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Integrated Nutrient Management Practices for Enhancing Yield and Profitability of Rice (*Oryza Sativa* L.)

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Field experiment was conducted at Rice Research Station, Moncompu, Kerala to find out the best integrated nutrient management practice for enhancing the yield and profitability of transplanted rice. The experiment was laid out in randomized block design with four replications in plots of 50 m^2 during *kharif* 2011 and *rabi* 2011-12. The treatments comprised of four different integrated nutrient management practices and farmers practice of applying chemical fertilizers alone. The results revealed that application of magnesium sulphate (20 kg ha^{-1}) with the recommended dose of NPK (90-45-15 kg ha^{-1}), farm yard manure (5 t ha^{-1}) and lime top dressing (250 kg ha^{-1}) significantly improved the growth and yield attributes, uptake of nutrients and produced the highest grain yield of 7570 kg ha^{-1} and 3883 kg ha^{-1}, respectively during *kharif* and *rabi* season. The stimulatory effect on plant growth by the inoculation of NPK bio-fertilizer (PGPR Mix-1) was found to be more pronounced when it was applied with half the recommended dose of NPK (45-22.5-7.5 kg ha^{-1}) and lime top dressing (250 kg ha^{-1}) and recorded the highest benefit cost ratio (3.25 and 1.67) and net returns (71316 and 21146 Rs ha^{-1}) with grain yield of 7355 kg ha^{-1} and 3520 kg ha^{-1}, respectively during both the seasons.

Key words: Integrated nutrient management, magnesium sulphate, NPK bio-fertilizer, PGPR, farmers practice, farm yard manure, lime top dressing

In India rice is cultivated in an area of 44.1 million hectares with a production of 103.4 million tonnes (USDA, 2012), which plays a key role in food security. The country has to produce about 130 million tons of rice by 2025 to meet the food requirement of the growing population (Hugar *et al*., 2009). Every year, huge amount of chemical fertilizers are applied to achieve maximum production in rice to meet the food requirement of our country. Due to the indiscriminate and injudicious use of chemical fertilizers, pesticides and aberrant weather conditions, the production and productivity of rice in India is facing a sustainability problem. The injudicious use of chemical fertilizers without the addition of organic manures has created problems such as environmental pollution, health hazards, interruption of natural ecology, destruction of biological communities that support crop production, the depletion of soil organic carbon and mineral nutrients, water logging, salinization and increase in the concentration of nitrate and phosphate contents in well water, rivers, lakes and streams (George, 2012; Naveen Kumar *et al*., 2012). This necessitates adoption of best management practices that would maintain the soil health and keep the production system more sustainable and profitable.

Adoption of nutrient management practices involving the use of organic manures, chemical fertilizers, soil conditioners and bio-fertilizers is one of the best alternatives to make the production system more sustainable and profitable. Bio-fertilizers are often considered as a potential tool for reducing the use of chemical fertilizers and enhancing the productivity by fixing atmospheric nitrogen, solubilizing soil phosphorous, mobilizing or solubilizing soil potassium or by promoting crop growth by the production of growth promoting substances. In order to derive maximum benefits and for cost effectiveness, bio- fertilizer containing combined cultures (NPK) are to be used instead of using individual bio-fertilizer for N, P and K. Keeping all these in view the present investigation was undertaken with an objective to find out the best suitable nutrient management practice for enhancing the yield and profitability of transplanted irrigated rice.

Materials and Methods

The field experiment was conducted during *kharif* 2011 and *rabi* 2011-12 at Rice Research Station, Moncompu, Kerala, India (geographically situated 9 º5'N latitude and 76º 5' E longitude and at an altitude of 1 m below MSL). The soil belongs to silty clay textural class with pH of 6- 6.4 (wet). During *kharif* and *rabi* season, the experiments were laid out in different plots. The organic carbon status, available P and K of the experimental plots were 2.8 %, 23.2 and 281 kg ha^{-1}, respectively in *kharif* season and 3.53 %, 26.8 and 263 kg ha^{-1}, respectively in *rabi* season. The total rainfall received during the *kharif* (June-October) and *rabi* season (December –April) was 1555.6 mm and 387.8 mm, respectively. The mean monthly maximum and minimum temperature was 30.4º C and 24.6ºC, respectively during *kharif*

