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Research Article

INTEGRATED NUTRIENT MANAGEMENT PRACTICES ON YIELD ATTRIBUTES, YIELD AND NUTRIENT UPTAKE OF HYBRID RICE GROWN UNDER SYSTEM OF RICE INTENSIFICATION - MUSTARD CROPPING SEQUENCE

NAYAK A.[1]*, MANDI N.[1], MAHAPATRA A.[2] AND KHANDA C.M.[1]
[1]Regional Research and Technology Transfer Station, Bhawanipatna, 766001, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 751003, India
[2]AICRP on Sunflower, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 751003, India
*Corresponding Author: Email - anshumanouat@gmail.com

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Abstract: The field experiment was conducted during 2013-14 and 2014-15 at Regional Research and Technology Transfer Station (RRTTS) of Orissa University of Agriculture and Technology (OUAT), Bhawanipatna to evaluate the effect of Integrated Nutrient Management (INM) practices on yield, yield attributes and nutrient uptake of hybrid rice grown under System of Rice Intensification (SRI) –mustard cropping sequence. The results revealed that application of 120-60-60 kg N-P_2O_5-K_2O (RDF) + FYM 5 t ha^{-1} with split application of N, ¼at transplanting (TP), ½ at active tillering (AT) and ¼ at panicle initiation(PI) registered significantly higher effective tillers m^{-2} (183), filled grains panicle^{-1} (213), grain yield (7545 kg ha^{-1}) and straw yield (7241kg ha^{-1}) of hybrid rice Ajay. The yield attributes and yield of mustard differed significantly with the residual effect of the nutrient management practices adopted in rice. At harvest, significantly higher siliquae plant $^{-1}$, seeds siliqua^{-1}, 1000 seed weight and seed yield (806 kg ha^{-1}) were recorded in the treatment applied with 100% RDF + 5 t FYM ha^{-1} with split application of N ¼ at transplanting, ½ at active tillering and ¼ at panicle initiation. Higher siliquae plant $^{-1}$, seeds siliqua^{-1}, 1000 seed weight and seed yield (805 kg ha^{-1}) were recorded with basal application of 20-10-10 kg N-P_2O_5-K_2O (50% RDF) + 5 kg ha^{-1} *Azotobacter* and PSB to mustard. The treatment combination of RDF+5 t FYM (¼ N at TP, ½ N at AT and ¼ N at PI stage) to rice and 50% RDF+ Biofertilizer(BF) to mustard recorded highest Rice Equivalent Yield(REY) of 10122 kg ha^{-1} as well as total N, P and K uptake of 146.6, 51.1 and 219.0 kg ha^{-1}, respectively by the rice-mustard sequence..

Keywords: *INM, Hybrid rice, SRI, Mustard, Nutrient uptake*
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Introduction

During Green Revolution, the spread of rice-rice system was the predominant one in the eastern parts of India which caused an eclipse on productivity and sustainability of the system in post Green Revolution era. The main reason behind yield stagnation and declining soil productivity of the rice-rice system is attributed mainly to the monotony of the system as well as the over exhaustive nature of the cereal-cereal crop sequence with huge exploitation of soil resource base coupled with imbalanced use of inputs. Moreover, the rice production in the country remains stagnant over a decade because of reduction in cultivated area, indiscriminate use of agro-chemicals and biotic and abiotic stress factors. System of rice intensification (SRI) developed in Madagascar by Henri de Laulanie seems to be an alternative to conventional rice production technology for improving productivity of rice. SRI offers the opportunity to achieve the yield potential already existing in rice genome through a change in plant, soil, water and nutrient management resulting in both improvement of soil health and increased yield. As the productivity of hybrid rice was about 8.0 to 10.0 t ha^{-1} with yield advantage of 30% over conventional variety [1], adoption of hybrids may help to raise the rice productivity in India. Mishra *et al*. (2013) [2] pointed out that inclusion of high value and high-volume crop like oilseed in the rice based cropping system improves the economic condition of the farmers, particularly small and marginal farmers of Odisha, owing to higher productivity and net return from unit area. Due to high productivity and low water requirement, the oilseed crop like mustard adds profitability to the traditionally cereal based cropping system, helps to break the cycle of soil borne pathogens and is potentially suitable for double cropping systems like rice-mustard, maize-mustard and sorghum-mustard. The current crop production systems are characterized by inadequate and imbalanced uses of fertilizers. Future gains in productivity and input use efficiency require soil and crop management technologies that are tailored to specific cropping system. In Eastern India, farmers mostly invest in nitrogenous fertilizer and very little on P and K fertilizers. The average fertilizer use in Odisha is 57.11 kg ha^{-1} against the national average of 125.39 kg ha^{-1} with N, P and K use ratio of 5.5: 2.08: 1 during 2013-14 [3]. Nutrient supply exclusively through inorganic sources is not sustainable over the years and there has been reduction in overall response of applied fertilizers in terms of increase in output. Nutrient management must be sound to produce quality produce by optimum uptake of nutrients. Application of organics along with inorganic fertilizers results in increasing productivity of the system which sustains the soil health for longer period (Singh et al., 2013)[4].Hence, the present experiment was designed to study the comparative effects of different integrated nutrient management practices on yield attributes, yield and nutrient uptake of rice - mustard cropping system.

