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Sulphur, zinc and boron nutrition on yield, economics and nutrient uptake in wet season rice (*Oryza sativa* L.) under rainfed ecosystem of Odisha, India

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Abstract

A field experiment was conducted during wet seasons of 2010-11 and 2011-12 at Instructional farm, Department of Agronomy, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India on sandy loam medium land soil with and medium in organic carbon (0.54%) and available N (295 kg ha^{-1}), P (15 kg ha^{-1}) and K (162 kg ha^{-1}) and low in availability of S (8 ppm), Zn (0.33 ppm) and B (0.43ppm).The experiment was laid out in randomized block design with eleven treatments with three replications. The test variety 'Lalat' of 125 days duration was raised with different integrated nutrient management practices. Application of recommended fertilizer dose(RFD) @ 80-40-40 kg N-P_2O_5-K_2O ha^{-1}+$ZnSO_4$ @ 25 kg ha^{-1}+B @ 1 kg ha^{-1} recorded maximum grain and straw yield followed by application of RFD+Zn-EDTA @1kg ha^{-1}+S @ 30 kg ha^{-1}+B @1kg ha^{-1}. The increase in yield and yield attributes was observed with RFD+$ZnSO_4$ @ 25 kg ha^{-1}and RFD+FYM @ 5 t ha^{-1} over RFD alone or combined application of RFD with S/B/Zn-EDTA. The highest uptake of N (135.5 kg ha^{-1}), P (33.10 kg ha^{-1}), K (178.1 kg ha^{-1}), S (13.30 kg ha^{-1}), Zn (256 g ha^{-1}) and B (177 g ha^{-1}) was recorded with use of RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}followed by RFD + Zn –EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}. Application of RFD+$ZnSO_4$+B registered higher gross return, net return and B: C ratio than other management practices. Incorporation of FYM with RFD proved its superiority over sole application of RFD or combined application of RFD with S/B/Zn-EDTA in term of yield and economic return. Integration of $ZnSO_4$ @ 25 Kg ha^{-1} with RFD proved its superiority over RFD+ FYM @ 5 t ha^{-1}, due to the lower cost of commercial grade and more effectiveness in improving yield of rice.

Keywords: Sulphur, zinc and boron nutrition, yield, nutrient uptake, economics, wet season rice

Introduction

Asian countries produce about 90 per cent of rice. India is one of the leading rice producing countries of the world along with China, Thailand, Vietnam, USA and Pakistan. The imbalanced fertilizer use and low fertilizer use efficiency are the main reasons in achieving low productivity. With introduction of high yielding and fertilizer responsive varieties, the supply of nutrients in adequate quantities at right time has assumed considerable importance in rice production. Introduction of high yielding and hybrid varieties, indiscriminate use of high analysis fertilizers and low or no use of organic source of nutrients along with adoption of intensive cropping system has led to imbalances in soil fertility and mining of plant nutrients through harvested crops. This had has caused the deficiency of S as secondary nutrient and Zn along with B as micronutrients resulting in major problem in achieving targeted yield of rice.

Sulphur is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus, and potassium. Sulphur deficiency is more acute in coarse textured soils having low organic matter. Sulphur deficiency is increasing with each passing year which is restricting crop yields, quality of produce, nutrient use efficiency and economic returns (Tandon, 2011) [12]. Zinc has been identified as the third most important nutrient element after N and P in low land rice limiting growth and yield of crop. Zinc is essential for normal, growth and yield of in plants. It has particular functions in the plants such as maintenance of structural and functional integrity of biological membranes and facilitation of protein synthesis and gene expression (Shukla and Behera., 2011) [9]. Coarse textured alluvial soils are very low in Zn while fine textured red and black clay soils are rich in Zn. Similarly highly weathered coarse textured red and lateritic and calcareous soils are poor in zinc (Tandon, 2009) [11].

