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Partial substitution of nitrogenous fertilizer through organics enhances yield, nutrients uptake and physiological characteristics of transplanted rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted to explore the possibility of substituting fertilizer N with organic manure and bio-fertilizers (Blue Green Algae) in an integrated manner. The experiment was conducted in a randomized block design with 12 different Integrated Nutrient Management (INM) modules with 3 replications involving different levels of nitrogen. All the treatments increased the yield and nutrient uptake significantly over the control. The highest paddy yield (50.51 q ha^{-1}) and uptakes of N and K by plants were recorded in plot where 25% N through green manure + 75% through chemical fertilizer were applied. Similar trend was observed in case of leaf area index at 45 and 90 days after transplanting (DAT) and dry matter accumulation at harvest stage. The maximum uptake of P was recorded in 25% N through Poultry manure + 75% N through Fertilizer. The physiological efficiency of NPK were higher with the application of 100% N through fertilizer.

***Keywords**: Integrated nutrient management, FYM, green leaf manure, poultry manure*

Introduction

Nitrogen (N) application is essential to realize the yield potential of high yielding varieties of rice. But the low recovery of fertilizer N applied to rice, its high cost, low price of grain as well as low purchasing power of the farmers with small holdings are main constraints that keep the rates of N application to rice low in Asia (Prasad and De Datta, 1979). Since the farmers of the region are resource poor, therefore, there is a need for complete or partial substitution of fertilizers, especially N-fertilizers, by locally available organic sources for sustaining rice production (Acharya and Mandal, 2010; Yadav *et al.*, 2013). The concept of INM seeks to sustain soil fertility through an integration of different available nutrient sources and their application methods that will produce maximum crop yield per unit input use (De Datta and Buresh, 1989). The benefits of organic manure for rice are well known (Singh, 1984; Mehdi *et al.*, 2011). In this context, green manure (GM) and farmyard manure (FM) offer greater potential as a feasible and cheap substitute for fertilizer N and to stabilize the income of rice farmers on a sustained basis. Enhancement in yield up to 20-30% and other physiological characteristics as well as better nutrient uptake for rice upon integrated use of these organic manures along with chemical fertilizers were reported by Dixit *et al.* (2000), Kumar *et al.* (2001), Mehdi *et al.* (2011) and Yadav *et al.* (2013).

Sustainable productivity of rice could be achieved only when best nutrient management practices are adopted. Cereal crops consume maximum quantities of major nutrients usually added through fertilizers. Judicious application of inorganic along with organic sources to crops, particularly to rice, is one of the judicious management practices. Moreover, application of imbalanced nutrients like N could lead to declining nutrient-use efficiency making fertilizer consumption uneconomical and adversely affecting the atmosphere (Aulakh and Adhya, 2005) and groundwater quality (Aulakh *et al.*, 2009) causing health hazards and climate change. Under such a condition there is need to explore the possibilities of using the expanding native sources of plant nutrient. The bio- and organic source such as Blue Green Algae (BGA) (Singh and Singh, 1987; Dixit and Gupta, 2000) and organic manure (Chakraborty *et. al*., 1988) are gaining global importance for rice (*Oryza sativa* L.) culture. The BGA can contribute 20-30 kg N/ha to rice crop and can be used alone or in combination with fertilizer. In this context, the present study was undertaken to study the effect of integrated supply of nitrogen through substitution of fertilizer N with green manure, FYM, Poultry manure and blue green algae on yield, nutrients uptake and physiological properties of transplanted rice.

Materials and Methods

A field experiment was conducted at Banaras Hindu University, Agricultural Research Farm, Varanasi, Uttar Pradesh, India during *kharif* seasons of the two consecutive years. The soil of the experimental field was sandy loam with pH, 7.8; EC, 0.38 dS m^{-1}; CEC, 12.70 C mole p^{+} kg^{-1},