Material and Methods

The field experiment was conducted at RRTTS, Bhawanipatna having latitude 19.550 N, longitude 83.90 E and height 245m above mean sea level during 2013-14 and 2014-15. Rice was grown in *kharif* season in RBD and mustard was sown during *rabi* season in split plot design with three replications. The treatment combinations wereK1:120- 60-60 kg N-P_2O_5-K_2O ha^{-1} (⅓ N each at transplanting (TP), active tillering (AT) and panicle initiation (PI)), K2:50% RDF(⅓ N each at TP, AT and PI) + FYM 5t ha^{-1}, K3:75%RDF (⅓ N each at TP, AT and PI) + FYM 5t ha^{-1} , K4:100% RDF (⅓ N each at TP, AT and PI) + FYM 5t ha^{-1}, K5:100% RDF (½ N at TP, ¼ N at AT, ¼ N at PI) +FYM 5 t ha^{-1}, K6:100% RDF (¼ N at TP, ½ N at AT,

¼ N at PI) + FYM 5 t ha^{-1}, K7:50% RDF (⅓ N each at TP, AT and PI) + FYM 10 t ha^{-1} and K8:FYM 5 t ha^{-1} + Vermicompost (VC) 2.5 ha^{-1} + *Azospirillum* 5 kg ha^{-1} + PSB 5kg ha^{-1}. Hybrid rice var. Ajay was grown under SRI method. During *rabi*, the eight *Kharif* season plots were taken as main plot and three nutrient management practices v*iz*., R1-100% RDF (40-20-20 kg N-P_2O_5-K_2O ha^{-1}), R2- 50% RDF + *Azotobacter* and PSB @ 5 kg ha^{-1} each (Biofertilizer- BF) and R3-control (no fertilizer) were taken in subplot. Altogether twenty-four treatment combinations were imposed in split plot design during *rabi* season to mustard (cv. Anuradha). The soil of the experimental site was silty clay with neutral pH (6.6), high in organic carbon content (0.70%), low in available N (132.5 kg ha^{-1}), medium in available phosphorus (11.8 kg P ha^{-1}) and high in available potassium (338.7 kg K ha^{-1}). Twelve days old seedlings were transplanted with a spacing of 25cm x 25cm and mustard was sown with row to row spacing of 30cm and plant to plant distance of 10cm. FYM, vermicompost and bio-fertilizers were applied before transplanting of rice crop as per treatment. Full does of phosphorous and potassium were applied as basal before transplanting and nitrogen was applied as basal and two top dressing at active tillering and panicle initiation stage of rice as per treatment. The biofertilizers *Azospirillum* / *Azotobacter* 5kg ha^{-1} + PSB 5kg ha^{-1} were inoculated with FYM two days prior to application in field. The bio-fertilizers and chemical fertilizers were applied to mustard at the time of sowing according to the treatment. The source of N, P_2O_5 and K_2O were Urea, Di-ammonium phosphate and Muriate of potash. Observations recorded in the two years experiment on yield attributes and yield were pooled together and system productivity in terms of rice equivalent yield (REY) were also calculated on pooled data. The N, P and K contents of rice grain and straw and mustard seed and stover were determined at harvest. The N, P and K analysis in plant materials were done by micro-kjeldahl, vanadomolybdate acid yellow colour and flame photometry method, respectively. The N, P and K uptake by grain and straw of rice and seed and stover of mustard were calculated separately by multiplying the respective yield with corresponding nutrient content and were expressed in kg ha^{-1}. The moisture content in respective plant parts was taken into account for determining nutrient uptake

The total uptake of a particular nutrient was found by adding the individual uptake values for grain and straw in case of rice and for seed and stover in case of mustard. The biometric data and yield of grain and straw/stover recorded during pre-harvest and post-harvest stages were compiled in appropriate tables and analyzed statistically by applying "Analysis of Variance" (ANOVA) technique for a randomized block design for data on rice crop and split-plot design for data on mustard and cropping system (Gomez and Gomez, 1984)[5]. Standard error of mean (SEm ±) was determined in all the cases, while least square difference (LSD) at 5% level of significance was estimated only in cases where 'F' test was found significant.