Tabassum *et al*. (2013) [10] found that the yield attributes increased significantly with increasing levels of zinc and organic manures over control (no zinc).Coarse textured red, laterite, mixed red and yellow soils are prone to B deficiency. The primary function f B is in plant cell wall structure integrity that is essential for normal transport of water, nutrients and organic compounds to new growth and cell wall stability which is important for pollen tube growth that is responsible or seed development in plants (Havlin *et al.*, 2010). As rice is grown under submerged anaerobic conditions, integrated management of nutrients offer a wide scope for harnessing the efficiency of different nutrients, and their combinations. Information on management of S, Zn and B for rice in lateritic soils of Odisha, India is lacking for which the present study is proposed to assess the nutrition of S, Zn and B along with FYM on rice yield, nutrient uptake and economics in uptake in wet season rice under rainfed ecosystem of Odisha, India.

Materials and Methods

Field experiment was conducted in Instructional Farm, Department of Agronomy, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during wet seasons of 2010-11 and 2011-12. The experimental field was lateritic soil of sandy loam texture with acidic pH (5.8) and medium in available N (295 kg ha^{-1}), P (15 kg ha^{-1}) and K (162 kg ha^{-1}). The soil was deficient in available S (16 kg/ha), Zn (0.66 kg/ha) and B (0.0.86 kg/ha). The experiment was laid out in randomized block design with eleven treatments replicated thrice.The treatments comprised of recommended fertilizer dose (RFD) @ 80-40-40 kg of N-P_2O_5-K_2O ha^{-1}, RFD + FYM @ 5 t ha^{-1}, RFD + $ZnSO_4$ @ 25 kg ha^{-1}, RFD + ethylene di amine tetra acetic acid (EDTA) @ 1 kg ha^{-1},RFD + S @ 30 kg ha^{-1},RFD + B @ 1 kg ha^{-1},,RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1},,RFD + Zn-EDTA @1 Kg ha^{-1}+B @1 kg ha-^{1}, RFD + S @ 30 kg ha-^{1} + B @ 1 kg/ha-1, RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha-1 and RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha-^{1}. The treatments were depicted in table 1,2 and 3.The different nutrient sources were urea(46 %N), diammonium phosphate (18%N and 46%P_2O_5), muriate of potash(60% K_2O), Fertisulph-G (90 S), $ZnSO_4$ (23 % Zn) and Zn EDTA (12% Zn) and Borax (10.5 % B) applied as per the treatments. All P, K, S, Zn and B along with 25 % N were applied as basal dose at transplanting. The farm yard manure (FYM) contained N (0.49%), P (0.19%), K (0.47%), S(0.019%), Zn(20mg/kg) and B(15 mg/kg). The split application of nitrogen was done as top dressing of 50 % N at tillering and rest 25% N at reduction division stage. The test variety 'Lalat'with duration of 125 days was transplanted on 20.07.2010 and 22.07.2011 at a spacing of 15 cm x 10 cm with two seedlings $hill^{-1}$. The crop was harvested at full maturity stage, threshed by Japanese paddy thresher. The weight of grain and straw from each plot was recorded after perfect sun drying. The economics of production influenced by different treatments were worked out taking into account the cost of cultivation and the value of input and output as per the prevailing farm and market price of the locality.

Result and Discussion

Yield and yield attributes

The perusal of data pooled over two seasons depicted that yield attributes like number of panicles m^{-2}, number of fertile grains $panicle^{-1}$ and test weight were significantly influenced by different treatments(Table 1).Integrated application of recommended dose of fertilizer (RFD) + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1} produced the maximum number of panicles m^{-2} (307), and fertile grains $panicle^{-1}$ (157) and the highest test weight (24.14 g) followed by integrated application of RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} +B @ 1 kg ha^{-1}. It was due to favorable effect$ZnSO_4$ + B along with RFD resulting in better absorption and availability on Zn, S and B throughout the growth period in adequate amounts and their synergistic effect in improving yield attributes. The results are in conformity with findings of Arif *et al*., 2012. Moreover, the performance of $ZnSO_4$ was better than Zn-EDTA due to supplementary effect of S with higher percentage of Zn present in the former.Application of $ZnSO_4$ + B along with RFD proved its superiority over single application of $ZnSO_4$/B/S/ Zn-EDTA with RFD or their combinations along with RFD in improving the yield attributing characters. However, single application of RFD or RFD along with FYM was found to be inferior over application of $ZnSO_4$ + B along with RFD resulting in lesser yield attributes. This is supported by the findings of Khurana *et al*., 2008.

