The Pharma Innovation Journal 2021; 10(12): 2887-2890

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(12): 2887-2890

www.thepharmajournal.com
Received: 10-10-2021
Accepted: 16-11-2021

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Effect of integrated nutrient management on growth and yield of rice (*Oryza sativa* L.) in east and south eastern coastal plain zone of Odisha

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Abstract
A field experiment was undertaken during *kharif* season of 2014 and 2015 in Agronomy Main Research Farm, Department of Agronomy, Odisha University of Agriculture and Technology, Bhubaneswar to study performance of integrated nutrient management (INM) on rice (Variety- Naveen). The experiment was laid out in a Randomised Block design with 12 treatment combinations and replicated thrice. Different treatments were T_1- RDN, T_2- 75% RDN + 25% N through FYM, T_3- 50% RDN + 50% N through FYM, T_4- RDN + Zinc EDTA, T_5- RDN + Sulphur (30 kg ha^{-1}), T_6- RDN + $ZnSO_4$ (25 kg ha^{-1}), T_7- 75% RDN + 25% N through FYM + Zinc EDTA, T_8- 75% RDN + 25% N through FYM + Sulphur (30 kg ha^{-1}), T_9- 75% RDN + 25% N through FYM + $ZnSO_4$ (25 kg ha^{-1}), T_{10}- 50% RDN + 50% N through FYM + Zinc EDTA, T_{11}- 50% RDN + 50% N through FYM + Sulphur (30 kg ha^{-1}) and T_{12}- 50% RDN + 50% N through FYM + $ZnSO_4$ (25 kg ha^{-1}). Application of 75% RDN + 25% N through FYM + ZnSO4 @ 25 kg ha^{-1} resulted the best superior growth performances, yield attributes and maximum grain yield (5146 kg ha^{-1}) and statistically similar with the application of 75% RDN + 25% N through FYM + Zn EDTA (sprayed @ 0.2% at 15, 30 and 45 DAT).

Keywords: INM, FYM, $ZnSO_4$, rice, growth, grain yield

Introduction
Rice (*Oryza sativa* L.) is an imporatnat cereal crop and staple food for about half of the population on the world (Pathak *et al.*, 2020) [1]. In India rice is cultivated in an area of 43.79 million ha with production of 116.42 million tonnes and productivity of 2659 kg ha^{-1} (Anonymous, 2019) [2]. In Odisha, rice is the most important crop and cultivated in about 41 lakh ha (Mangaraj *et al.*, 2021) [3]. Average rice productivity in Odisha (1972 kg ha^{-1}) is quite low as compared to national average (Anonymous, 2019) [2]. Nutrient management is one of the important factors for higher rice production. Though the use of nitrogenous fertilizers per unit area for rice production is high, but the fertilizer use efficiency is generally low. Integrated nutrient management system plays a vital role in balancing the soil fertility and plant nutrient supply by judicious and efficient use of chemical fertilizers along with others. Integration of nutrients from organic and inorganic sources which can help in obtaining good crop yields as well as the sustainable production system (Ullah *et al*., 2019; Shankar *et al*., 2020) [4, 5]. The use of farm yard manure (FYM) not only helps in supplementing requirement of nutrients but also improves soil properties. Nitrogen plays the most important role for realizing higher yield potential of rice (Sharma and Das, 1994) [6]. Zn has synergistic effect with N in rice and it plays an important role in nitrogen metabolism, protein synthesis (Alloway, 2008) [7]. On other hand, S has been identified as a nutritional problem for rice and deficiency has been observed in most parts of the country. Combined use of organic manures and chemical fertilizers has advantages over use of only organic manures or chemical fertilizers. Considering the above facts the present experiment has been conducted to evaluate the performance of integrated nutrient management (INM) on rice in East and South Eastern Coastal Plain Zone of Odisha.

Materials and Methods
The field experiment was conducted at Agronomy Main Research Farm, Department of Agronomy, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar during *kharif* season of 2014 and 2015. The experimental site was situated at an