Results and Discussion

Yield attributes and yield of hybrid rice

The integrated nutrient management (INM) practices imposed on *kharif* hybrid rice grown under system of rice intensification (SRI) had significantly influenced number of effective tillers (ET) m^{-2}, filled grains panicle-1, 1000 grain weight, grain yield and straw yield during both the years of study. Maximum effective tillers m^{-2} (179, 188 and 183), filled grains panicle-1(203, 22 and 213), 1000 grain weight (26.5, 26.4 and 26.4 g), straw yield (7042, 7439 and 7241 kg ha^{-1}) and grain yield (7248, 7805 and 7545 kg ha^{-1}) were observed in application of FYM 5 t ha^{-1} along with 100% recommended dose of fertiliser (RDF) with split application of N as ¼ at transplanting, ½ at active tillering and ¼ at panicle initiation (K6), respectively. The treatment with 5 t FYM + 2.5 t VC + *Azospirillum* and PSB 5kg ha^{-1} each (K8) recorded minimum number of effective tillers m^{-2} [Table-1].

The number of effective tillers m^{-2} and filled grains panicle^{-1} in 100 % RDF (¼ N at TP, ½ N at AT, ¼ N at PI) + FYM 5 t ha^{-1} were 44, 53.7%and 26.7, 29.8% higher than inorganic and organic source of nutrition, respectively. Gautam *et al*. (2013) [6] also recorded higher effective tillers m^{-2}, spikelete panicle^{-1}, 1000 grain weight with integrated application of FYM and fertilizer than over application of inorganic fertilizers. Growing hybrid rice in SRI with organic source of nutrients (FYM) only did not result in higher grain yield as compared to 100% inorganic fertilizer application (Reddy et al., 2013)[7].The grain yield (7545 kg ha^{-1}) due to application of FYM 5 t ha^{-1} along with recommended dose of fertiliser (RDF) with split application of N as ¼ at transplanting, ½ at active tillering and ¼ at panicle initiation increased by 59 % over RDF (4745 kg ha^{-1}) and 80% over organic manuring (4180 kg ha^{-1}) respectively [Table-1]. The combined application of organic manures and inorganic fertilizers might have prevented losses of nutrients from soil and supplied nutrients in optimal level with crop demand improving synthesis and translocation of metabolites to various reproductive structures resulting in increased yield by Raju and Sreenivas, 2008 [8] and Kumari *et al*., 2010) [9]. The straw yield and harvest index were also the more with INM practices. The increase in straw yield was due to high N availability to the plants from an optimal combined source of inorganic and organic matter that usually promotes tillering, plant height and dry matter production, which was responsible for increase in straw yield [10].

Yield attributes and yield of mustard

The residual effect of *kharif* nutrient management practices applied to hybrid rice 'Ajay' under SRI method were beneficial in enhancing the yield attributes and seed yield of mustard during both the years. In general, the residual effect of INM treatment was superior to sole organic and RDF (sole inorganic). Application of RDF with 5 t FYM, where N applied as ¼ at TP, ½ at AT and ¼ at PI (K6) to rice was found to be superior with respect to number of siliquae plant^{-1} (89.5), seeds siliqua^{-1} (9.7), 1000 seed weight (3.9 g), seed yield (806 kg ha^{-1}), stover yield (1423 kg ha^{-1}) and HI (36.3%) of mustard than other nutrient combinations [Table-2 and 4]. The seed yield under this treatment (806 kg ha^{-1}) was 40.4% and 72.9% higher than sole organic (K8) and sole inorganic (K1), respectively. The superior performance of residual effect of organics in combination with inorganic fertilizers was due to the prolonged availability of nutrients. The benefits of residual effect of INM on mustard can be explained through the fact that certain portion of the nutrient applied to rice in organic form may remain unutilized due to slow decomposition to release the nutrients for crop utilization. Besides, the favourable modifications in physico-chemical properties of soil resulted in better release of nutrients, which is ultimately available for the growth and development of succeeding crop. Bejabaruha *et al*., (2009)[11] from their experiment on direct and residual effect of organic and inorganic sources of nutrients on rice-based cropping system recorded higher yield in winter crops in INM treatment than only 100% NPK through chemical fertilizers.

The direct effect of integrated nutrient management to mustard revealed that application of 50% RDF (40-20-20 kg N-P_2O_5-K_2O ha^{-1}) along with biofertilizers *Azotobacter* and PSB @ 5 kg ha^{-1} each (R2) recorded higher number of siliquae plant^{-1} and seeds siliqua^{-1} [Table-2] which was at par with application of 100% RDF (R2). Both 100% RDF and 50% RDF + BF treatments were equally efficient in maintaining the photosynthetic surface area and superior to no fertilizer application. The result collaborates with the finding of Rathore *et al*., (2012) [12] and Singh and Gujar (2012) [13]. The seed and stover yield (805 and 1455 kg ha^{-1}) were higher in 50% RDF + BF treated plants and was at par with 100% RDF to mustard which was significantly superior than unfertilized plot to mustard during both the years and pooled data [Table-4]. The seed yield in 50% RDF+BF was 1.6% and 89.5% higher over 100% RDF and control, respectively. Similar trend was noticed for stover yield. The superiority of the treatment, 50% RDF with *Azotobacter* and PSB was due to fixation of atmospheric nitrogen, availability of native phosphorous and production of siderophores which regulates the availability of nutrient to the crop [14]. The ability of the *Azotobacter* to produce growth substances and antifungal substances in addition to enhanced release of fixed N made available to plants was the reason of higher yields [15]. Interaction effect between *kharif* and *rabi* nutrient management practices was found to be significant for siliquae plant^{-1}, seeds siliqua^{-1}, 1000 seed weight [Table-3] seed yield, stover yield and HI [Table-5] by rice-mustard cropping system. Application of RDF+FYM 5 t ha^{-1} (¼ N at TP, ½ N at AT and ¼ N at PI) (K6) to *Kharif* hybrid rice followed by50% RDF+ *Azotobacter* and PSB 5 kg ha^{-1} each (R2) to mustard was found to be superior in terms of siliquae plant^{-1} (116), seeds siliqua^{-1} (11.7), 1000 seed weight(3.98g), seed yield (997 kg ha^{-1}), stover yield (1755 kg ha^{-1}) and harvest index (36.2 %).