The same treatment i.e RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1} produced maximum grain (5.28 t ha^{-1}) and straw (6.33 t ha^{-1}) yield followed by integrated application of RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} +B @ 1 kg ha^{-1}. Among different sources of Zn used as soil application with RFD, $ZnSO_4$ @ 25 kg ha^{-1}recorded significantly higher grain yield (4.6 t ha^{-1}) than in Zn-EDTA @ 1 kg ha^{-1} (3.86 t ha^{-1}). Application of $ZnSO_4$ @ 25 kg ha^{-1} with RFD increased grain yield (4.6 t ha^{-1}) over FYM (4.44 t ha^{-1}), S (3.99 t ha^{-1}), B (3.71 t ha^{-1}), Zn-EDTA + S (4.32 t ha^{-1}), Zn-EDTA + B (4.07 t ha^{-1}) and S + B (4.14 t ha^{-1}) when applied with RFD. Application of $ZnSO_4$ alone could replace FYM, S, B, Zn-EDTA, Zn-EDTA+S, Zn-EDTA + B and S + B. The grain yield during wet seasons was significantly increasing level of nutrients probably exerted a positive effect on source and sink strength of plants, which ultimately resulted enhanced yield. This might be due to direct or cumulative effect of supplied macro and micro nutrients on metabolic process of rice. Boron and zinc are known to influence translocation of metabolites and thereby improving source and sink strength in plants (Maurya *et al*., 2013). Increase in grain yield with application of $ZnSO_4$ + B along with the RFD was obtained due to low inherent Zn status of the soil (0.66 kg/ha) being below the optimum level (1.20 kg/ha). Application of RFD+ZnSO4+B recorded and 48 % yield increase over RFD without secondary and micronutrient where as RFD + Zn-EDTA+S+B recorded 34 % increase over RFD. It was observed that the effect of Zn and B was synergistic when integrated with RFD thereby improved grain and straw yield compared with other treatments. The effectiveness of application of S in the form of elemental S (Fertisulph-G) is less as the experimental soil was acidic in nature. For higher grain yield, with reference to Zn sources, $ZnSO_4$ proved better than Zn-EDTA due to its slow and longer period of availability (Ratan *et al.*, 1997). The better availability of Zn from RFD+$ZnSO_4$+B resulted in maximum 32.5 % increase in straw yield over control (RFD) while RFD +Zn-EDTA+S+B recorded 22 % increase over control (RFD).

Nutrient uptake

During the wet seasons, the effect of different treatments had a marked influence on the uptake of various nutrients is N, P, K, S, Zn and B by rice (Table 2 and Table 3). It was observed that application of $ZnSO_4$ + B integrated with RFD produced had the highest uptake of N, P and K both in grain, straw and total uptake. It was followed by the treatment i.e., application of Zn-EDTA + S + B integrated with RFD. Application of $ZnSO_4$ along with RFD was significantly superior over sole application of $ZnSO_4$, B, Zn-EDTA or their combined application and FYM with respect to uptake of N, P and K. Application of RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1} recorded highest total (grain + straw) uptake of N (135.5 kg ha^{-1}), P (33.10 kg ha^{-1}), K (178.1 kg ha^{-1}), S (13.30 kg ha^{-1}), Zn (256 g ha^{-1}) and B (177 g ha^{-1}) followed by application of RFD + Zn –EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}.The uptake of N, P and K by plant was enhanced by application of $ZnSO_4$ +B along with RFD which might be due to synergistic effect of Zn with S and B in the uptake of plant nutrients. This is in conformity with findings of Pervaiz *et al*., 2012. Application of FYM along with NPK fertilizer mineralized the organic matter rapidly and supplied adequate N, P and K and hence increased its availability and use efficiency thus reflected the N, P and K uptake over NPK alone. Similar was the trend with regard to uptake of S, Zn and B because of quick decomposition and faster release of nutrients. Application of $ZnSO_4$ + B along with RFD was significantly superior over other treatments with regards to uptake of various nutrients because of higher grain and straw yield and higher concentration of nutrients i.e., (N, P, K, S, Zn and B) in the biomass. The synergistic effect of these nutrients and correlated higher uptake with grain and straw yield improved the total nutrient uptake of N, P, K, S, Zn and B. The results are in agreement with the findings of Mohapatra (2003) and Sahoo (2005).

