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Effect of S, Zn, B and FYM on yield and economics of rice-rice cropping system in coastal ecosystem of Odisha, India

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Abstract
A field experiment was conducted during wet and dry seasons of 2010-11 and 2011-12 at Instructional farm, Orissa University of Agriculture and Technology, Bhubaneswar on sandy loam soil with medium availability of organic carbon (0.54%), available N (295 kg ha^{-1}), P (15 kg ha^{-1}), K (162 kg ha^{-1}) and low 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 and three replications. During kharif season, rice variety 'Lalat' was raised with different integrated nutrient management practices involving RFD (N-P_2O_5-K_2O @ 80-40-40-kg/ha), FYM, S, Zn and B. During rabi season 'Lalat' was grown in these treatment plots with acommon dose of N-P2O5-K2O @ 80-40-40 kg ha-1 only to study the residual effect of FYM, S, Zn and B on growth, yield, nutrient uptake and economics of rice, as well as the effect on rice-rice cropping system. Application of recommended fertilizer dose (N-P_2O_5-K_2O @ 80-40-40 kg ha-^{1})+$ZnSO_4$ @ 25 kg ha^{-1}+B @ 1 kg ha^{-1} recorded the highest values of yield attributes viz. number of panicles m^{-2},length of panicle, fertile grains $panicle^{-1}$ and test weight resulting in the maximum grain and straw yield of the rice-rice cropping system followed by application of RFD+Zn-EDTA @1kg ha^{-1}+S @ 30 kg ha^{-1}+B @1kg ha^{-1}. Application of RFD+$ZnSO_4$+B recorded highest gross return, net return and B: C ratio over other management practices.

Keywords: S, Zn, B, FYM, economics, rice-rice and yield

Introduction
A field experiment was conducted in Instructional Farm, Department of Agronomy, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during wet and dry seasons of 2010-11 and 2011-12.The soil of the experimental field was sandy loam in texture with acidic pH (5.8), 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 (8 ppm), Zn (0.33 ppm) and B (0.43 ppm). The experiment consisted of eleven treatments with three replications. It was laid out in randomized block design (RBD).The sources of different fertilizers were i.e. N from Urea, P_2O_5 from DAP, K_2O from MOP, S from Fertisulph-G (90% Elemental S), Zn from $ZnSO_4$ (23% Zn) and Zn EDTA (12% Zn) and B from(Borax (10.5% B).During rabi season rice variety 'Lalat' was grown in these treatment plots with a common dose of N-P_2O_5-K_2O @ 80-40-40 kg ha^{-1} to study the residual effect of FYM, S, Zn and B on growth, yield, nutrient uptake and economics of rice-rice cropping system

The treatments comprised of T_1- Recommended Fertilizer Dose (RFD) N-P_2O_5-K_2O @ 80-40-40 kg ha^{-1}, T_2- RFD + FYM @ 5 t ha^{-1}, T_3- RFD + $ZnSO_4$ @ 25 kg ha^{-1} T_4-RFD + Zn-EDTA @ 1 kg ha^{-1}. T_5-RFD + S @ 30 kg ha^{-1},, T_6-RFD + B @ 1 kg ha^{-1},T_7-RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1},, T_8-RFD + Zn-EDTD @1 Kg ha^{-1}+B @1 kg ha-^{1}, T_9- RFD + S @ 30 kg ha-^{1} + B @ 1 kg/ha-^{1}, T_{10}-RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha-1 and T_{11}-RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha-^{1} The duration of the test variety 'Lalat' was 125 days and planted at a spacing of 15 cm x 10 cm with two seedlings $hill^{-1}$. The crop was transplanted on 20.07.2010 and 22.07.2011 during wet seasons and on 21.01.2011 and 20.01.2012 in dry seasons.

Results and discussion

Yield and yield attributes

Yield and yield parameters were significantly influenced by different nutrient management practices. Averaged over two kharif seasons, integrated application of RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1} produced the maximum number of panicles m^{-2} (307), longest (27 cm) panicles, maximum fertile grains $panicle^{-1}$ (157) and 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}. The same trend was also observed for rabi seasons. (Table 1)

Due to metabolic role of Zn in protein synthesis, enzyme activation and carbohydrate metabolism, application of fertilizers containing this element increased the yield attributes and yield. Several research workers indicated a positive influence of micronutrient (Zn) on yield and yield attributing characters (Tabassum *et al*. (2013) [8].

Integrated application of RFD along with ZnSO4 (25 kg ha^{-1}) and B (1 kg ha^{-1}) to Kharif rice produced the maximum total grain (29.96 t ha^{-1}) and straw yield (27.56 t ha^{-1}), net return (₹.86543 ha^{-1}) and B:C ratio (1.70) in rice-rice- cropping system.(Table 2)

The grain yield was significantly influenced by various treatments during kharif and rabi seasons. Considering the data for individual years and the pooled data of grain yield, it was observed that application of $ZnSO_4$+ B along with RFD increased the yield significantly as the inherent Zn status of the soil (0.33 ppm) was poor and below the optimum level (0.6 ppm).