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organic carbon, 0.40%; available N (mineralizable N measured through Kjeldahl method), P and K were 201, 19.40 and 221 kg ha^{-1}, respectively The experiment was laid out in a randomized block design with 12 different INM modules involving different levels of N *viz.* T_1-Control (without fertilizer), T_2-100%N through fertilizer urea containing 46% N, T_3-25% N through FM + 75% N through fertilizer, T_4-50% N through FM + 50% N through fertilizer, T_5-75% N through FM + 25% N through fertilizer, T_6-25% N through GM + 75% N through fertilizer, T_7-50%N through GM + 50% N through fertilizer, T_8-75%N through GM + 25% N through fertilizer, T_9-25% N through poultry manure (PM) + 75% N through fertilizer, T_{10}-50% N through PM + 50% N through fertilizer, T_{11}-75% N through PM + 25% N through fertilizer, T_{12}-25% N through FM + 50% N through fertilizer + blue green algae (BGA) at 10kg ha^{-1}. The FM, GM and PM were taken as organic sources of N. The N content in various organic manure were determined to account for amount of N in the respective treatments. The N content in FM, GM and PM were 0.49, 1.60 and 1.42% respectively. Recommended doses of N, phosphorus (P_2O_5) and potassium (K_2O) were 120, 60 and 60 kg ha^{-1}. The all quantities of P_2O_5 and K_2O were applied to rice as single super phosphate and muriate of potash as basal dose to all the plots. Full doses of FYM, Poultry manure and green leaf manure were incorporated 20 days before transplanting of rice seedling whereas half the dose of N as urea was given as basal application, remaining half dose of N was applied in two equal splits at tillering and flowering stages and BGA was applied as bio-fertilizer at 10 kg ha^{-1}. The plant grain and straw samples were collected at harvest and analyzed for total N, P and K (Jackson, 1973). The leaf area index (LAI) was calculated according to the formula given by Watson (1974). The harvest index (HI) was as suggested by Singh and Khangrot (1987).

HI = Economic Yield/Biological Yield x 100

Nutrient Uptake (kg ha^{-1}) = Nutrient content in dry matter (%) x yield of dry matter/100.

Physiological Efficiency of applied N (kg grain per kg N) = [Grain yield with N applied (kg) - Grain yield of control (kg)] /Total N uptake from N treated plot (kg) -Total N uptake of control (kg).

Physiological Efficiency of applied P (kg grain per kg P) = [Grain yield with N applied (kg) - Grain yield of control (kg)] /Total P uptake from P treated plot (kg) - Total P uptake of control (kg).

Physiological Efficiency of applied K (kg grain per kg K) = [Grain yield with N applied (kg) - Grain yield of control (kg)] /Total K uptake from K treated plot (kg) -Total K uptake of control (kg).

Results and Discussion

Grain and straw yield and harvest index

The effect of various integrated nutrient management practices on grain and straw yields of rice showed wide variations among the treatments compared. Inorganic fertilizer and their combination with FYM, green manure and poultry manure influenced the grain and straw yield of rice significantly over the control. On an average, grain yield of rice varied from 19.64 to 50.51 q ha^{-1} with a mean value of 45.36 q ha^{-1} and straw yield from 39.74 to 74.49 q ha^{-1} with a mean value of 69.06 q ha^{-1} (Table 1). Results showed 131 to 157% enhancement in grain yield, while 74 to 87% enhancement in straw yield upon incorporation of various inorganic and organic sources of nutrients over the control. It is obvious from the data that the highest grain and straw yields of crop was found in plots receiving 25% N through GM + 75% N through urea while the lowest in control during both the years. Addition of N as urea alone also increased yields of grain and straw but less than combination with different organic manures. Grain and straw yields under various inorganic fertilizers in combination with organic manures gave better results over fertilizer alone. This is due to improved physical condition of the soil, thereby improving the efficiency of native as well as applied nutrients. These results corroborate with the finding of Jana and Ghosh (1996), Misra and Prasad (2000), Khan *et al.* (2007) and Acharya and Mandal (2010) who reported that for sustained production in a rice-wheat cropping system, INM practices are essential. In control plots receiving no organic manures/residues but as high as 120 kg N ha^{-1}, only 8 t ha^{-1} year^{-1} grains could be produced. The productivity could be achieved by *Sesbania*/cowpea green manuring or application of mung bean residue or FYM with lower dose of N i.e. 80 kg ha^{-1} year^{-1}. Since the availability of farmyard manure, poultry manure are decreasing due to increases mechanization, the generation of in situ organic residues, preferably a legume is a better alternative.

It is evident from Table 1 that the highest HI was observed under the treatment having 25% N through GM+75% N through fertilizer and the lowest harvest index was in control (T_1) during both the years. The highest HI in green manure treated plots was mainly due to higher grain yield. These results corroborated with the finding of Sengar *et al.* (2000).