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2011 and 32.4 ˚C and 23.4˚C, respectively during *rabi* 2011-12. The experiment was laid out in randomized block design with four replications in plots of 50 m^2 size. The treatments were NPK @ 90-45-15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} + $MgSO_4$ @ 20 kg ha^{1} (T_1), NPK @ 90-45-45 kg ha^{-1} (farmers practice) (T_2), NPK @ 45-22.5-7.5 kg ha^{-1} + farm yard manure 2.5 t ha^{-1} + PGPR Mix-1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1} (T_3), NPK @ 90-45-15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} (T_4), NPK @ 45-22.5-7.5 kg ha^{-1} + PGPR Mix -1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1} ((T_5).

Farm yard manure was applied as basal at the time of final ploughing. PGPR Mix-1, the consortium of nitrogen fixer, P and K solubilizing bacteria developed by College of Agriculture, Vellayani (Kerala Agricultural University) was used as the NPK bio-fertilizer. PGPR Mix-1 after mixing with dried powdered farm yard manure in the ratio of 1:50 was applied four days after transplanting (DAT). Eighteen day's old seedlings of medium duration variety "Uma" was transplanted at a spacing of 20 x 10 cm on 16 June 2011 and 27 December 2011. One third dose of N and K and half P was applied 15 DAT, one third dose of N and K and half P at 35 DAT and remaining one third N and K at 55 DAT. Magnesium sulphate was applied on fourth DAT. Lime was top dressed one week before the second split application of fertilizers. All the other agronomic and plant protection measures were adopted as per POP recommendations (KAU, 2011). Observations on plant growth attributes were recorded at flowering stage and yield attributes and grain yield were recorded at harvest stage. The LAI was worked out as per the method proposed by Palaniswamy and Gomez (1974). The grain yield was recorded at 13 % moisture. The plant samples were collected at flowering stage for estimating the N, P and K content to determine the N, P and K uptake using the standard procedures. The cost of cultivation was worked out on the basis of prevailing market rate of inputs and labour cost involved. Economics was worked out based on the minimum support price for paddy given by the Government of Kerala.

Results and Discussion

Effect on crop growth

Data on growth attributes at flowering stage of two seasons revealed that the plant height was not significantly influenced by the treatments (Table. 1). However, application of magnesium sulphate (20 kg ha^{-1}) with recommended dose of NPK fertilizers, farm yard manure (5 t ha^{1}) and lime top dressing (250 kg ha^{-1}) (T_1) recorded taller plants and treatment with half the recommended dose of NPK fertilizers, farm yard manure (2.5 t ha^{-1}), PGPR Mix-1 (2 kg ha^{1}) and lime top dressing (250 kg ha^{-1}) (T_3) recorded plants with least height in both the seasons. Tiller production was significantly influenced by the treatments. The treatment T_1 recorded higher number of tillers per square meter in *kharif* season and recommended dose of NPK, farm yard manure (5 t ha^{-1}) and lime top dressing (250 kg ha^{-1}) (T_4) recorded higher number of tillers per square meter in *rabi* season. In both seasons, T_3 recorded the lowest number of tiller per meter square. LAI was also significantly influenced by the treatments during both seasons. The treatment T_1 registered the highest LAI (5.79 and 4.94) during *kharif* and *rabi* season and the lowest LAI (5.17) was observed in T_3 during *kharif* season and T_2 (3.22) in *rabi* season.

