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Integrated nutrient management module to improve productivity and economics of short grain aromatic rice (*Oryza sativa*)-greengram (*Vigna radiata*) sequence

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ABSTRACT

The present field study was carried out during 2017–18 and 2018–19 rainy (*kharif*) and winter (*rabi*) seasons in order to examine the impact caused by integrated nutrient management (INM) on the yield and quality of the short grain aromatic rice (*Oryza sativa* L.)-greengram (*Vigna radiata* L.) combination. Two years experimental data concluded that integration of 50% recommended dose (RD) as fertilizer + 50% RD of nitrogen via farm yield manure (FYM) resulted in considerably higher economic yield (3837.1 and 3917.7 kg/ha) of short grain aromatic rice cv. Nua Acharamati which were at par with 75% RD as fertilizer + green manuring of dhaincha (3438.5 and 3539.1 kg/ha). Pooled data revealed that, residual effect of 50% RD as fertilizer + 50% RD of nitrogen (FYM) and 75% RD as fertilizer + *Rhizobium* + PSB in greengram recorded the highest number of pods/plant (18.2), seeds/pod (11.3), pod length (9.3 cm), test weight (32.7 g), seed yield (925.7 kg/ha) and stover yield (2240.7 kg/ha) in greengram cv. IPM-02-03. Application of 50% RD as fertilizer + 50% RD of nitrogen (FYM) to aromatic rice recorded the highest hulling recovery (75.8 and 75.5%), milling recovery (68.0 and 68.3%), head rice recovery (60.0, 59.7%) and crude protein content (8.75 and 9.11%) during both of the years experiment being at par with application of 75% RD as fertilizer + green manuring. Economics of the system revealed the highest gross return, net return and B:C ratio by application of 50% RD as chemical fertilizer + 50% RD of nitrogen (FYM) in rice followed by 75% RD as chemical fertilizer + *Rhizobium* + PSB in greengram.

Keywords: Economics, Head rice recovery, Hulling per cent, Protein content, Short grain aromatic rice

Aromatic rice (*Oryza sativa* L.) is a generic term adopted interchangeably with Basmati rice across India and foreign markets. Apart from considerable demand of long and extra-long grain basmati rice in international rice trade, non-basmati type short grain aromatic rice has fetched a unique position owing to its premium quality and aroma (Puhan and Das 2018). Owing to the presence of popcorn-like aroma by 2-acetyl-1-pyrroline (2-AP) as well as essential lysine, leucine and other amino acids, these rice grains are ingested locally as pulao, pudding or desert. Given their distinct and strong fragrance and extended retention capability in warmer climates, short grain aromatic rice has an advantage over basmati rice. In the last few years, the market for aromatic rice has grown to a greater degree for both local consumption and export.

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The intensive rice-rice growing strategy in irrigated areas or keeping rice fallow in rainfed areas along with indiscriminate use of inorganic fertilizers in Eastern India jeopardizes the soil and crop microclimate and atmospheric environment. The growing price of chemical fertilizers along with shortage of nitrogenous fertilizers in market at peak time of rice cultivation has rekindled curiosity about introducing low cost and locally available organic sources of nutrients into soil which can substitute a part of inorganic sources used (Mangaraj *et al.* 2018, 2023). Short duration pulses like greengram (*Vigna radiata* L.) are an effective option for crop diversification in rainfed environments, harnessing residual soil moisture to improve system yield and farmer economics (Acharya and Mondal 2011, Baishya *et al.* 2014). On the other hand, slow and gradual availability of release of nutrients owing to decomposition of organic matter by incorporation of organic inputs like farm yard manure, sesbania, biofertilizers like *Azotobacter, Azospirillum, Rhizobium,* PSB fosters quality of grains along with soil biodiversity, while boosting the efficiency of rice-based cropping systems. Considering all of the aforementioned factors into consideration, the present research investigation was conceived to analyze the impact of the integrated nutrient management (INM) module on the productivity, profitability, and quality of a short grain aromatic rice-greengram sequence grown under rainfed scenarios.