Leaf area index (LAI)

The LAI at different growth stage of rice crop showed wide variations among the treatments compared (Table 1). On an average, LAI at 45 DAT ranged from 5.33 to 10.06 with a mean value of 9.09 and 90 DAT from 4.48 to 9.33 with a mean value of 8.28. Different organic and inorganic fertilizer treatments were found to have significant effect on leaf area index over control during both the years. The maximum leaf area index (10.06) was found under the treatment 25%N through GM+75% N through fertilizer and it slightly decreased at 90 days after transplanting of rice during both the years (Table 1). Sharma and Mittra (1992) reported that significant positive correlation of grain yield with leaf area index justified the beneficial effect of organic materials on growth and yield of the crop. Green manure decomposed rapidly and supplied N to rice plants due to its narrow C:N ratio, whereas farmyard manure proved advantageous because of depletion of C and initiation of mineralization a few weeks after its application. Poultry manure treated plots were adequately decomposed but growth of rice plants under these sources slowed down at later stages, because of their inadequacy to keep pace with increasing crop demand for nutrients. Similar finding was observed by Sharma and Mittra (1992).

Table 1: Effect of integrated nutrient management on important agro-morphic parameters of rice (pooled data for two years)

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	HI (%)	Dry matter accumulation (kg m^{-2})	Leaf area index	
					45 DAT	90 DAT
Control	19.64	39.74	33.04	0.68	5.33	4.48
100%N through fertilizer	46.84	71.00	39.76	1.25	9.67	8.37
25% N through FM + 75% N through fertilizer	49.13	72.86	40.28	1.30	9.98	9.19
50% N through FM + 50% N through fertilizer	46.87	71.21	39.69	1.26	9.34	8.57
75% N through FM + 25% N through fertilizer	46.52	70.62	39.71	1.25	8.83	8.26
25% N through GM + 75% N through fertilizer	50.51	74.49	40.41	1.33	10.06	9.33
50%N through GM + 50% N through fertilizer	48.60	72.38	40.17	1.29	9.38	8.66
75%N through GM + 25% N through fertilizer	47.10	71.43	39.74	1.27	9.29	8.53
25% N through PM + 75% N through fertilizer	48.78	72.58	40.19	1.30	9.85	8.91
50% N through PM + 50% N through fertilizer	46.58	70.96	39.63	1.26	9.31	8.40
75% N through PM + 25% N through fertilizer	45.55	69.60	39.56	1.23	8.76	8.07
25% N through FM + 50% N through fertilizer + BGA at 10kg ha^{-1}	48.27	71.93	40.16	1.29	9.36	8.62
SEd±	1.28	1.30	-	0.025	0.295	0.346
CD (p = 0.05)	2.65	2.68	-	0.051	0.613	0.717

Dry matter accumulation

The highest dry matter accumulation was recorded with treatment comprising 25%N through GM+75% N through fertilizer which was at par with the treatment receiving 25%N through FM+75% N through fertilizer and lowest dry matter accumulation was recorded in control during both the years (Table 1). Mahapatra *et al.* (1991) and Rao and Sitaramayya (1997) also observed that application of nitrogen had a positive effect on dry matter production of rice and N uptake at harvest in a field experiment. The dry matter accumulation was maximum with green manure treated plots followed by FYM and poultry manure treated plots among the treatments compared to 100%N applied as urea.

Nitrogen content in grain and straw

The effect of various integrated nutrient management practices on nitrogen content in rice grain and straw have been presented in Table 2. The maximum nitrogen content in grain and straw was recorded in the plot where 75% N through GM + 25% N through fertilizer (1.49%) and the lowest N content in grain and straw was observed in control plot (1.15%) during both the years. The N contents in grains as well as in straw increased significantly through application of chemical fertilizers alone or in combination with manures compared with the control. Similar findings were observed by Mandal *et al.* (1992). The increase in N content in grains and straw was due to application of manures, which might be attributed to slow and continuous supply of N throughout the crop growth by these organic manures. The application of green manure, FYM, BGA, poultry manure, and N fertilization increased the N concentration in rice grain and straws.

