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Effect of integrated nutrient management on growth, yield, nutrient uptake and economics of wet season rice (*Oryza sativa*) in Odisha

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ABSTRACT

The experiment was conducted during *kharif* seasons of 2007-08 and 2008-09 at Central Research Station of the Odisha University of Agriculture and Technology, Bhubaneshwar on sandy loam, well drained upland lateritic soil. The experimental soil was low in organic carbon (0.43%), N (228 kg/ha) and K (122 kg/ha) and medium in available P (18 kg/ha). The experiment was laid out in randomized block design with twelve treatments each replicated thrice. The test variety of rice, RGL 2538 (Vasundhara), was raised following the recommended package of practices. Application of 1/3rd recommended dose (RD) of N each through chemical fertilizer; FYM and *Azolla* registered the highest plant height and leaf area index in rice (*Oryza sativa* L.) as compared to other treatment combinations. Higher yield components (viz. number of panicles/m^2, number of filled grains/panicle) and grain and straw yield of rice were also achieved from the same treatment as compared to 100% recommended dose of fertilizer and control. This was at par with the application of 50% RDN as chemical fertilizer + 50% RDN either as *dhaincha* or *Azolla.* N and P uptake by rice was highest with the use of 1/3rd N each as chemical fertilizer, FYM and *Azolla,* but higher K uptake was reported with application of 50% N as chemical fertilizer and 50% N as *dhaincha*. The highest gross return, net return and return per rupee investment were achieved from rice supplied with 1/3rd N each as chemical fertilizer, FYM and *Azolla*. Gross return and net return were significantly superior to that of 100 % chemical fertilizer alone. However, return per rupee investment was at par with that of sole use of chemical fertilizers due to lower cost of cultivation incurred in chemical farming practices.

Key words: *Azolla, Dhaincha,* Economics, FYM, Nutrient uptake, Rice, Yield

Rice (*Oryza sativa* L.) is the staple food crop of 63 to 65 percent people of India. The crop at present is grown in 43 million hectares of land with production of 96.7 million tonnes. Its production has to be raised to 160 million tonnes by 2030 with a minimum annual growth rate of 2.35% (Venkatramani 2005). Use of chemical fertilizers though has increased the crop yield, it has several ill effects on soil, environment as well as human and animal health hazards besides making the crop productivity unsustainable in the long run. Indiscriminate use of high levels of N, P and K fertilizers, often leads to nutritional imbalance particularly for micronutrients which ultimately cause deterioration in physicochemical properties of soil and steadily decrease crop yield (Gupta *et al*. 2000).

This calls for development of integrated nutrient management systems (INMS) where chemical fertilizer is supplemented through organic source of plant nutrients, viz. well decomposed FYM, sugar factory press mud cake, green manures and biofertilizers for improvement and maintenance of soil fertility leading to sustained crop production. In this study efforts were made to find out a suitable proportion and combination of organic sources of plant nutrients with inorganic fertilizers to optimize rice yield.

MATERIALS AND METHODS

The experiment was conducted at Central Research Station of the Odisha University of Agriculture and Technology, Bhubaneswar during 2007-08 and 2008-09 on the same site and layout. The experimental field was well drained upland lateritic soil with bulk density 1.47 g/cc, particle density 2.42 g/cc and field capacity 12.90 %. The soil was sandy loam in texture and was low in organic carbon (0.43%), N (228 kg/ha) and K (122 kg/ha) and medium in available P (18 kg/ha). In 2007-08, rainfall received during the cropping season was 1407.2 mm and during 2008-09 it was 1521.4 mm.

The experiment was laid out in randomized block design with twelve treatments each replicated thrice. The treatments

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were T_1- Control, i e no manure and fertilizer, T_2 -100% RDN (recommended dose of nitrogen, i e 120 kg/ha) as chemical fertilizer (CF through urea), T_3 - 75% RDN as CF+25% RDN as FYM, T_4 -75% RDN as CF+25% RDN as *dhaincha* , T_5 - 75% RDN as CF + 25% RDN as *Azolla* , T_6 - 50% RDN as CF + 50% RDN as FYM, T_7 - 50% RDN as CF +50% RDN as *dhaincha*, T_8 -50% RDN as CF +50% RDN as *Azolla*, T_9 -1/3 rd N as CF +1/3 rd N as FYM +1/3rd N as *dhaincha,* T_{10} - 1/3 rd N as CF +1/3 rd N as FYM +1/3rd N as *Azolla*, T_{11} - 1/3 rd N as CF +1/3 rd N as *Azolla* +1/3rd N as *dhaincha* and T_{12} -50% RDN as CF+ 25% RDN as FYM +*Azospirillum*. The test variety of rice was RGL 2538 (Vasundhara) which is of 125 days duration. Twenty five days old seedlings were transplanted with row spacing of 20 cm and plant spacing of 10 cm at the depth of 2 to 3 cm with 2-3 seedlings/hill. The dates of nursery sowing, transplanting and harvesting of paddy were 25 June, 20 July and 2 November in 2007 and 12 June, 19 July and 19 October in 2008, respectively. Five plants were randomly selected at 30, 45, 60 and 75 DAP and the leaf area was measured by a Systronics leaf area meter Model 211 to compute leaf area index. The crop growth rate (CGR) was calculated on the basis of above ground dry matter accumulation using the formula as suggested by Radford (1967).