MATERIALS AND METHODS

The present study was carried out at instructional farm of the Odisha University of Agriculture and Technology, Bhubaneswar, Odisha during rainy (*kharif*) and winter (*rabi*) seasons in 2017–18 and 2018–19. The soil was sandy loam in texture having good water holding capacity and internal drainage. The soil was moderately acidic in response (*p*H 5.66), had a low level of organic carbon (3.82 g/kg), a poor available $KMnO_4$-nitrogen (199.32 kg/ha), a medium readily available Brays'-phosphorus (17.33 kg/ha), and a medium available NH_4OAc-potassium (269.14 kg/ha). The research trial consisting of rice-greengram cropping system was designed in split-plot with a total of three replications. During *kharif* 2017 and 2018, main plots involving integrated nutrient management modules, i.e. M_1, Full RD (100%) as chemical fertilizer (CF) (60:30:30 kg/ha NPK); M_2, 75% RD as CF + 25% RD of nitrogen (FYM); M_3, 50% RD as CF + 50% RD of nitrogen (FYM); M_4, 50% RD as CF + 25% RD of nitrogen (FYM); M_5, 5% RD as fertilizer + green manuring (GM) and; M_6, 50% RD as fertilizer + GM were designed in randomised block design with three replications. *Azotobacter* and *Azospirillum* @200 g each were mixed with 12 kg FYM are incorporated in all treatments at the time of transplanting. After harvesting of aromatic rice crop, three INM strategies including S_1, 100% RD as chemical fertilizer (CF) (20:40:40 N kg/ha NPK); S_2,75% RD as CF and; S_3, 75% RD as CF + *Rhizobium* + PSB in greengram as the sub-plots in *rabi* season. The experiment was started in the year 2017–18 with short grain aromatic rice as *kharif* season crop followed by greengram as *rabi* season crop. In *kharif* season, the main plot treatments were allotted randomly to different experimental units of rice and in *rabi* season, the sub plot treatments to greengram were allotted randomly within main plots of rice (*kharif* aromatic rice). The same experiment was repeated during 2018–19 without changing the layout and randomization of treatments. Short grain aromatic rice cv. Nua Acharamati and greengram cv. IPM-02-03 were used in the experiment.

Organic manures (FYM and dhaincha) were applied to rice crops based on the treatments. Dhaincha (*Sesbania aculeata*) was sown on onset of monsoon in respective treatments and incorporated at 40–42 DAS. Before incorporation of organic manures, NPK contents were analysed and presented in Supplementary Table 1. For the purpose of determining hulling recovery percentage, 100 g of well-dried rice with rough texture had been hulled in a small rice huller, then the quantity of brown rice had been measured.

$$\text{Hulling recovery (\%)} = \frac{\text{Weight of brown rice (g)}}{\text{Weight of rough rice (g)}} \quad \text{(Hallick and Kelly 1959)}$$

For determining milling recovery per cent, hulled brown rice samples were milled for 5 min and the polished rice was weighed and calculated as:

$$\text{Hulling recovery (\%)} = \frac{\text{Weight of milled rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

The head rice recovery was computed by manually sorting the whole grain and three-quarters grains and presented as a percentage.

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of whole milled rice (g)}}{\text{Weight of rough rice (g)}} \times 100$$

Protein content (%) of short grain aromatic rice was calculated by multiplying nitrogen content of grain by a factor of 6.25 (Tsen and Martin 1971).

For computing greengram yield, the pods were picked up from randomly selected five plants of each plot and counted the average number of pods/plants, seeds/pod, pod length and 1000-seed weight. Yield from the net plot was threshed separately to obtain clean seeds. The plot wise seed yield and stover yield were recorded after drying the seed and stover under sun to a standard moisture condition. The seed yield and stover yield of crop per plot was then converted to yield per hectare (kg/ha).