altitude of 25.9 m above mean sea level, 20° 15'N latitude, 85° 52'E longitude. The soil of the experimental plot was sandy loam in texture; acidic in nature (pH 5.40); low in available nitrogen (204.4 kg ha^{-1}) and available organic carbon (0.48%); medium in potassium (181.3 kg ha^{-1}) and phosphorus (18.5 kg ha^{-1}); low in sulphur (12.8 kg ha^{-1}) and zinc (0.48 ppm). Total rainfall amounting to 1328.8 mm in 84 rainy days and 843.1 mm in 66 rainy days was received during *kharif* season of 2014 and 2015, respectively. The field experiment was laid out in a Randomised Block design with three replications by taking 12 treatment combinations with recommended dose of nitrogen (RDN) *viz*. T_1- RDN, T_2- 75% RDN + 25% N through FYM, T_3- 50% RDN + 50% N through FYM, T_4- RDN + Zinc EDTA, T_5- RDN + Sulphur (30 kg ha^{-1}), T_6- RDN + $ZnSO_4$ (25 kg ha^{-1}), T_7- 75% RDN + 25% N through FYM + Zinc EDTA, T_8- 75% RDN + 25% N through FYM + Sulphur (30 kg ha^{-1}), T_9- 75% RDN + 25% N through FYM + $ZnSO_4$ (25 kg ha^{-1}), T_{10}- 50% RDN + 50% N through FYM + Zinc EDTA, T_{11}- 50% RDN + 50% N through FYM + Sulphur (30 kg ha^{-1}) and T_{12}- 50% RDN + 50% N through FYM + $ZnSO_4$ (25 kg ha^{-1}) in rice variety Naveen. Recommended dose of nitrogen was 80 kg ha^{-1} and a uniform dose of 40 kg ha^{-1} each of P_2O_5 and K_2O were applied to all treatments. In respect to treatments, Sulphur and $ZnSO_4$ were applied as basal dose, and Zinc EDTA was sprayed @ 0.2% at 15, 30 and 45 days after transplanting (DAT).

Observations on growth attributes were recorded at 30, 60, 90 DAT and at harvest. The plant height was measured from the base of the plant to the tip of the upper leaf and expressed in cm. Leaf area index (LAI) was obtained by dividing total leaf area with total ground area occupied. The dry matter accumulations were recorded in each plot and expressed as g m^{-2}. Crop growth rate (CGR) was calculated by using the formula suggested by Watson (1947) [8]. Number of effective tillers m^{-2}, panicle length (cm), number of filled grains $panicle^{-1}$, test weight (g) and grain yield (kg ha^{-1}) were recorded at harvest. The collected data were statistically analyzed by standard analysis of variance technique for randomized complete block design as suggested by Gomez and Gomez (1984) [9] and significant differences between the treatments were compared with the critical difference at ±5% probability by least significant difference.

Results and Discussion

The pooled data of two years (*kharif* season of 2014 and 2015) for growth and yield attributes as well as for yield of rice were presented in Table 1 to 5.

Effect of integrated nutrient management (INM) on growth of rice

Plant height was increased rapidly during the period between 30 and 60 DAT as well as between 60 and 90 DAT, and thereafter slowly due to exertion of panicles at later stage (Table 1). The results revealed that, application of 75% RDN + 25% N through FYM + $ZnSO_4$ (T_9) recorded significantly higher plant height in all stages of observations. However, it was statistically at par with treatment T_7 i.e. 75% RDN + 25% N FYM + Zn EDTA (spray). Leaf area index (LAI) increased rapidly with advancement of crop growth up to 60 DAT thereafter it was decreased due to senescence of lower leaves (Table 2). The leaf area index reached maximum at 60 DAT in all the treatments. Maximum leaf area index was recorded with 75% RDN + 25% N through FYM + $ZnSO_4$ (T_9) which was significantly higher as compared to other treatment and lowest LAI was observed under the RDN (T_1) at all stages of observations. The dry matter accumulation increased with advancement of crop stages (Table 3). In respect to different stages, highest dry matter was recorded with application of 75% RDN + 25% N through FYM + $ZnSO_4$ (T_9) which was significantly higher as compared to other treatment. The lowest dry matter was recorded under RDN (T_1) in all observations. In case of crop growth rate (CGR), it was recorded highest between 30-60 DAT and decreased thereafter (Table 4). Crop growth rate was significantly influenced by different INM practices and recorded better values with treatment T_9 at all stages of observations. Better performance with T_9 in respect to growth characters could be explained by greater release and supply of nutrients in varied proportions and times from the combined use of organic manures (FYM) and chemical fertilizer along with application of $ZnSO_4$ @ 25 kg ha^{-1} as basal dose. Similar observations on the effect of different proportion of organic manure and chemical fertilizer on influencing growth attributes of rice were also reported by several workers (Sahu *et al*., 2015; Biswanath *et al*., 2019; Ram *et al*., 2020) [10, 11, 12].