To determine the uptake of nutrients at harvest, the grain and straw samples of rice were analyzed for estimation of nitrogen, phosphorous, potassium as per Micro Kjeldahl, Tri-acid extraction followed by Spectro-Photometric method and Flame Photometry, respectively. The economics of cultivation of rice for different treatments was worked out taking into account the cost of various inputs as well as the price of seed and straw as per the prevailing market price during 2007-2008 and 2008-2009. The net returns for each treatment were calculated by deducting the cost of cultivation from the gross returns. Net returns per rupee invested were worked out by dividing the gross returns with the cost of cultivation.

RESULTS AND DISCUSSION

Plant height of rice at harvest exhibited significant differences due to integrated nutrient management (Table 1). At harvest 1/3rd N each through chemical fertilizer, FYM and *Azolla* registered the highest plant height (100.12 cm) as compared to other treatment combinations and was closely followed by application of 50 % RDN as chemical fertilizer + 25% RDN as FYM + *Azospirillum* (98.80 cm), 50 % N each through chemical fertilizer and *dhaincha* (97.95 cm). All these treatments were at par and were superior to sole application of 100 % chemical fertilizer alone. Similar results were reported by Mondal and Adhikary (2005) and Jha *et al*. (2004). This clearly indicated that combination of organic and inorganic sources of plant nutrients had advantageous effect over chemical fertilizer alone. The leaf area index attained the highest value at around 45 days after transplanting. The highest mean leaf area index (3.42) was recorded with use of 1/3rd N as CF + 1/3rd N as FYM + 1/3rd N as *Azolla* . This was closely followed by 100 % chemical fertilizer (3.18), 50% RDN as CF + 50% RDN as *dhaincha*, 1/3rd N as CF + 1/3rd N as FYM + 1/3rd N as *dhaincha* (both at 3.17). The increased plant height in the above mentioned treatments provided more space for formation of new leaves which in turn enhanced the leaf area index. This was in conformity with the findings of Sreedevi and Sreedharan (1999). Application of 1/3rd N each from chemical fertilizer, FYM and *Azolla* with higher leaf area index and more number of tillers/hill registered significantly the highest dry matter accumulation (984.95 g/m^2) at 75 DAT. It might be attributed to the beneficial effect of FYM and *Azolla* which supplied nutrients continuously required by the crop at various growth stages after proper decomposition and mineralization than other organic or chemical sources of nitrogen (Mandal and Adhikary 2005). The dry matter accumulation depends upon the photosynthesis and respiration rate, which finally increases the plant growth with respect to increase in plant height, leaf area and tillers/hill etc. The treatments which attained the highest growth also accumulated the higher dry matter (Jha *et al.* 2004). The treatment next in order was application of 50% N as chemical fertilizer + 50% N as *dhaincha* (884.95 g/m^2).

The crop growth rate was estimated at 30-45, 45-60 and 60-75 DAT during wet seasons of 2007-08 and 2008-09 (Table 1). Application of 100% N through chemical fertilizer showed the highest crop growth rate of 23.23 g/m^2/day. This was closely followed by 50% RDN as chemical fertilizer + 50% RDN as *dhaincha* (23.02 g/m^2/day) and 1/3rd N each as chemical fertilizer, FYM and *Azolla* (22.47 g/m^2/day) at the initial stage. But with advancement of the crop growth stage the integrated nutrient management practices proved to be superior in registering higher crop growth rate with application of 1/3rd N each as CF, FYM and *Azolla* producing maximum crop growth rate of 15.58 g/m^2/day at 45-60 DAT and 9.36 g/m^2/day at 60-75 DAT. Singh *et al.* (2005) also reported that N fixed by *Azolla* and the organic matter if added along with FYM contributed to the available N pool of the soil in later stages of growth to produce higher crop growth rate in rice at 45-60 and 60-75 DAT.

