value was observed in control that is Strip L_0 which was 24.67 kg ha^{-1}. The treatment T_8L_2 recorded the highest value for available phosphorus (57.20 kg ha^{-1}).

The availability of phosphorus increased due to incorporation of vermicompost along with inorganic P and this might be due to increase in mineralization of organic P and reduction in fixation of water soluble P [9]. This increase could be justified owing to solubilization of the native P and microbial degradation of organic matter in the soil resulting in release of various organic acids. Organic acids such as tartaric, citric, malonic and malic acids liberated during the decomposition of organic matter are known to chelate with Fe, Al and Ca preventing them from reacting with phosphate. The organic matter increases the availability of P by chelating the phosphate fixing cations (Al^{3+}, Fe^{3+}, Ca^{2+}) and exchange of adsorbed PO_4^{3-} ions by organic anions through protective action [21].

3.3.3 Available potassium

The mean available potassium ranged from 136.21 to 243.68 kg ha^{-1} in pooled analysis. Among the three strips, the highest average value of available potassium content was recorded in the Strip L_2 with 243.68 kg ha^{-1} and lowest was observed in strip L_0 with 136.21 kg ha^{-1} (Table 5). Similar to that of available N and P_2O_5, the highest value of available potassium was observed in the treatment T_8L_2 (358.18 kg ha^{-1}) where N, P_2O_5 and K_2O was applied @ 60:10:10 kg ha^{-1} along with 3 t ha^{-1} of vermicompost.

Due to combined application of vermicompost and inorganic fertilizer, the CEC of the soil might have improved and increased the retention of K in exchangeable form by reducing its fixation. Similar findings were recorded by Gogoi *et al*. [23] Basumatary *et al.* [12] and Kashyap *et al.* [10].

3.3.4 Organic carbon

The organic carbon content of the soil was found to be 0.91, 0.98 and 1.05% in strip L_0, L_1 and L_2, respectively (Table 5). In general, organic carbon content was found to be highest in the treatment T_8L_2 (1.28%) consisting of higher level of vermicompost and it is seen that every increment in fertilizer N and vermicompost led to increase in organic matter content of the soil.

The increase in organic carbon is possibly due to increase in microbial activity in soil and also due to better root growth. With increased addition of NPK fertilizers, the root and shoot growth obviously got improved which in turn led to higher production of biomass resulting in higher organic carbon content in soil as observed by Babhulkar *et al.* [24]. These results are also supported by the findings of Basuamatary *et al.* [12] Das *et al.* [9] and Kashyap *et al.* [10] in soils of Assam.

4. CONCLUSION

The results obtained from the present investigation revealed that among the integrated treatments, application of 60 kg N, 10 kg P_2O_5 and 10 kg K_2O per hectare along with 3 tonnes of vermicompost per hectare exhibited the highest value in case of crop yield, nutrient uptake and soil test values as compared to other treatments.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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