Phosphorus content in grains and straw

The phosphorus content in rice grain and straw has been influenced considerably by fertilizer and organic manure application during both the years. The incorporation of organics gave significantly higher P content in grain and straw as compared to N fertilizer application alone. Among the treatments, the P concentration in grain and straw was more or less same but significantly higher than control. The maximum phosphorus content in rice grain and straw was observed in plots having 75% N through GM + 25% N through fertilizer, whereas, minimum P content in grain and straw was recorded in control plot during both the years.

inorganic source of fertilizers in a rice-rice crop sequence. The uptake of nitrogen by plants was highest with 75% N through fertilizers applied as inorganic and 25% N as organic sources (Table 3).

Table 2: Effect of integrated nutrient management on N, P and K content (%) of rice (pooled data for two years)

Treatment	N content		P content		K content	
	Grain	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
Control	1.15	0.40	0.26	0.09	0.22	1.66
100%N through fertilizer	1.42	0.51	0.29	0.10	0.24	1.68
25% N through FM + 75% N through fertilizer	1.44	0.54	0.33	0.11	0.27	1.71
50% N through FM + 50% N through fertilizer	1.46	0.56	0.34	0.12	0.28	1.74
75% N through FM + 25% N through fertilizer	1.47	0.58	0.35	0.13	0.29	1.77
25% N through GM + 75% N through fertilizer	1.46	0.56	0.34	0.12	0.28	1.73
50%N through GM + 50% N through fertilizer	1.47	0.58	0.35	0.14	0.29	1.76
75%N through GM + 25% N through fertilizer	1.49	0.59	0.36	0.15	0.30	1.78
25% N through PM + 75% N through fertilizer	1.43	0.53	0.32	0.10	0.29	1.74
50% N through PM + 50% N through fertilizer	1.45	0.55	0.33	0.11	0.30	1.77
75% N through PM + 25% N through fertilizer	1.46	0.57	0.34	0.12	0.31	1.79
25% N through FM + 50% N through fertilizer + BGA at 10kg ha^{-1}	1.47	0.57	0.33	0.11	0.26	1.73
SEd±	0.013	0.010	0.011	0.011	0.010	0.015
CD (p = 0.05)	0.027	0.020	0.023	0.023	0.021	0.031

Potassium content in grain and straw

Data pertaining to K concentration in rice grain and straw have been presented in Table 2. The maximum potassium concentration in rice grain and straw was observed with the treatment supplying 75% N through PM + 25% N through fertilizer, which was at par with all the treatments except control and 100% N through fertilizer during both the years (data not presented). The minimum concentration of K in rice grain and straw was observed with control plot. The difference between all the treatments was non-significant except T_1 and T_2 during both the years. In general, results showed that increased application of organic sources influenced the potassium concentration in rice grain and straw.

Nitrogen uptake

It is obvious from the data that highest nitrogen uptake by rice crop was recorded with the treatment T_6, while minimum in control (T_1). The nitrogen uptake by rice grains, straw as well as total nitrogen uptake increased with the application of N fertilizer alone or in combination with FYM or green manure or BGA over control. Similar trends were found in both the years. The enhanced nitrogen uptake may be due to adequate availability of such nutrient under the treatments in question. The pattern of nitrogen uptake obtained here is similar to that reported by Mondal *et al.* (1994), Singh *et al.* (1994) and Jana and Ghosh (1996) under integrated nutrient management with organic and

Phosphorus uptake

Perusal of data showed that the maximum P uptake in grain was computed under the treatment T_6 receiving 75% N through inorganic fertilizers and 25% N through green manure, while the maximum P uptake by straw was calculated under the treatment T_8 having 75% N through green manure and 25% N through fertilizer and minimum P uptake was computed under control (Table 3). Addition of various organic sources viz., green manure, farmyard manure and poultry manure in combination with inorganic fertilizer increased phosphorus uptake by the crop might be because of enhanced available phosphorus content of soil as well as improved soil physical conditions rendering native phosphorus available. The above results corroborate with the finding of Raju and Reddy (2000). Sreedevi and Thangamuthu (1991) reported that the organic acids produced during decomposition of organic materials in flooded soil resulted in mineralizing the insoluble phosphate in to more soluble phosphorus and this might be the reason for greater phosphorus uptake with green manuring.