RESULTS AND DISCUSSION

Yield attributes of rice and greengram: INM strategies applied to short grain aromatic rice significantly improved the grain yield as compared to chemical fertilizer alone as illustrated in Fig 1. Application of (M_3) 50% RD (CF) + 50% RD of nitrogen (FYM) resulted in significantly higher grain yield (3837.1 and 3913.7 kg/ha) during first and second year of experiment, respectively which was at par with 75% RD (CF) + GM (M_5). Further, M_5 treatment and M_6 treatment were at par with each other with respect to grain yield. The treatment receiving 50% RD (CF) + 25% RD of nitrogen (FYM) (M_4) produced the lowest grain yield. Efficient photosynthate transport towards the sink possibly benefitted cell functions throughout panicle development giving rise to excellent filling of grains which in turn increased the grain yield. The aforementioned result was backed up by Gogoi *et al.* (2010), Mohanty *et al.* (2013), Alagappan and Venkitaswamy (2016) and Verma *et al.* (2020). Integration of organic manure sources like FYM, GM and biofertilizers along with inorganic sources release the macro and micro nutrients slowly and gradually synchronising with demand of nutrients from plants at the time of peak need eliminating the loss of inorganic fertilisers from soil. Due to synchrony in demand and supply of nutrients, physio biochemical processes like C assimilation, formation of starch, translocation of proteins etc enhanced and a major portion of assimilates moved from source to sink and help during panicle differentiation stage resulting in higher grain yield of aromatic rice (Bhatt *et al.* 2017, Sharma *et al.* 2018, Meena *et al.* 2020).

Residual effect of INM strategies applied to aromatic rice crop as well as INM practices to greengram marked

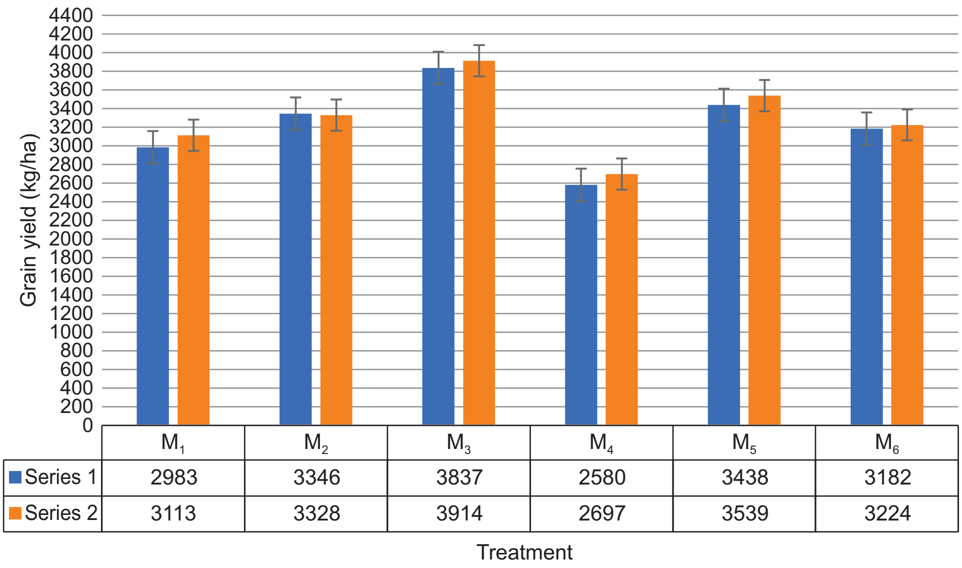

Fig 1 Grain yield of short grain aromatic rice (kg/ha) in 2017 and 2018. Treatment details are given under Materials and Methods.

Among all the treatments, M_4S_2 treatment recorded the lowest yield attributes of greengram (10.7, 5.7, 5.1 cm, 27.7 g, 400.6 kg/ha and 1436.0 kg/ha, respectively). Under rainfed situations, residual soil moisture along with residual and carry over supply of organic sources like FYM, green manures aids in meeting the nutrient demand-supply for growth of greengram crop and helps in sustaining the productivity in rice-greengram cropping system. Also, incorporation of biofertilizers (*Rhizobium* and PSB) along with inorganic fertilizers to greengram have synergistic effect on availability of nutrients to pulse crop by fixation of nitrogen in root nodules from atmosphere and solubilization of insoluble phosphate to readily available phosphate by PSB. These results are in conformity with Pal *et al.* (2006), Alagappan and Venkitaswamy (2016), Mahunta *et al.* (2016), Dewangan *et al.* (2017) and Pandey *et al.* (2019).

significant increase in yield attributes of greengram in both years of study (Table 1). Significantly higher pods/plant, seeds/pod, pod length (8.26 and 8.30 cm), test weight (30.9 and 31.7 g), seed yield (798 and 815 kg/ ha) and stover yield (1953 and 1922 kg/ha) in 2017–18, 2018–19 were recorded due to M_3S_3 followed by M_6S_3, $M_6S_1$and M_2S_3.