Table 1: Effect of INM on plant height (pooled data of two years)

Treatment	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	Harvest
T_1- RDN	50.5	93.5	116.1	118.1
T_2- 75% RDN + 25% N through FYM	51.9	96.7	118.8	122.0
T_3- 50% RDN + 50% N through FYM	51.0	95.8	118.1	121.2
T_4- RDN + Zn (spray)	52.8	97.9	119.9	123.3
T_5- RDN + Sulphur	52.0	97.0	119.0	122.3
T_6- RDN + $ZnSO_4$	53.0	98.0	120.8	123.4
T_7- 75% RDN + 25% N through FYM + Zn (spray)	56.8	101.8	125.4	127.4
T_8- 75% RDN + 25% N through FYM + Sulphur	53.9	98.9	122.1	124.1
T_9- 75% RDN + 25% N through FYM + $ZnSO_4$	56.9	102.6	126.2	128.2
T_{10}- 50% RDN + 50% N through FYM + Zn (spray)	54.6	99.6	123.1	124.9
T_{11}- 50% RDN + 50% N through FYM + Sulphur	53.3	98.3	121.6	123.6
T_{12}- 50% RDN + 50% N through FYM + $ZnSO_4$	55.9	100.9	124.2	126.2
S.Em(±)	0.73	0.81	0.81	0.91
CD (0.05)	2.1	2.3	2.3	2.6

Table 2: Effect of INM on Leaf area index (LAI) of rice (pooled data of two years)

Treatment	Leaf area index (LAI)			
	30 DAT	60 DAT	90 DAT	Harvest
T_1- RDN	1.44	3.69	2.49	1.59
T_2- 75% RDN + 25% N through FYM	1.61	3.86	2.66	1.76
T_3- 50% RDN + 50% N through FYM	1.53	3.78	2.58	1.68
T_4- RDN + Zn (spray)	1.70	3.95	2.75	1.85
T_5- RDN + Sulphur	1.67	3.92	2.72	1.82
T_6- RDN + $ZnSO_4$	1.72	3.97	2.77	1.87
T_7- 75% RDN + 25% N through FYM + Zn (spray)	1.83	4.08	2.88	1.98
T_8- 75% RDN + 25% N through FYM + Sulphur	1.73	3.98	2.78	1.88
T_9- 75% RDN + 25% N through FYM + $ZnSO_4$	1.89	4.14	2.94	2.04
T_{10}- 50% RDN + 50% N through FYM + Zn (spray)	1.75	4.00	2.80	1.90
T_{11}- 50% RDN + 50% N through FYM + Sulphur	1.74	3.99	2.79	1.89
T_{12}- 50% RDN + 50% N through FYM + $ZnSO_4$	1.80	4.05	2.85	1.95
S.Em(±)	0.035	0.045	0.153	0.095
CD (0.05)	0.10	0.13	0.44	0.27

Table 3: Effect of INM on dry matter of rice (pooled data of two years)

Treatment	Dry matter (g m^{-2})			
	30 DAT	60 DAT	90 DAT	Harvest
T_1- RDN	174.5	687.5	933.4	975.2
T_2- 75% RDN + 25% N through FYM	181.8	733.9	1048.7	1112.0
T_3- 50% RDN + 50% N through FYM	177.4	723.5	1032.5	1086.3
T_4- RDN + Zn (spray)	188.2	752.3	1085.0	1160.5
T_5- RDN + Sulphur	184.8	739.9	1060.7	1132.5
T_6- RDN + $ZnSO_4$	190.5	760.4	1099.4	1183.3
T_7- 75% RDN + 25% N through FYM + Zn (spray)	203.5	809.6	1181.4	1292.7
T_8- 75% RDN + 25% N through FYM + Sulphur	195.6	777.7	1131.5	1230.8
T_9- 75% RDN + 25% N through FYM + $ZnSO_4$	208.3	829.2	1207.2	1324.0
T_{10}- 50% RDN + 50% N through FYM + Zn (spray)	196.5	781.6	1141.4	1246.8
T_{11}- 50% RDN + 50% N through FYM + Sulphur	193.1	769.0	1114.2	1207.0
T_{12}- 50% RDN + 50% N through FYM + $ZnSO_4$	200.7	794.8	1157.6	1265.5
S.Em(±)	2.84	5.12	7.71	9.52
CD (0.05)	8.3	14.9	22.5	27.8

Table 4: Effect of INM on crop growth rate of rice (pooled data of two years)