Table-1 *Effect of different nutrient management treatments on yield attributes of hybrid rice under SRI during Kharif 2013 and 2014*

Treatment		Effective tillers m^{-2}			Filled grains panicle^{-1}			1000 grain weight (g)			Straw yield (kg ha^{-1})			Grain yield (kg ha^{-1})		
		2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
K_1	RDF (⅓ N each at TP, AT and PI)	130	125	127	168	167	168	25.2	25.1	25.1	4825	5023	4924	4822	4668	4745
K_2	50% RDF+5t FYM (⅓ N each at TP, AT and PI)	133	131	132	182	174	178	25.4	25.5	25.4	5098	5440	5269	5103	5246	5175
K_3	75% RDF+5t FYM (⅓ N each at TP, AT and PI)	144	142	143	192	187	190	25.7	25.6	25.6	5808	6177	5993	5838	6237	6037
K_4	RDF+5tFYM (⅓ N each at TP, AT and PI)	164	168	166	195	197	196	26.2	26.2	26.2	6548	6845	6697	6621	7176	6899
K_5	RDF+5tFYM (½ N at TP, ¼ N at AT and ¼ N at PI)	158	161	159	194	191	192	25.8	25.9	25.9	6485	6711	6598	6526	6974	6750
K_6	RDF+5tFYM (¼ N at TP, ½ N at AT and ¼ N at PI)	179	188	183	203	222	213	26.5	26.4	26.4	7042	7439	7241	7284	7805	7545
K_7	50%RDF+10tFYM (⅓ N each at TP, AT and PI)	134	138	136	190	183	187	25.4	25.5	25.5	5775	6035	5905	5797	5940	5869
K_8	5tFYM+2.5 t VC+*Azosporillum* and PSB 5kg ha^{-1} (BF)	118	120	119	161	166	164	24.9	25.1	25	4128	4598	4363	4119	4241	4180
	SEm±	7	6	5	8	7	5	0.5	0.2	0.3	254	219	168	188	202	138
	$LSD_{0.05}$	22	18	13	25	21	15	1.5	0.7	0.8	771	663	486	571	612	400
	CV(%)	8.5	7	7.7	7.6	6.3	7	3.2	1.7	2.6	7.7	6.3	7	5.7	5.8	5.7

Table-2 *Effect of different Kharif and Rabi nutrient management treatments on number of siliquae plant-1, seeds siliquae-1 and 1000 seed weight (g) of mustard under SRI rice-mustard cropping system during 2013-14 and 2014-15*

Treatment		Siliquae plant^{-1}			Seeds siliquae^{-1}			1000 seed weight (g)		
		2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Kharif treatment										
K_1	RDF (⅓ N each at TP, AT and PI)	53.2	60.3	56.8	6	5.6	5.8	3.69	3.63	3.66
K_2	50% RDF+5t FYM (⅓ N each at TP, AT and PI)	60.9	65.8	63.4	7	7.2	7.1	3.7	3.74	3.72
K_3	75% RDF+5t FYM (⅓ N each at TP, AT and PI)	67	72	69.5	7.6	7.8	7.7	3.76	3.77	3.77
K_4	RDF+5tFYM (⅓ N each at TP, AT and PI)	85.9	88.9	87.4	8.8	9.4	9.1	3.85	3.89	3.87
K_5	RDF+5tFYM (½ N at TP, ¼ N at AT and ¼ N at PI)	84.1	87.7	85.9	8.6	9	8.8	3.8	3.85	3.83
K_6	RDF+5tFYM (¼ N at TP, ½ N at AT and ¼ N at PI)	87.7	91.3	89.5	9.4	9.9	9.7	3.89	3.91	3.9
K_7	50%RDF+10tFYM (⅓ N each at TP, AT and PI)	71.2	75.3	73.2	8	8.2	8.1	3.78	3.84	3.81
K_8	5tFYM+2.5 t VC+*Azosporillum* and PSB 5kg ha^{-1} (BF)	57.7	65	61.4	6.8	6.4	6.6	3.69	3.67	3.68
	SEm±	3	2.4	1.9	0.2	0.2	0.1	0.06	0.08	0.05
	$LSD_{0.05}$	9.1	7.3	5.6	0.7	0.6	0.4	NS	NS	0.15
	CV(%)	12.7	9.5	14	8.4	7.7	11.6	5.1	6.7	5.8
Rabi treatment										
R_1	RDF (40:20:20 kg N:P_2O_5:K_2O ha^{-1})	80.2	85	82.6	8.6	8.9	8.7	3.79	3.82	3.8
R_2	50% RDF + Azotobacter and PSB 5kg ha^{-1} each	86.8	90.5	88.6	9.1	9.5	9.3	3.84	3.85	3.84
R_3	Control	45.9	51.9	48.9	5.6	5.4	5.5	3.69	3.7	3.69
	SEm±	2.2	2	1.5	0.2	0.2	0.1	0.04	0.05	0.03
	$LSD_{0.05}$	6.3	5.7	4.2	0.5	0.6	0.4	NS	NS	0.1
	CV(%)	15.2	12.8	14	11.3	11.9	11.6	5.5	6	5.8