Application of 1/3rd N each from chemical fertilizer, FYM and *Azolla* produced significantly higher number of tillers/m^2, i e 375.75 (Table 2) which was closely followed by 50% N supplied through chemical fertilizer and rest 50% N through *dhaincha* (345.83).The higher number of effective tillers/m^2 at harvest ultimately led to higher grain yield in the corresponding treatments as reported by Natarajan *et al.* (2008).Application of 1/3rd N each from chemical fertilizer, FYM and *dhaincha* registered significantly highest number of grains/panicle (108.33) as compared to 100% recommended dose of fertilizer and control. This was closely followed by the treatment receiving 1/3rd N as CF + 1/3rd N as FYM + 1/3rd N as *Azolla* (107.17) and was at par with

Table 1 Effect of integrated nutrient management on growth parameters of rice (Pooled data of two years)

Treatment	Plant height at harvest (cm)	No. of tillers/hill (45 DAT)	Leaf Area Index			Dry matter accumulation (g/m^2)				CGR (g/m^2/day)		
			30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	75 DAT	30-45 DAT	45-60 DAT	60-75 DAT
T_1-Control (no manure and fertilizer)	80.37	7.2	0.88	2.21	2.03	107.55	276.42	388.87	463.17	11.26	7.50	4.95
T_2-100% RDN as CF	96.40	13.8	1.73	3.18	3.02	250.22	598.67	767.85	883.77	23.23	11.28	7.73
T_3-75% RDN as CF+25% RDN as FYM	92.93	12.2	1.45	2.53	2.43	227.74	549.00	727.73	855.49	21.42	11.92	8.52
T_4-75% RDN as CF+25% RDN as *dhaincha*	94.63	11.9	1.26	2.73	2.65	243.09	534.33	720.24	825.27	19.42	12.39	7.00
T_5-75% RDN as CF+25% RDN as *Azolla*	97.28	11.6	1.20	2.82	2.77	221.92	557.92	754.78	863.83	22.40	13.12	7.27
T_6-50% RDN as CF+50% RDN as FYM	94.18	10.4	1.53	2.89	2.82	236.78	561.58	741.14	867.47	21.65	11.97	8.42
T_7-50% RDN as CF+50% RDN as *dhaincha*	97.95	14.4	1.58	3.17	3.08	238.58	583.83	756.89	884.95	23.02	11.54	8.54
T_8-50% RDN as CF+50% RDN as *Azolla*	96.85	11.1	1.35	3.06	2.92	249.38	576.75	735.74	861.83	21.82	10.60	8.41
T_9-1/3 rd N as CF+1/3 rd N as FYM+ 1/3 rd N as *dhaincha*	95.65	13.2	1.68	3.17	3.02	246.22	569.83	751.06	874.75	21.57	12.08	8.25
T_{10}-1/3 rd N as CF+1/3 rd N as FYM+ 1/3 rd N as *Azolla*	100.12	16.5	1.78	3.42	3.26	273.83	610.92	844.60	984.95	22.47	15.58	9.36
T_{11}-1/3 rd N as CF+1/3 rd N as *Azolla*+ 1/3 rd N as *dhaincha*	97.53	10.5	1.41	3.16	2.93	201.89	523.00	715.74	828.76	21.41	12.85	7.53
T_{12} -50% RDN as CF+25% RDN as FYM +*Azospirillum*	98.80	12.4	1.15	3.13	2.85	194.94	510.83	702.62	805.18	21.06	12.79	6.84
SEm (±)	1.94	0.58	0.09	0.21	0.21	6.50	14.32	26.95	27.72	0.98	1.84	1.04
CD (P=0.05)	5.48	1.65	0.26	0.60	0.60	18.38	40.49	76.21	78.39	2.77	NS	NS

Table 2 Effect of integrated nutrient management on yield parameters and yield of rice (Pooled data of two years)