Table 1 Yield attributes of greengram as influenced by integrated nutrient management practices

Treatment	Pods/ plant	Seeds/ pod	Pod length (cm)	Test weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)
M_1S_1	11.8	6.7	5.9	29.4	524.6	1503.9
M_1S_2	11.3	6.0	5.2	28.4	444.5	1331.1
M_1S_3	12.6	7.8	6.3	30.2	604.8	1697.9
M_2S_1	13.8	8.8	6.3	30.5	628.1	1718.9
M_2S_2	12.9	8.4	6.1	29.0	574.8	1605.8
M_2S_2	15.4	9.6	6.7	31.3	657.2	1773.0
M_3S_1	16.3	11.0	8.4	31.3	811.7	2034.2
M_3S_2	15.2	10.3	7.1	29.8	680.8	1737.4
M_3S_3	18.2	11.0	9.3	32.7	925.7	2240.7
M_4S_1	11.2	6.4	5.5	28.5	490.7	1488.8
M_4S_2	10.7	5.7	5.1	27.7	400.6	1436.0
M_4S_3	11.8	7.2	5.9	29.6	550.0	1537.0
M_5S_1	13.5	9.3	6.7	29.5	697.8	1833.9
M_5S_2	12.1	8.7	6.0	28.0	630.8	1754.6
M_5S_3	15.0	9.4	6.9	30.1	823.7	1930.8
M_6S_1	15.7	10.8	8.0	30.9	535.0	1593.3
M_6S_2	15.4	10.1	7.7	30.0	503.9	1536.6
M_6S_3	16.3	11.3	8.4	31.7	572.9	1693.4
SEm±	0.30	0.11	0.22	0.32	24.7	40.3
CD (P=0.05)	0.42	0.31	0.31	0.92	35.0	114.8

Treatment details are given under Materials and Methods.

Table 2 Quality parameters of short grain aromatic rice as influenced by integrated nutrient management practices

Treatment	Hulling (%)		Milling (%)		Head rice recovery (%)		L/B ratio of kernel		Kernel length after cooking (mm)		Crude protein (%)	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
M_1	70.0	70.4	63.1	63.6	54.8	53.9	1.76	1.72	7.20	7.08	7.83	7.95
M_2	71.1	71.6	64.2	65.0	56.9	56.4	1.75	1.71	7.21	7.10	8.15	8.27
M_3	75.8	75.9	68.0	68.3	60.0	59.7	1.77	1.72	7.24	7.16	8.86	9.11
M_4	70.3	71.0	62.3	62.5	54.3	53.9	1.74	1.70	7.15	7.06	7.94	8.08
M_5	75.1	75.5	66.1	66.6	59.1	59.0	1.77	1.72	7.23	7.16	8.46	8.71
M_6	73.1	71.4	63.4	63.7	55.6	54.7	1.75	1.71	7.19	7.14	8.00	8.19
SE(m)±	0.49	0.81	0.95	0.78	0.42	0.27	0.01	0.01	0.03	0.03	0.07	0.11
CD (P=0.05)	1.56	2.55	2.99	2.45	1.32	0.85	NS	NS	NS	NS	0.22	0.33

Treatment details are given under Materials and Methods.