Table-3 *Interaction effect of Kharif and Rabi nutrient management treatments on number of siliquae plant-1, seeds siliqua-1 and 1000 seed weight of mustard under SRI rice-mustard cropping system (pooled over 2013-14 and 2014-15)*

Treatments		Siliquae plant^{-1}			Seeds siliquae^{-1}			1000 seed weight (g)		
		Rabi treatment			*Rabi* treatment			*Rabi* treatment		
		R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
Kharif treatment		100%RDF	50%RDF+BF	Control	100%RDF	50%RDF+BF	Control	100%RDF	50%RDF+BF	Control
K_1	RDF (⅓ N each at TP, AT and PI)	69.7	60.8	39.8	7.0	6.7	3.7	3.70	3.66	3.62
K_2	50% RDF+5t FYM (⅓ N each at TP, AT and PI)	77.1	70.7	42.3	8.5	8.1	4.7	3.93	3.66	3.59
K_3	75% RDF+5t FYM (⅓ N each at TP, AT and PI)	77.1	85.1	46.3	8.6	8.9	5.6	3.84	3.86	3.60
K_4	RDF+5tFYM (⅓ N each at TP, AT and PI)	98.6	106.6	57.2	9.7	11.2	6.4	3.81	4.03	3.78
K_5	RDF+5tFYM (½ N at TP, ¼ N at AT and ¼ N at PI)	96.3	107.0	54.6	9.4	10.9	6.1	3.72	3.94	3.82
K_6	RDF+5tFYM (¼ N at TP, ½ N at AT and ¼ N at PI)	93.3	116.0	59.1	10.7	11.7	6.6	3.84	3.98	3.88
K_7	50%RDF+10tFYM (⅓ N each at TP, AT and PI)	83.8	88.8	47.0	8.9	9.2	6.3	3.81	3.86	3.75
K_8	5tFYM+2.5 t VC+*Azosporillum* and PSB 5kg ha^{-1} (BF)	65.0	74.1	45.0	7.2	8.1	4.4	3.76	3.76	3.51
			SEm±	$LSD_{0.05}$		SEm±	$LSD_{0.05}$		SEm±	$LSD_{0.05}$
Sub x Main			4.2	11.8		0.4	1.1		0.1	0.3
Main x Sub			5.2	14.8		0.5	1.3		0.1	0.3

N.B.- RDF to rice: 120:60:60 kg N:P_2O_5:K_2O ha^{-1}, Transplanting(TP), Active tillering (AT), Panicle initiation (PI), Vermicompost (VC), RDF to mustard : 40:20:20 kg N:P_2O_5:K_2O ha^{-1}, BF: biofertilizers (Azotobacter and PSB 5kg ha^{-1} each)

Table-4 *Effect of different Kharif and Rabi nutrient management treatments on seed yield, stover yield, harvest index of mustard and System REY under SRI rice-mustard cropping system during 2013-14 and 2014-15.*