Treatment	No. of effective tillers/m^2	No. of filled grains/panicle	Test weight (g)	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)
T_1-Control (no manure and fertilizer)	188.33	80.50	21.72	1.58	2.67
T_2-100% RDN as CF	334.42	91.33	22.55	3.87	6.02
T_3-75% RDN as CF+25% RDN as FYM	322.75	86.67	22.07	3.98	5.83
T_4-75% RDN as CF+25% RDN as *dhaincha*	327.00	97.50	22.43	3.98	5.67
T_5-75% RDN as CF+25% RDN as *Azolla*	324.17	93.67	21.78	4.23	5.77
T_6-50% RDN as CF+50% RDN as FYM	326.00	96.00	22.07	4.21	5.88
T_7-50% RDN as CF+50% RDN as *dhaincha*	345.83	103.17	22.47	4.58	6.16
T_8-50% RDN as CF+50% RDN as *Azolla*	318.33	104.33	22.60	4.27	5.93
T_9-1/3 rd N as CF+1/3 rd N as FYM+1/3 rd N as *dhaincha*	333.33	108.33	22.15	4.37	5.64
T_{10}-1/3 rd N as CF+1/3 rd N as FYM+1/3 rd N as *Azolla*	375.75	107.17	22.26	4.88	6.23
T_{11}-1/3 rd N as CF+1/3 rd N as *Azolla*+1/3 rd N as *dhaincha*	302.02	94.83	21.93	3.96	5.39
T_{12} -50% RDN as CF+25% RDN as FYM + as *Azolla*	299.17	91.67	22.33	3.69	5.48
SEm (±)	15.35	3.011	0.327	0.14	0.14
CD (P=0.05)	43.41	8.516	0.924	0.39	0.40

application of 50% RDN as CF + 50% RDN as *dhaincha* (103.17) and 50% RDN as chemical fertilizer + 50% N through *Azolla* (104.33). Application of 50% RDN as chemical fertilizer + 50% RDN as *Azolla* exhibited the highest test weight of 22.60 g.

Pooled analysis of the data revealed that the productivity of rice was the highest (4.88 tonnes/ha) with the use of 1/3rd N each as chemical fertilizer, FYM and *Azolla* (Table 2) which was at par with application of 50% RDN as chemical fertilizer + 50% RDN as *dhaincha* (4.58 tonnes/ha). The same treatment registered the highest straw yield (6.23 tonnes/ha). Variations in performance of rice grown with various integrated nitrogen management practices may be explained due to acceleration in crop growth and yield attributes.

The highest nitrogen uptake by rice grain (63.27 kg/ha), straw (30.69 kg/ha) and total uptake (93.96 kg/ha) was with use of 1/3rd N each as chemical fertilizer, FYM and *Azolla* (Table 3). This was followed by 50% RDN as CF + 50% RDN as *dhaincha* having rice grain uptake of 58.12 kg/ha, straw uptake of 30.61 kg/ha and total uptake of 88.72 kg/ha. The results were in conformity with the findings of Bhaskar (2003). This might be due to increased supply of nutrients directly through organic and inorganic sources to the crop as well as indirectly through reducing the loss of nutrients from soil solution which in turn resulted in better growth, higher biological yield as well as more nutrient concentration. Singh *et al*. (2005) also mentioned that incorporation of *Azolla* and *dhaincha* resulted in addition of N to the available pool of the soil through N_2-fixation thus facilitated higher uptake of N by rice. Beneficial effect of farmyard manure and *Azolla* through their mineralization releasing profuse amount of nitrogen to the soil and checking downward movement of N making it available to the growing crop was also reported by Pathak *et al*. (2005).

The uptake pattern of P was directly influenced by the yield of rice grain and straw. The highest P uptake in rice grain (23.65 kg/ha) and straw (17.15 kg/ha) was observed with application of 1/3rd N each from chemical fertilizer, FYM and *Azolla* resulting in a total P uptake of 40.80 kg/ha and was significantly higher over other treatment combinations. Use of 50% N as chemical fertilizer along with 50% N as *dhaincha* was next in order with a total P uptake of 36.59 kg/ha (Table 3). Higher total uptake of P in the above treatments was the combined effect of higher nutrient content in the plant as well as total biological yield (Singh *et al*. 2005).

The higher uptake of potassium by rice grain was found with application of 1/3rd N each as chemical fertilizer, FYM and *Azolla* (28.63 kg/ha) owing to higher grain yield as compared to other treatments but the K uptake by rice straw was the highest when 50% N was supplied through chemical fertilizer and rest 50% N as *dhaincha* (83.04 kg/ha). However, the total K removal by the crop was highest (110.34 kg/ha) in the later treatment and closely followed by the former one (109.68 kg/ha) and both the treatments were statistically at par.