Potassium uptake

Effect of various treatments on potassium removal by rice crop is shown in Table 3 it is obvious from the data that highest potassium uptake in grain computed with treatment T_{11} receiving 25% N through inorganic fertilizers and 75% N through poultry manure, while the maximum potassium uptake by straw was observed under the treatment T_6 having 25% N through green manure and 75% N through fertilizer and minimum in control plot in both the years, respectively. Application of organic manures viz., poultry manure, green manure and farmyard manure along with inorganic fertilizer increased potassium uptake by the crop. Among the organic sourcess poultry manure enhanced more potassium uptake by grain as compared to green manure and farmyard manure. The uptake of potassium increased with organic manures due to more availability of potassium with poultry manure and other organic manure and hence increased efficiency of potassium applied. Similar results have been presented by Mondal *et al.* (1994), Jana and Ghosh (1996), and Kumar *et al.* (2001).

Physiological efficiency of N, P and K

Data with respect to physiological efficiency of N, P and K are presented in Table 4. The maximum physiological efficiency of N and P were recorded with the application of 100% N through fertilizer because of good proliferation of roots which could absorb more N as well as P from soil and minimum physiological efficiency of N and P were recorded with the treatment T_8 comprising 75% N through green manure and rest through inorganic fertilizer. In case of physiological efficiency of K the highest value was also observed with the application of 100% N through fertilizer. But minimum physiological efficiency was recorded with application of T_{11} treatment having 75% N

Tables 3: Effect of integrated nutrient management on N, P and K uptake (kg ha^{-1}) by rice (pooled data for two years)

Treatment	N uptake		P uptake		K uptake	
	Grain	Straw	Grain	Straw	Grain	Straw
Control	22.46	15.68	4.99	3.37	4.24	66.03
100%N through fertilizer	66.50	36.22	13.35	6.74	11.23	118.93
25% N through FM + 75% N through fertilizer	70.74	38.98	15.89	7.65	13.03	124.60
50% N through FM + 50% N through fertilizer	68.45	39.51	15.56	8.20	12.89	124.25
75% N through FM + 25% N through fertilizer	68.39	40.60	15.97	8.84	13.26	124.63
25% N through GM + 75% N through fertilizer	73.76	41.36	17.25	8.93	13.90	128.50
50%N through GM + 50% N through fertilizer	71.45	41.62	17.10	9.78	13.86	127.03
75%N through GM + 25% N through fertilizer	70.18	41.80	16.88	10.72	13.90	127.13
25% N through PM + 75% N through fertilizer	69.77	38.11	15.28	6.90	13.90	125.93
50% N through PM + 50% N through fertilizer	67.55	38.67	15.31	7.45	13.75	126.72
75% N through PM + 25% N through fertilizer	66.51	39.32	15.19	8.03	14.13	124.60
25% N through FM + 50% N through fertilizer + BGA at 10 kg ha^{-1}	70.71	40.68	15.70	7.91	12.55	124.44
SEd ±	1.780	1.010	0.560	0.815	0.590	2.785
CD (p = 0.05)	3.700	2.095	1.170	1.700	1.225	5.785

Table 4: Effect of integrated nutrient management on physiological efficiency of N, P and K by rice (pooled data for two years)

Treatment	Physiological efficiency of N (kg grain kg^{-1} N)	Physiological efficiency of P (kg grain kg^{-1} P)	physiological efficiency of K (kg grain kg^{-1} K)
100%N through fertilizer	42.1	232.1	45.4
25% N through FM + 75% N through fertilizer	41.2	187.9	43.8
50% N through FM + 50% N through fertilizer	39.0	176.9	40.7
75% N through FM + 25% N through fertilizer	37.9	163.5	39.7
25% N through GM + 75% N through fertilizer	40.1	173.4	42.8
50%N through GM + 50% N through fertilizer	38.7	156.5	41.0
75%N through GM + 25% N through fertilizer	37.2	142.9	38.8
25% N through PM + 75% N through fertilizer	41.8	210.9	41.9
50% N through PM + 50% N through fertilizer	39.6	187.3	39.2
75% N through PM + 25% N through fertilizer	38.3	174.5	37.9
25% N through FM + 50% N through fertilizer + BGA at 10kg ha^{-1}	39.1	187.9	42.9

through poultry manure+25% N through fertilizer, might be due to the reason that poultry manure contains more amount of K, which led to less competitions among plants for absorption of potassium in soil.

Conclusion

The data indicated that application of 25% N through GM + 75% N through chemical fertilizer resulted in higher grain as well as straw yields, LAI, dry matter accumulation, uptakes of N and P by rice plant. It may be concluded on the basis of results that 25% N requirement through GM or FM or PM may save expenditure on N fertilizers for getting higher yield of rice.

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