Treatments		Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Harvest index (%)			System REY (kg ha^{-1})		
		2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Kharif treatment													
K_1	RDF (⅓ N each at TP, AT and PI)	474	458	466	1011	979	995	31.7	31.7	31.7	6053	5847	5950
K_2	50% RDF+5t FYM (⅓ N each at TP, AT and PI)	614	617	616	1107	1116	1111	35.6	35.5	35.6	6696	6835	6765
K_3	75% RDF+5t FYM (⅓ N each at TP, AT and PI)	666	674	670	1209	1221	1215	35.6	35.6	35.6	7568	7970	7769
K_4	RDF+5tFYM (⅓ N each at TP, AT and PI)	778	795	786	1381	1411	1396	36.1	36.1	36.1	8641	9222	8931
K_5	RDF+5tFYM (½ N at TP, ¼ N at AT and ¼ N at PI)	744	757	750	1319	1344	1332	36.1	36	36.1	8458	8921	8689
K_6	RDF+5tFYM (¼ N at TP, ½ N at AT and ¼ N at PI)	797	816	806	1406	1440	1423	36.3	36.3	36.3	9352	9905	9629
K_7	50%RDF+10tFYM (⅓ N each at TP, AT and PI)	688	700	694	1247	1270	1258	35.6	35.6	35.6	7582	7742	7662
K_8	5tFYM+2.5 t VC+*Azosporillum* and PSB 5kg ha^{-1} (BF)	583	565	574	1059	1027	1043	35.5	35.5	35.5	5632	5695	5664
	SEm±	22	23	16	40	41	29	0.9	0.9	0.6	186	207	139
	$LSD_{0.05}$	66	69	46	121	126	83	NS	NS	1.9	565	626	403
	CV(%)	9.8	10.2	9.5	9.8	10.1	8.4	7.8	7.8	4.9	7.4	8	2.1
Rabi treatment													
R_1	RDF (40:20:20 kg N:P_2O_5:K_2O ha^{-1})	785	792	788	1438	1450	1444	35.2	35.2	35.2	7801	8073	7937
R_2	50% RDF + Azotobacter and PSB 5kg ha^{-1} each	798	812	805	1443	1467	1455	35.5	35.5	35.5	7836	8125	7980
R_3	Control	421	415	418	771	761	766	35.1	35.1	35.1	6856	7104	6980
	SEm±	12	13	9	20	22	15	0.4	0.4	0.3	32	35	24
	$LSD_{0.05}$	36	39	26	57	64	42	NS	NS	0.7	93	100	66.7
	CV(%)	9.1	9.8	9.5	7.9	8.8	8.4	4.9	4.9	4.9	2.1	2.2	2.1

Table-5 *Interaction effect of Kharif and Rabi nutrient management treatments on seed yield, stover yield and harvest index of mustard and System REY under SRI rice-mustard cropping system (pooled over 2013-14 and 2014-15)*

Treatments		Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})			Harvest index (%)			System REY (kg ha^{-1})		
		Rabi treatment			*Rabi* treatment			*Rabi* treatment			*Rabi* treatment		
		R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
		100%RDF	50%RDF+BF	Control	100%RDF	50%RDF+BF	Control	100%RDF	50%RDF+BF	Control	100%RDF	50%RDF+BF	Control
Kharif treatment													
K_1	RDF (⅓ N each at TP, AT and PI)	595	516	288	1245	1065	674	32.4	32.6	30	6282	6078	5488
K_2	50% RDF+5t FYM (⅓ N each at TP, AT and PI)	742	704	400	1346	1249	740	35.5	36	35.1	7093	6994	6209
K_3	75% RDF+5t FYM (⅓ N each at TP, AT and PI)	786	809	415	1422	1468	755	35.7	35.5	35.5	8069	8127	7111
K_4	RDF+5tFYM (⅓ N each at TP, AT and PI)	927	952	480	1665	1678	845	35.8	36.2	36.2	9295	9360	8139
K_5	RDF+5tFYM (½ N at TP, ¼ N at AT and ¼ N at PI)	855	929	468	1529	1645	821	35.9	36.1	36.2	8959	9150	7960
K_6	RDF+5tFYM (¼ N at TP, ½ N at AT and ¼ N at PI)	948	997	473	1698	1755	816	35.8	36.2	36.7	9996	10122	8768
K_7	50%RDF+10tFYM (⅓ N each at TP, AT and PI)	796	850	436	1446	1550	779	35.5	35.4	35.8	7925	8066	6995
K_8	5tFYM+2.5 t VC+*Azosporillum* and PSB 5kg ha^{-1} (BF)	657	683	382	1203	1229	698	35.3	35.7	35.4	5878	5947	5166
			SEm±	$LSD_{0.05}$		SEm±	$LSD_{0.05}$		SEm±	$LSD_{0.05}$	SEm±	$LSD_{0.05}$	
Sub x Main			26	73		42	118		0.7	2		67	189
Main x Sub			34	96		56	161		1	3		159	459

Table-6 *Effect of different Kharif and Rabi nutrient management treatments on total uptake of N, P and K by rice-mustard cropping system during 2013-14 and 2014-15*