The highest average net return of ₹ 18 777/ha was achieved in the treatment receiving 1/3rd N each as chemical fertilizer, FYM and *Azolla* to rice crop which was significantly superior to that of application of 100% chemical fertilizer alone (₹ 13 042/ha). This treatment also showed the highest average gross return (₹ 40 926/ha) due to the higher level of

Table 3 Effect of integrated nutrient management on N, P and K uptake of rice (Pooled data of two years)

Treatment	N uptake (kg/ha)			P uptake (kg/ha)			K uptake (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1-Control (no manure and fertilizer)	15.01	10.59	25.60	5.89	5.44	11.33	7.89	32.26	40.15
T_2-100% RDN as CF	49.21	28.37	77.58	18.47	16.57	35.04	22.72	81.10	103.82
T_3-75% RDN as CF+25% RDN as FYM	48.77	27.57	76.33	15.88	13.32	29.19	21.61	75.87	97.48
T_4-75% RDN as CF+25% RDN as *dhaincha*	48.16	26.70	74.87	16.43	14.52	30.95	21.31	72.89	94.20
T_5-75% RDN as CF+25% RDN as *Azolla*	52.77	26.80	79.56	19.37	13.82	33.18	24.79	75.23	100.01
T_6-50% RDN as CF+50% RDN as FYM	52.11	27.24	79.35	17.85	15.21	33.05	24.35	77.29	101.64
T_7-50% RDN as CF+50% RDN as *dhaincha*	58.12	30.61	88.72	20.74	15.85	36.59	27.30	83.04	110.34
T_8-50% RDN as CF+50% RDN as *Azolla*	53.85	28.16	82.01	18.83	13.95	32.78	24.47	78.19	102.66
T_9-1/3 rd N as CF+1/3 rd N as FYM+1/3 rd N as *dhaincha*	54.78	26.25	81.03	20.39	14.64	35.03	24.19	74.74	98.92
T_{10}-1/3 rd N as CF+1/3 rd N as FYM+1/3 rd N as *Azolla*	63.27	30.69	93.96	23.65	17.15	40.80	28.63	81.05	109.68
T_{11}-1/3 rd N as CF+1/3 rd N as *Azolla*+1/3 rd N as *dhaincha*	47.76	25.03	72.80	17.92	13.19	31.11	23.01	70.42	93.43
T_{12} -50% RDN as CF+25% RDN as FYM + as *dhaincha*	44.10	26.24	70.34	16.37	13.47	29.84	20.61	70.14	90.75
SEm (±)	1.75	1.06	2.00	0.63	0.51	0.77	1.15	1.95	2.09
CD (P=0.05)	4.94	3.00	5.64	1.78	1.43	2.16	3.25	5.50	5.91

Table 4 Effect of integrated nutrient management on economics of rice (Mean data of two years)

Treatment	Gross return (₹/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)	Return per rupee investment (B:C)
T_1-Control (no manure and fertilizer)	13 743	16 671	–2 928	0.82
T_2-100% RDN as CF	33 262	20 220	13 042	1.65
T_3-75% RDN as CF+25% RDN as FYM	33 933	21 637	12 297	1.57
T_4-75% RDN as CF+25% RDN as *dhaincha*	33 817	21 534	12 282	1.57
T_5-75% RDN as CF+25% RDN as *Azolla*	35 737	20 714	15 022	1.73
T_6-50% RDN as CF+50% RDN as FYM	35 693	22 413	13 280	1.59
T_7-50% RDN as CF+50% RDN as *dhaincha*	38 627	22 354	16 273	1.73
T_8-50% RDN as CF+50% RDN as *Azolla*	36 153	20 868	15 285	1.73
T_9-1/3 rd N as CF+1/3 rd N as FYM+1/3 rd N as *dhaincha*	36 698	20 601	16 097	1.78
T_{10}-1/3 rd N as CF+1/3 rd N as FYM+1/3 rd N as *Azolla*	40 926	22 149	18 777	1.85
T_{11}-1/3 rd N as CF+1/3 rd N as *Azolla*+1/3 rd N as *dhaincha*	33 499	20 601	12 898	1.63
T_{12} -50% RDN as CF+25% RDN as FYM +*Azospirillum*	31 488	21 842	9 647	1.44

Sale price: ₹/tonnes, Grain 7500, Straw 700

yield achieved in these treatments due to balanced fertilization (Table 4). This was in conformity with the findings of Natarajan *et. al.* (2008).

The return per rupee invested was the highest in the treatment receiving 1/3rd N each as chemical fertilizer, FYM and *Azolla* (₹ 1.85). This was closely followed by use of 1/3 rd N as CF+1/3 rd N as FYM+1/3 rd N as *dhaincha* (₹ 1.78).

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