Table 1. Effect of nutrient management practices on growth attributes of rice during *kharif* 2011 and *rabi* 2011-12

Treatment	Plant height (cm)		Tillers (No. m^{-2})		LAI		DMP(kg ha^{-1})	
	kharif	rabi	kharif	rabi	kharif	rabi	kharif	rabi
NPK @ 90-45-15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} + $MgSO_4$ @ 20 kg ha^{1} (T_1)	102.4	80.1	356	342	5.79	4.94	17117	9827
NPK @ 90-45-45 kg ha^{-1} (farmers practice) (T_2)	99.0	77.3	292	320	5.30	3.22	13345	8328
NPK @ 45-22.5-7.5 kg ha^{-1} + farm yard manure 2.5 t ha^{-1} + PGPR Mix-1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1} (T_3)	99.4	76.8	292	314	5.17	3.50	13466	7147
NPK @ 90-45-15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} (T_4)	101.3	76.1	302	347	5.39	3.34	13159	9095
NPK @ 45-22.5-7.5 kg ha^{-1}+ PGPR Mix -1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1} ((T5).	101.9	77.4	327	336	5.64	3.66	15509	8185
SEd	1.5	1.4	12	9	0.17	0.16	389	175
CD (P=0.05)	NS	NS	25	19	0.37	0.35	845	381

Dry matter production was also significantly influenced by the treatments. Application of magnesium sulphate (20 kg ha^{-1}) with recommended dose of NPK, farm yard manure and lime top dressing (T_1) recorded plants with higher DMP of 17117 kg ha^{-1} and 9827 kg ha^{-1}, respectively in *kharif* and *rabi* season. The lowest DMP was recorded in treatment T_4 in *kharif* season and T_3 in *rabi* season. Higher LAI, tillers per square meter and DMP in T_1 might be due to the favourable influence of Mg on photosynthetic carbon dioxide fixation, chlorophyll formation, N uptake and assimilation in rice and production and partitioning of carbohydrates between roots and shoots as reported by Ding *et al*. (2006). The treatment T_3 recorded lesser LAI, DMP and tillers per square meter in both the seasons compared to T_5 (Table.1). This is attributed to the fact that that the organic acids produced during the decomposition of farm yard manure might have increased the acidity of the soil which repressed the growth and activities of soil organisms like nitrogen fixing and nitrifying bacteria. The nitrates are not then produced in adequate quantities and atmospheric nitrogen is also not fixed and the plants do not get enough nitrogen in the initial stages of crop development causing the slowdown of crop growth (Sankaran and Mudaliar, 1993). The growth enhancement in treatment T_5 was due to the production of phytohormones such as auxins, gibberellins and cytokinins by the plant growth promoting rhizobacteria like nitrogen fixers, P and K solubilizing bacteria present in the PGPR Mix-1. Indole-3- acetic acid is the major one among auxins, which functions as an important signal molecule in the plant development including organogenesis, tropic responses and cellular responses such as cell expansion, division and differentiation (Ryu and Pattern, 2008). Another reason could be the fact that the stimulatory effect on plant growth by the plant growth promoting rhizobacteria is more in nutrient deficient soil than in nutrient rich soil (Egamberdiyeva, 2007).

Effect of treatments on nutrient uptake

The N uptake was not significantly influenced by the treatments during *kharif* season, but P and K uptake was significantly influenced by the treatments (Table.2). During *rabi* season N uptake was significantly influenced by the treatments, but P and K uptake was not significantly influenced. During both the seasons, higher uptake of N, P and K was recorded in T_1. This was due to the production of more number of tillers per square meter, high LAI, DMP (Table. 1), vigorous root development and high water uptake. These results were positively correlated with the grain yield of rice in both seasons. The treatment T_5 recorded more uptake of N, P and K than farmers practice (T_2) of applying chemical fertilizers alone. This was due to the favorable influence of plant growth promoting bacteria in PGPR Mix-1 in enhancing the plant growth including the root development by the production of growth promoting substances resulting in the improved uptake of nutrients (Vikram, 2007). The treatment T_4 also recorded more uptake of nutrients than T_2. In both the seasons, T_3 recorded the lowest uptake of N, P and K. This might be due to lesser crop growth and DMP as evident in the present study.