Treatment	Crop growth rate (g m^{-2} day^{-1})		
	30-60 DAT	60-90 DAT	90 DAT - Harvest
T_1- RDN	17.1	8.2	1.4
T_2- 75% RDN + 25% N through FYM	18.4	10.5	2.1
T_3- 50% RDN + 50% N through FYM	18.2	10.3	1.8
T_4- RDN + Zn (spray)	18.8	11.1	2.5
T_5- RDN + Sulphur	18.5	10.7	2.4
T_6- RDN + $ZnSO_4$	19.0	11.3	2.8
T_7- 75% RDN + 25% N through FYM + Zn (spray)	20.2	12.4	3.7
T_8- 75% RDN + 25% N through FYM + Sulphur	19.4	11.8	3.3
T_9- 75% RDN + 25% N through FYM + $ZnSO_4$	20.7	12.6	3.9
T_{10}- 50% RDN + 50% N through FYM + Zn (spray)	19.5	12.0	3.5
T_{11}- 50% RDN + 50% N through FYM + Sulphur	19.2	11.5	3.1
T_{12}- 50% RDN + 50% N through FYM + $ZnSO_4$	19.8	12.1	3.6
S.Em(±)	0.10	0.07	0.07
CD (0.05)	0.3	0.2	0.2

Effects of INM on yield attributes and yield of rice

In the present study (Table 5), application of 75% RDN + 25% N through FYM + ZnSO4 @ 25 kg ha^{-1} (T_9) significantly exhibited its superiority to increase the number of productive tillers m^{-2} (307), panicle length (25.9 cm), number of filled grains $panicle^{-1}$ (124). It was followed by the application of 75% RDN + 25% N through FYM + Zn EDTA (T_7). Application of inorganic fertilizers with FYM with micronutrients might have showed better performance of yield attributing characters than other organic and inorganic nutrients applied. The grain yield significantly varied due to various integrated nutrient management practices. Application of 75% RDN + 25% N through FYM + $ZnSO_4$ @ 25 kg ha^{-1} (T_9) recorded the higher grain yield (5146 kg ha^{-1}). There was no statistical difference between T_9 and T_7 for grain yield (Table 5). This was due to high inorganic nitrogen supply to the crop which helped to exhibit superior growth parameters resulting in the better productivity with the treatment T_9. The lowest grain yield was recorded with the application RDN (T_1) as there might be lack of nutrients due to absence of FYM and micronutrient. This results corroborate with the findings of Apon *et al*., 2018; Shankar *et al*., 2020 and Ram *et al*., 2020 [13, 5, 12].

Table 5: Effect of INM on yield attributes and yield of rice (pooled data of two years)

Treatment	No. of effective tillers m^{-2}	Panicle length (cm)	No. of filled grains $panicle^{-1}$	Test weight (g)	Grain yield (kg ha^{-1})
T_1- RDN	286	21.0	87	21.4	3340
T_2- 75% RDN + 25% N through FYM	301	22.8	105	21.6	4013
T_3- 50% RDN + 50% N through FYM	297	22.6	99	21.5	4043
T_4- RDN + Zn (spray)	295	23.6	108	22.0	4172
T_5- RDN + Sulphur	300	23.4	109	21.8	4090
T_6- RDN + $ZnSO_4$	303	23.8	112	22.1	4302
T_7- 75% RDN + 25% N through FYM + Zn (spray)	305	24.8	120	22.5	5078
T_8- 75% RDN + 25% N through FYM + Sulphur	301	23.9	115	22.2	4505
T_9- 75% RDN + 25% N through FYM + $ZnSO_4$	307	25.9	124	22.6	5146
T_{10}- 50% RDN + 50% N through FYM + Zn (spray)	297	24.1	117	22.3	4722
T_{11}- 50% RDN + 50% N through FYM + Sulphur	304	23.9	114	22.2	4525
T_{12}- 50% RDN + 50% N through FYM + $ZnSO_4$	294	24.3	118	22.4	4895
S.Em(±)	0.75	0.4	0.84	0.38	34.9
CD (0.05)	2.1	1.1	2.4	NS	101.8

Conclusion

In general, this study indicates that integrated application of organic manure (FYM) along with chemical fertilizer increased growth and yield of rice in East and South Eastern Coastal Plain Zone of Odisha. Further, application of 75% RDN + 25% N through FYM + ZnSO4 @ 25 kg ha^{-1} resulted in superior growth performances with maximum grain yield and this was statistically similar with the application of 75% RDN + 25% N through FYM + Zn EDTA (sprayed @ 0.2% at 15, 30 and 45 DAT). So, farmers should adopt INM either of 75% RDN + 25% N through FYM + ZnSO4 @ 25 kg ha^{-1} or 75% RDN + 25% N through FYM + Zn EDTA (sprayed @ 0.2% at 15, 30 and 45 DAT) for achieving higher yield.

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