Application of $ZnSO_4$ + B increased the grain and straw yield compared to no Zn/B application which might be due to better utilization of N and P to increase metabolic activities (Khanda and Dixit, 1991) [3]. Increase in yield due to $ZnSO_4$ + B application might be attributed to its role in various enzymatic reaction and catalytic effect on growth process and hormone productions and protein synthesis (Channabasavanna *et al*., 2001) [1]. Besides, application of $ZnSO_4$ + B favoured the root growth with mobilization of plant nutrients at optimum levels and there by increased grain and straw yield of rice. (Das and Singh, 1982) [2]

The increase in grain yield was 48 per cent in kharif and 45 per cent during rabi as compared to RFD due to application of $ZnSO_4$ + boron. It might be due to the influence of Zn on the uptake of extra plant nutrients i.e. NPK, Zn, S and B, during kharif and rabi through enzymatic action in metabolic process which ultimately accounted for the higher grain yield. It was observed that the effect of Zn and B was synergistic when integrated with RFD in enhancing the grain yield. Considering the treatment on application of Zn-EDTA + S+ B integrated with RFD recording the second highest grain yield which was due to delay in availability of Zn and S to the crop and also the content of Zn in Zn-EDTA was less than $ZnSO_4$.

Promising grain yield was also recorded with RFD incorporated with FYM during kharif season. This was due to the fact that organic manure (FYM) acts as the store house of plant nutrients which are easily available to the crop. Organic manure mobilizes the native Zn through chelation and complex formation, with organic ligands and thereby making better availability of native Zn which enhances the zinc use efficiency (ZUE). For higher grain yield, with reference to source, $ZnSO_4$ proved better than Zn-EDTA due to its slow and longer period of availability (Ratan *et al*. 1997) [5].

Highest straw yield was recorded with the application of $ZnSO_4$ + B integrated with RFD followed by application of Zn-EDTA + S + B integrated with RFD. The increase in straw yield followed the same trend as that of the grain yield. Table 2)

Residual effect of $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1} produced the longest (28.1 cm) panicle, maximum number of panicles m^{-2} (331), more fertile grains $panicle^{-1}$ (166) and the highest test weight (24.58 g) during rabi season. (Table 1)

The productive panicles m^{-2} and panicle length due to the residual effect of $ZnSO_4$+B and Zn-EDTA+S+B were at par during rabi. But the residual effect of $ZnSO_4$ + B recorded the highest number of fertile grains panicle-[1]and test weight being significantly superior over residual effect of Zn-EDTA+S+B. (Table. 1). Residual effect of $ZnSO_4$+B recorded favorable effect on yield attributes that might be due to better absorption / availability of Zn / S and B in adequate amount throughout the growth period and their synergistic effect in improving yield components. Mohapatra (2003) [4] reported similar findings with residual effects of S+Zn+B on rabi rice.

Application of $ZnSo_4$ + B integrated with RFD produced more photosynthetic products due to integration of Zn, S and B causing greater availability of N, Zn and S for longer period, resulting in better yield. Similar results were obtained by Srivastava and Gangwar, 1987 [6].

Grain yield during rabi season was higher than that of kharif which might be due to maximum production of photosynthates and better translocation of the same from source to sink. This was also influenced by the favourable conditions (maximum day light hours and temperature), experienced by the crop during its reproductive stage. Application of $ZnSO_4$ + B integrated with RFD increased the grain yield significantly which was found to be superior over other treatments and similar trend was also observed in rabi season.

The study revealed that the residual effect of $ZnSO_4$ + B during rabi season proved to be superior over single use of $ZnSO_4$/S/B or Zn-EDTA or their combinations. Organic sources of plant nutrients (FYM) applied to kharif rice benefitted the succeeding rabi rice due to residual effect which resulted in higher grain yield as compared to sole application to S/B/Zn-EDTA and control (RDF). The grain yield for rabi 2010 and 2011 revealed that highest increase in yield (45%) was recorded with residual effect of $ZnSO_4$ + B over RFD. This was followed by the treatment of residual effect of Zn-EDTA + B recording an yield increase of 32% as compared to RFD.

The straw yield was influenced by the residual effect of various treatments imposed during the kharif and the trend followed similar to that of grain yield. Highest straw yield was recorded due to the residual effect of $ZnSO_4$ + B followed by residual effect of Zn-EDTA + S + B. The residual effect of $ZnSO_4$+ B was significantly superior over sole application of $ZnSO_4$/S/B/Zn-EDTA or their combinations. It was also superior over residual effect of FYM. While considering the source, $ZnSO_4$ proved superior over Zn-EDTA in increasing the straw yield. Sujathamma *et al*. (2013) [7] reported the superiority of $ZnSO_4$ in improving rice yield in rice-rice cropping system.