Table 2. Effect of nutrient management practices on nutrient uptake at flowering stage during *kharif* 2011 and *rabi* 2011-12

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})	
	kharif	rabi	kharif	rabi	kharif	rabi
NPK @ 90-45-15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} + $MgSO_4$ @ 20 kg ha^{-1} (T_1)	179.42	130.98	58.54	16.61	286.51	177.91
NPK @ 90-45-45 kg ha^{-1} (farmers practice) (T_2)	140.52	105.62	52.92	14.49	227.90	156.61
NPK @ 45-22.5-7.5 kg ha^{-1} + farm yard manure 2.5 t ha^{-1} + PGPR Mix-1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1} (T_3)	140.14	92.72	44.67	13.15	232.29	149.27
NPK @ 90-45-15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} (T_4)	143.36	110.36	53.94	17.67	235.03	157.65
NPK @ 45-22.5-7.5 kg ha^{-1} + PGPR Mix -1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1}((T5).	147.74	106.02	58.06	14.60	265.35	163.79
SEd	13.95	5.21	4.35	1.90	18.41	9.96
CD (P=0.05)	NS	11.35	9.50	NS	40.11	NS

Effect on yield attributes

Yield attributes viz., panicles per square meter, panicle weight and fertile grains per panicle were significantly influenced by the treatments during both the seasons (Table.3). The highest number of panicles per square meter was recorded in T_1 and it was followed by treatment with half the recommended dose of fertilizers, PGPR Mix-1and lime top dressing (T_5). This was due to more number of tillers per square meter produced on account of better availability and uptake of nutrients. The treatment T_1 recorded panicles with more weight and fertile grains per panicle. This was owing to the fact that Mg enhanced N assimilation resulting in higher production of proteins which increased the production of fertile grain per panicle (Srivastava *et al*., 2006) and it also played a major role in the phloem transport of carbohydrates from source into the sink

Table 3. Effect of nutrient management practices on yield attributes of rice during *kharif* 2011 and *rabi* 2011-12

Treatment	Number of panicles per square meter		Panicle weight (g)		Number of fertile grains per panicle		1000 grain weight (g)	
	kharif	rabi	kharif	rabi	kharif	rabi	kharif	rabi
NPK @ 90 -45-15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} + $MgSO_4$@ 20 kg ha^{-1} (T_1)	352	339	4.23	2.69	173.4	98.7	22.03	22.20
NPK @ 90-45-45 kg ha^{-1} (farmers practice) (T_2)	290	30	3.68	2.35	152.3	83.7	22.70	22.40
NPK @ 45-22.5-7.5 kg ha^{-1} + farm yard manure 2.5 t ha^{-1} + PGPR Mix-1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1} (T_3)	280	300	4.03	2.52	154.0	91.1	22.60	21.70
NPK @ 90 -45- 15 kg ha^{-1} (recommended dose) + farm yard manure 5 t ha^{-1} + lime top dressing 250 kg ha^{-1} (T_4)	296	318	3.68	2.28	152.2	94.7	22.40	21.80
NPK @ 45-22.5-7.5 kg ha^{-1}+ PGPR Mix -1 @ 2 kg ha^{-1} + lime top dressing 250 kg ha^{-1} ((T_5).	322	321	3.98	2.52	162.3	90.3	23.40	22.80
SEd	22	7	0.14	0.11	4.0	2.7	0.45	0.44
CD (P=0.05)	48	16	0.31	0.14	8.7	5.9	NS	NS

Table 4. Effect of nutrient management practices on grain yield and economics of rice during *kharif* 2011 and *rabi* 2011-12