Quality parameters of short grain aromatic rice: Data on quality parameters of short grain aromatic rice are depicted in Table 2. Among various integrated nutrient management strategies adopted in short grain aromatic rice, application of 50% RD (CF) + 50% RD of nitrogen (FYM) (M_3) recorded the highest hulling recovery (75.8 and 75.5%), milling recovery (68.0 and 68.3%), head rice recovery (60.0 and 59.7%) and crude protein content (8.86 and 9.11%) which was at par with application of 75% RD (CF) + GM (75.1 and 75.5; 66.1 and 66.6; 59.1 and 59.0; 7.83 and 7.95% respectively). Lowest hulling recovery, milling recovery, head rice recovery per cent and crude protein content were found from 100% RD (CF) treatment. Combination of chemical fertilizer with FYM and green manure increased hulling and milling recovery owing to undisrupted supply of nutrients throughout crop growth period resulting in better quality of grain. Considerable improvement in head rice recovery could be related to an expansion of kernel length of short grain aromatic rice resulting from organic manure superimposition. Increasing sunlight duration during the grain filling phase leads to improved transportation of photosynthates to sink, which boosts grain quality. These results were confirmed with Harikesh *et al.* (2017), Ramesh *et al.* (2019) and Chaudhary *et al.* (2021). Mangaraj *et al.* (2021) stated that applications of organic manures with chemical fertilizers were increasing milling quality and enhancing head rice recovery of rice. Improvement in quality parameters due to combined use of organic and inorganic nutrient sources was also reported by Mangaraj *et al.* (2021). Increasing crude protein content from INM treatments applied to aromatic rice might be explained by sustained N supply as well as efficient N translocation to grain; higher levels of nitrogen in grain modified the percentage of grain component.

Economics of the system: Economics of rice-greengram were influenced by integrated nutrient management practices to rice and greengram (Table 3). The treatment receiving 50% RD (CF) + 50% RD of nitrogen through FYM had the highest cost of cultivation (₹68909 and 71407/ha) followed by application of 75% RD as fertilizer + 25% RD of nitrogen through FYM (₹65536 and 67624/ha) during 2017 and 2018, respectively. Lowest cost of cultivation was recorded by 100% RD as fertilizer (₹61534 and 63211/ha) in 2017–18 and 2018–19, respectively. Highest gross return (₹140050 and

Table 3 Economics of rice-greengram cropping system as influenced by integrated nutrient management practices

Treatment	Cost of cultivation (₹/ha)		Gross return (₹/ha)		Net return (₹/ha)		B:C ratio	
	2017	2018	2017	2018	2017	2018	2017	2018
Nutrient management in rice								
M_1	61534	63211	101239	106059	39705	42848	1.64	1.68
M_2	65536	67624	116237	117088	50701	49463	1.77	1.73
M_3	68909	71407	140050	142914	71141	71506	2.03	2.00
M_4	64147	66235	88877	94228	24730	27992	1.39	1.42
M_5	64506	66183	124606	128986	60100	62803	1.93	1.95
M_6	62886	64563	106337	109541	43451	44978	1.69	1.70
Nutrient management in greengram								
S_1	64824	66442	113305	116103	48480	49661	1.74	1.74
S_2	63967	65585	107294	111593	43327	46008	1.67	1.70
S_3	64967	67585	118074	121712	53107	54127	1.81	1.80

Treatment details are given under Materials and Methods.

142914/ha), net return (₹71141 and 71506 /ha) and B:C ratio (2.03 and 2.00) were recorded with the treatment receiving 50% RD as fertilizer + 50% RD of nitrogen through FYM followed by 75% RD as fertilizer + green manuring and 75% RD as fertilizer + 25% RD of nitrogen through FYM during 2017 and 2018, respectively. Lowest gross return, net return and B:C ratios were obtained in 50% RD as fertilizer + 25% RD of nitrogen through FYM. The treatment receiving 75% RD as fertilizer + *Rhizobium* + PSB in greengram recorded the highest cost of cultivation (₹64967 and 67585/ha), gross return (₹118074 and 121712/ha), net return (₹53107 and 54127/ha) and B:C ratio (1.81 and 1.80) during 2017 and 2018, respectively followed by 100% RD as fertilizer. Lowest values were recorded from 75% RD as fertilizer treatment (Table 3).

Based on two years of field experiment, it was concluded that the highest grain/seed yield of short grain aromatic rice and greengram can be obtained by substituting 50% inorganic sources of nutrients with application of farm yard manure or *in situ* green manuring of dhaincha. Similarly, the quality traits like hulling recovery, milling recovery, head rice recovery and crude protein content of short grain aromatic rice can be improved by integrated nutrient management practices along with higher gross return, net return and B:C ratio of the cropping system compared to sole inorganic fertilizer application.

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