Economics

From the presented data (Table1), it was revealed that maximum gross return (Rs63087 ha^{-1}) and net return(Rs 38162ha^{-1}) were recorded with application of RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1} followed by with application of RFD + Zn EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}giving the corresponding values of (Rs 57154 ha^{-1}) and (Rs 31394 ha^{-1}). The highest B-C ratio was recorded with application of RFD+$ZnSO_4$+B (1.65) followed by application of RFD +Zn-EDTA+S+B (1.26). Sole application of Zn-EDTA/S/B applied along with RFD recorded lower B-C ratio ranging from 0.97 to 1.04.It was evident from the study that the cost of commercial grade of $ZnSO_4$ was less (Rs 45 kg^{-1}) as compared with the cost of commercial grade of Zn-EDTA (Rs 790 kg^{-1}). It was observed that $ZnSO_4$ was much more effective in increasing the yield of the crop. Hence, it influenced gross return, net return and B-C ratio very much than in other forms commercial grade fertilizers.

Conclusion

The combined application of recommended fertilizer dose @ 80-40-40 kg N-P_2O_5-K_2O ha^{-1}along with $ZnSO_4$ @ 25 kg ha^{-1} and B @1 kg ha^{-}1 in kharif rice cv 'Lalat' recorded maximum grain yield of 5.28 t ha^{-1} and nutrient uptake of N (135.5 kg ha^{-1}), P (33.10 kg ha^{-1}), K (178.1 kg ha^{-1}), S (13.30 kg ha^{-1}), Zn (256 g ha^{-1}) and B (177 g ha^{-1}) followed by application of RFD + Zn –EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}. The said treatment also recorded highest net return of Rs 38612 $ha^{-1}$and B:C ratio of 1.65 as against grain yield of 3.57 t ha^{-1},net return of Rs 21101 ha^{-1} and B:C ratio of 0.96 recorded in recommended dose of fertilizer only.

Table 1: Effect of FYM, sulphur, zinc and boron on yield attributes, yield and economics of *wet season* rice (Pooled of 2010-11 and 2011-12)

Treatments	Panicle m^{-2}	Fertile grains $panicle^{-1}$	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	Benefit cost ratio
RFD (80-40-40kg of N-P_2O_5-K_2O ha^{-1})	234	97	19.38	3.57	4.78	43101	21101	0.96
RFD + FYM @ 5 t ha^{-1}	278	132	23.10	4.44	5.59	53293	28293	1.13
RFD + Zn SO_4 @ 25 kg ha^{-1}	283	145	23.38	4.60	5.71	55147	31522	1.38
RFD + Zn EDTA @ 1 kg ha^{-1}	247	112	20.45	3.86	5.03	46504	23714	1.04
RFD + S @ 30 kg ha^{-1}	254	115	20.55	3.99	5.11	47980	23680	1.01
RFD + B @ 1 kg ha^{-1}	247	108	20.13	3.71	4.88	44667	21997	0.97
RFD + Zn EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1}	267	128	20.08	4.32	5.47	51875	26785	1.10
RFD + Zn-EDTA @ 1 kg ha^{-1} + B @ 1 kg ha^{-1}	254	120	21.23	4.07	5,26	48986	25526	1.09
RFD + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}	262	125	21.95	4.14	5.33	49859	25429	1.02
RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}	307	157	24.14	5.28	6.33	63087	38162	1.65
RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}	292	154	23.25	4.77	5.83	57154	31394	1.26
SEm (±)	3.54	2.97	0.59	0.06	0.04	642	654	0.03
CD (P = 0.05)	10.54	8.97	1.78	0.17	0.13	1892	1962	0.08