Treatment	Grain yield(kg ha-1)		Gross returns(Rs ha-1)		Net returns(Rs ha-1)		B:C ratio	
	kharif	rabi	kharif	rabi	kharif	rabi	kharif	rabi
NPK @ 90-45-15 kg ha-1 (recommended dose) + farm yard manure 5 t ha-1 + lime top dressing 250 kg ha-1 + $MgSO_4$@ 20 kg ha-1 (T_1)	7570	3883	105980	58245	68433	20698	2.82	1.55
NPK @ 90-45-45 kg ha-1 (farmers practice) (T_2)	6749	3393	94486	50895	57154	13563	2.53	1.36
NPK @ 45-22.5-7.5 kg ha-1 + farm yard manure 2.5 t ha-1 + PGPR Mix-1 @ 2 kg ha-1 + lime top dressing 250 kg ha-1 (T_3)	6598	3253	92372	48795	58218	14641	2.70	1.43
NPK @ 90-45-15 kg ha-1 (recommended dose) + farm yard manure 5 t ha-1 + lime top dressing 250 kg ha-1 (T_4)	6873	3533	96222	52995	58975	15748	2.58	1.42
NPK @ 45-22.5-7.5 kg ha-1 + PGPR Mix -1 @ 2 kg ha-1 + lime top dressing 250 kg ha-1 ((T_5).	7355	3520	102970	52800	71316	21146	3.25	1.67
SEd	148	114	-	-	-	-	-	-
CD (P=0.05)	323	248	-	-	-	-	-	-

organs (Cakmak and Kirkby, 2008). Fertile grains per panicle were found to be more in treatments receiving farm yard manure. This implied the beneficial effects of farm yard manure on yield parameters of rice particularly fertile grains per panicle. The result is in conformity with the findings of Bhattacharya *et al.* (2003). Thousand grain weight was not significantly influenced by the treatments. But grains with higher weight were recorded in treatment receiving half the recommended dose of chemical fertilizers, PGPR Mix-1 and lime top dressing (T_5). This might be due to the efficient filling of photosynthates from current photosynthesis and partitioning of assimilates to grain leading to the production of grains of greater size (Singh and Singh, 1992).

Yield and economics

Application of magnesium sulphate (20 kg ha-1) with recommended dose of NPK fertilizers, farm yard manure and lime top dressing (T_1) recorded significantly higher grain yield of 7570 and 3883 kg ha-1, respectively during *kharif* and *rabi* season. This was due to the production of more number of panicles per square meter, fertile grains per panicle and heavy panicles. PGPR Mix-1 application with recommended half the dose of chemical fertilizers and lime top dressing (T_5) recorded grain yield of 7355 kg ha^{-1} which was significantly superior to T_4 during *kharif* season and was on par with T_4 during *rabi* season (3520 kg ha-1). The yield enhancement in T_5 might be due to the improved plant growth resulting from the production of growth promoting substances like auxins, increased availability of nutrients by nitrogen fixation, N mineralization and solubilization of P and K and improved uptake of mineral nutrients by the plant (Kaushal *et al*., 2011). PGPR Mix-1 with half the recommended dose of chemical fertilizers, farm yard manure and lime top dressing (T_3) recorded the lowest grain yield of 6598 kg ha-1 and 3253 kg ha-1, respectively during *kharif* and *rabi* seasons. This was mainly attributable to relatively lesser uptake of nutrients, production of lesser number of tillers, and panicles per square meter. Higher benefit cost ratio of 3.25 and 1.67 was recorded during *kharif* and *rabi*, respectively in treatment receiving PGPR Mix-1 with half the recommended dose of chemical fertilizers and lime top dressing (T_5). This might be due to lower cost of cultivation resulting from the reduction in the use of chemical fertilizers and better yield. Even though, the application of magnesium sulphate (20 kg ha-1) with recommended dose of farm yard manure, NPK and lime top dressing recorded the highest grain yield and gross returns, it registered a less benefit cost ratio of 2.82 and 1.55, respectively during *kharif* 2011 and *rabi* 2011-12.

Conclusion

It was concluded that magnesium sulphate (20 kg ha-1) with recommended dose of NPK (90-45-15 kg ha-1), farm yard manure (5 t ha-1) and lime top dressing (250 kg ha-1) can be recommended as the best integrated nutrient management practice for achieving higher yield and NPK bio-fertilizer (PGPR Mix- 1) (2 kg ha-1) with half the recommended dose of NPK (45-22.5-7.5 kg ha-1) and lime top dressing (250 kg ha-1) can be recommended as the best integrated nutrient management practice for higher net returns and benefit cost ratio in transplanted rice.

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