Treatments		N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})		
		2013-14	2014-15	Pooled	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
Kharif treatment										
K_1	RDF (⅓ N each at TP, AT and PI)	67.8	71.3	69.5	20.3	20	20.1	106	97.5	101.7
K_2	50% RDF+5t FYM (⅓ N each at TP, AT and PI)	79.1	87.6	83.4	23.5	24.7	24.1	121.4	118	119.7
K_3	75% RDF+5t FYM (⅓ N each at TP, AT and PI)	92.4	104.1	98.3	28	31.3	29.7	152.8	148.7	150.7
K_4	RDF+5tFYM (⅓ N each at TP, AT and PI)	112.6	130	121.3	38.3	41.6	39.9	188	179.7	183.8
K_5	RDF+5tFYM (½ N at TP, ¼ N at AT and ¼ N at PI)	108.3	121.1	114.7	36.5	39.1	37.8	183.5	173.8	178.7
K_6	RDF+5tFYM (¼ N at TP, ½ N at AT and ¼ N at PI)	126.9	145.4	136.2	43.4	47.8	45.6	211.3	202.1	206.7
K_7	50%RDF+10tFYM (⅓ N each at TP, AT and PI)	92.4	101.8	97.1	29.4	31.6	30.5	153.5	148.7	151.1
K_8	5tFYM+2.5 t VC+*Azosporillum* and PSB 5kg ha^{-1} (BF)	63.3	68.1	65.7	19.5	19.8	19.6	83.9	84.1	84
	SEm±	2.2	2.8	1.8	0.7	0.9	0.6	5.5	5.7	4
	$LSD_{0.05}$	6.6	8.6	5.2	2.1	2.8	1.7	16.7	17.4	11.5
	CV(%)	7	8.2	3.4	7	8.7	6.6	11	11.9	2.8
Rabi treatment										
R_1	RDF (40:20:20 kg $N:P_2O_5:K_2O$ ha^{-1})	97	107.8	102.4	31.7	33.8	32.8	155.2	149.2	152.2
R_2	50% RDF + Azotobacter and PSB 5kg ha^{-1} each	99.3	110.7	105	33	35.4	34.2	157.4	152.1	154.7
R_3	Control	82.4	92.6	87.5	24.9	26.8	25.8	137.6	130.8	134.2
	SEm±	0.6	0.7	0.5	0.4	0.4	0.3	0.8	0.9	0.6
	$LSD_{0.05}$	1.9	2	1.3	1.1	1.3	0.8	2.3	2.5	1.7
	CV(%)	3.4	3.3	3.4	6.3	6.8	6.6	2.7	3	2.8

N.B.- RDF to rice: 120:60:60 kg $N:P_2O_5:K_2O$ ha^{-1}, Transplanting(TP), Active tillering (AT), Panicle initiation (PI), Vermicompost (VC)

Table-7 *Interaction effect of Kharif and Rabi nutrient management treatments on total uptake of N, P and K by SRI rice-mustard cropping system (pooled over 2013-14 and 2014-15)*

Treatments		Total uptake (kg ha^{-1})								
		N			P			K		
		Rabi treatment			*Rabi* treatment			*Rabi* treatment		
		R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
		100%RDF	50%RDF+BF	Control	100%RDF	50%RDF+BF	Control	100%RDF	50%RDF+BF	Control
Kharif treatment										
K_1	RDF (⅓ N each at TP, AT and PI)	76	70.3	62.4	23.1	20.3	16.9	108.9	102.8	93.5
K_2	50% RDF+5t FYM (⅓ N each at TP, AT and PI)	89.8	85.8	74.5	27.2	25.2	19.9	127.1	122.8	109.2
K_3	75% RDF+5t FYM (⅓ N each at TP, AT and PI)	101.4	105.4	88	31.2	33	24.8	155.1	158.9	138.3
K_4	RDF+5tFYM (⅓ N each at TP, AT and PI)	125.6	130.4	108.1	41.7	44.5	33.7	189.5	194	168
K_5	RDF+5tFYM (½ N at TP, ¼ N at AT and ¼ N at PI)	117.8	123.8	102.5	39.3	42.3	32	182.9	189.2	163.9
K_6	RDF+5tFYM (¼ N at TP, ½ N at AT and ¼ N at PI)	140.9	146.6	121	47.6	51.1	38.1	212.6	219	188.5
K_7	50%RDF+10tFYM (⅓ N each at TP, AT and PI)	99.6	105.6	86.1	31.5	34.7	25.3	154.5	160.9	137.8
K_8	5tFYM+2.5 t VC+*Azosporillum* and PSB 5kg ha^{-1} (BF)	68	71.8	57.3	20.7	22.3	15.9	87.2	90.4	74.4
		SEm±	$LSD_{0.05}$		SEm±	$LSD_{0.05}$		SEm±	$LSD_{0.05}$	
Sub x Main		1.3	3.8		0.8	2.3		1.7	4.8	
Main x Sub		2.4	6.8		1.1	3.2		4.4	12.8	

N.B.- RDF to rice: 120:60:60 kg $N:P_2O_5:K_2O$ ha^{-1}, Transplanting(TP), Active tillering (AT), Panicle initiation (PI), Vermicompost (VC), RDF to mustard : 40:20:20 kg $N:P_2O_5:K_2O$ ha^{-1}, BF: biofertilizers (Azotobacter and PSB 5kg ha-1 each)

The seed yield of mustard with application of RDF+FYM 5 t ha^{-1} (¼ N at TP, ½ N at AT and ¼ N at PI) to *Kharif* rice followed by application of 50% RDF+ *Azotobacter* and PSB (BF) 5 kg ha^{-1} each to mustard during *rabi* season was 110% higher than no fertilizer to mustard (473 kg ha^{-1}) at the same level of fertilizer applied to *kharif* rice. However, it was noted that INM practice with RDF during *kharif* responded positively to INM practices of *rabi*, over the sole inorganic i.e. RDF and organic to rice and no fertilizer to mustard. These findings indicated the superiority of INM approaches over inorganic sources. Since, release of nutrients from organic sources is favoured by aerobic decomposition and mineralization of nutrients in SRI as it involved alternate wetting and drying of soil and frequent interculture by cono weeder facilitating aeration to rhizosphere soil.