Table 2: Effect of S, Zn and B nutrition on total nutrient uptake of *wet season* rice (Mean of 2010-11 and 2011-12).

Treatments	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
RFD	51.46	33.35	84.81	11.90	7.75	19.65	19.10	105.5	124.6
RFD+FYM	69.58	42.20	111.80	16.40	10.00	26.40	25.95	126.9	152.9
RFD+$ZnSo_4$	72.70	43.85	116.55	17.20	10.50	27.70	26.00	130.5	156.5
RFD+Zn-EDTA	56.95	35.95	92.90	13.25	8.45	21.70	21.05	111.7	132.8
RFD+S	59.27	36.90	96.20	13.90	8.70	22.60	22.00	114.0	136.0
RFD+B	54.01	34.50	88.50	12.60	8.05	20.65	20.05	108.3	128.4

RFD+ZnEDTA+S	66.23	40.65	106.88	15.50	9.70	25.20	24.75	123.8	148.6
RFD+ZnEDTA+B	61.08	38.30	99.38	14.45	9.05	23.50	22.90	117.9	140.8
RFD+S+B	62.70	39.20	101.90	14.85	9.35	24.20	23.60	120.0	143.6
RFD+ $ZnSo_4$+B	86.06	49.45	135.50	20.70	12.35	33.10	31.50	146.6	178.1
RFD+Zn-EDTA+S+B	76.26	45.30	121.55	18.15	11.00	29.15	28.25	133.6	161.9
SEm (±)	0.56	0.89	0.84	0.73	0.64	0.99	0.55	1.26	0.35
CD (P = 0.05)	1.68	2.67	2.52	2.19	1.92	2.97	1.65	3.78	1.05

Table 3: Total nutrient uptake of S, Zn and B as influenced by, S, Zn and B nutrition in wet season rice (Mean of 2010-11 and 2011-12).

Treatments		**S (kg ha^{-1})**			**Zn (g ha^{-1})**			**B (g ha^{-1})**		
		Grain	**Straw**	**Total**	**Grain**	**Straw**	**Total**	**Grain**	**Straw**	**Total**
T_1	Recommended fertilizer dose (RFD)	2.70	3.00	5.70	54	61	115	35	63	98
T_2	RFD+FYM	4.55	5.45	10.00	95	104	199	47	74	121
T_3	RFD+$ZnSo_4$	5.05	5.70	10.75	100	110	210	52	79	131
T_4	RFD+Zn-EDTA	3.30	3.65	6.95	67	77	144	39	67	106
T_5	RFD+S	3.50	3.80	7.30	71	81	152	41	65	106
T_6	RFD+B	3.00	3.30	6.30	61	71	132	44	73	117
T_7	RFD+Zn-EDTA+S	4.15	5.10	9.25	86	97	183	46	73	119
T_8	RFD+ZnEDTA+B	3.65	4.05	7.70	74	83	157	52	83	135
T_9	RFD+S+B	3.85	4.45	8.30	80	92	172	53	84	137
T_{10}	RFD+ $ZnSo_4$+B	6.25	7.00	13.30	123	133	256	72	105	177
T_{11}	RFD+ZEDTA+S+B	5.40	6.10	11.50	106	116	222	63	95	158
SEm (±)		1.12	1.32	0.56	2.08	1.79	0.58	1.33	4.87	98
CD (P = 0.05)		3.36	3.96	1.68	6.24	5.37	1.74	3.99	14.61	121

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