The rice equivalent yield (REY)was found to be maximum in the treatment receiving 100% RDF+5 t FYM ha^{-1} with N as ¼at TP, ½, at AT and ¼ at PI stage to rice and 50% RDF+BF to mustard during both the years.

The maximum REY (9629 kg ha^{-1}) was achieved in *kharif* nutrient management where RDF+5 t FYM ha^{-1} (¼ N at TP, ½ N at AT and ¼ N at PI stage) was supplied to rice and the lowest was in organic nutrient supply only (5664 kg ha^{-1}) on pooled basis. Maximum REY of 7980 kg ha^{-1} for the *rabi* treatment was registered with application of 50% RDF+BF (R2) to mustard followed by 7937 kg ha^{-1} with application of RDF (R1) and the least REY in control (6980 kg ha^{-1}) in rice-mustard cropping system on pooled data. The increase in REY in INM treatment was 14.3% as compared to control [Table-4].

Nutrient uptake by rice-mustard cropping system

The data on nutrient uptake of the SRI rice-mustard cropping system by different nutrient management practices revealed that the maximum uptake of N, P and K was found to be 136.2, 45.6 and 206.7 kg ha^{-1}, respectively in 100% RDF+5 t FYM where N applied as ¼ at TP, ½ at AT and ¼ at PI (K6) to rice. The maximum uptake of nutrients by INM than RDF and organic manure was because of higher system yield and nutrient content [Table-6]. This might be due to improvement in soil conditions, proliferation of roots and improved synchrony between supply and demand, which in turn utilized more nutrients. As regards to *rabi* nutrient management treatments to mustard, the crop receiving 50% RDF+BF recorded the total N, P and K uptake (105.0, 34.2, 154.7 kg ha^{-1}) respectively, which were significantly higher than those obtained by the use of RDF (102.4, 32.8 and 152.2 kg ha^{-1}) respectively and no fertilizer application during both the years. The plots receiving no fertilizer recorded least total N, P and K uptake by the rice-mustard cropping system under investigation [Table-6].

The interaction effect was significant for total N, P and K uptake by the rice-mustard cropping system. The treatment combination of RDF+5 t FYM (¼ N at TP, ½ N at AT and ¼ N at PI stage) to rice and 50%RDF+BF to mustard recorded highest total N, P and K uptake of 146.6, 51.1 and 219.0 kg ha^{-1}, respectively. This was due to additional amount of residual nutrients supplied by FYM as well as BF derived in connection with the improvement of soil physico-chemical properties, which was the reason of higher nutrient uptake. The N, P and K uptake of 57.3, 15.9 and 74.4 kg ha^{-1}, respectively was in the plots treated with5 t FYM + 2.5 t ha^{-1} +Vermicompost + *Azospirillum* and PSB 5 kg ha^{-1} each to rice and no fertilizer to mustard [Table-7]. Higher NPK content and higher biological yield in these treatments seems to be responsible for higher NPK uptake in both individual crops and the system. Roul *et al*. (2006) [16] reported higher uptake of total nitrogen by mustard due to application of 100% recommended dose of nitrogen (RDN) blended with FYM to *kharif* rice and direct application of 100% RDN to mustard in rice-mustard cropping sequence.

Conclusion

Integrated nutrient management practices proved to be better as compared to sole inorganic and organic mode of nutrient management for both hybrid rice and subsequent mustard crop in terms of yield attributes, productivity and nutrient uptake. Growing hybrid rice 'Ajay' in SRI method with application of 120-60-60 kg N-P_2O_5-K_2O + 5 t FYM ha^{-1} with split application of ¼N at transplanting, ½ N at active tillering and ¼N at panicle initiation during *kharif* season followed by application of 50% recommended dose of fertilizer *i.e*., 20:10:10 kg N-P_2O_5-K_2O (50% RDF) + 5 kg ha^{-1} *Azotobacter* and PSB each to mustard during *rabi* season produced 95.9 % higher REY (10122 kg ha^{-1}) as compared to 5 t FYM+2.5 t VC+BF to rice and no fertilizer to mustard (5166 kg ha^{-1}) in Western Undulating Zone of Odisha.

Application of Research: Can standardized the nutrient management in rice-mustard cropping system

Research Category: Integrated nutrient management

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**** Research Guide or Chairperson of research: Dr C.M. Khanda**
University: Odisha University of Agriculture and Technology, Bhubaneswar, Odisha 751003, India
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