Economics

The economics of production was influenced by different treatments have been worked out taking into account of cost of cultivation and the value of productionsat prevailing market price. From the rice-rice cropping system data it was revealed that maximum gross return (₹ 137318 ha^{-1}) was recorded by application of RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1} followed by (₹ 124965ha^{-1}) with application of RFD

+ Zn EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1kg ha$^{1.}$The gross return obtained from application of RFD+$ZnSO_4$+B (₹137318 ha^{-1}) recorded in an increase of 14 and 39% over gross return of RFD+$ZnSO_4$(₹ 120875 ha^{-1}) and RFD+B (₹98793 ha^{-1}). Application of RFD + $ZnSO_4$ recorded a gross return (₹ 120875 ha^{-1}) which was superior over RFD + Zn-EDTA recording a gross return of ₹ 101850 ha^{-1}. It was due to lower cost of commercial grade of $ZnSO_4$ as compared to Zn-EDTA and higher efficacy of $ZnSO_4$ over Zn-EDTA. The highest net return (₹ 86543 ha^{-1}) was recorded from RFD + $ZnSO_4$ + B followed by application of RFD + Zn-EDTA + S + B) (₹ 72725 ha$^{-1)}$). Application of RFD+$ZnSO_4$+B recorded 22 and 37% increase in net return than application of RFD + $ZnSO_4$ and RFD + B respectively. The rice-rice cropping system recorded highest B-C ratio with application of RFD+$ZnSO_4$+B (1.70) followed by application of RFD+Zn-EDTA+S+B (1.38). Sole application of Zn-EDTA/S/B applied along with RFD recorded lower B-C ratio ranging from 0.98 to 1.06. It was possible due to greater yield advantage and better fertilizer use efficiency by residual effect of $ZnSO_4$ + B over all other treatment or their combinations. (Table 2)

It was evident from the study that the commercial grade of $ZnSO_4$ is less costly and simultaneously played a great role in increasing the yield of the crop and there by influenced gross return, net return and B:C Ratio. However, the commercial grade of Zn-EDTA is more costly (₹ 790 kg^{-1}) as compared to $ZnSO_4$ (₹ 45 kg^{-1}) and proved less efficient in improving the yield of the crop for which the net return and B:C ratio was less by applying Zn-EDTA in comparison with $ZnSO_4$. Similar findings have been reported by Sujathamma *et al*., 2013 [7] in their study on residual effect of $ZnSO_4$ in rice-rice cropping system.

Conclusion: The combined application of recommended fertilizer dose (N-P_2O_5-K_2O) @ 80-40-40 kg ha^{-1}along with $ZnSO_4$ @ 25 kg ha^{-1} and B @1 kg ha^{-}1 to rice-rice cropping system recorded highest system grain yield of 22.96 t ha^{-1}, straw yield of 27.56 t 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 maximum gross return (₹ 1,37,318 ha^{-1}), net return (₹ 86543 ha$^{-1)}$ and B:C ratio (1.70) in rice-rice- cropping system.

Table 1: Effect of FYM, S, Zn and B on yield attributes of rice -rice cropping system. (pooled of two years).

Treatments		Kharif,2010 & 2011(Pooled)				Rabi,2010 & 2011 (Pooled)			
		Number of panicles m^{-2}	Panicle length (cm)	Fertile grains panicle^{-1}	1000-grain weight (g)	Number of panicles m^{-2}	Panicle length (cm)	Fertile grains panicle^{-1}	1000-grain weight (g)
T_1	RFD (N-P_2O_5-K_2O) @ 80-40-40kg ha^{-1}	234	18.1	97	19.38	258	21.8	107	21.75
T_2	RFD + FYM @ 5 t ha^{-1}	278	26.10	132	23.10	308	25.1	141	24.05
T_3	RFD + Zn SO_4 @ 25 kg ha^{-1}	283	26.2	145	23.38	319	26.5	152	24.25
T_4	RFD + Zn EDTA @ 1 kg ha^{-1}	247	20.0	112	20.45	278	22.4	117	22.88
T_5	RFD + S @ 30 kg ha^{-1}	254	20.5	115	20.55	283	22.5	122	23.20
T_6	RFD + B @ 1 kg ha^{-1}	247	18.5	108	20.13	272	22.3	114	22.65
T_7	RFD + Zn EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1}	267	26.7	128	22.08	301	23.7	137	24.00
T_8	RFD + Zn-EDTA @ 1 kg ha^{-1} + B @ 1 kg ha^{-1}	254	22.4	120	21.23	290	22.7	126	23.72
T_9	RFD + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}	262	24.5	125	21.95	293	23.1	132	23.90
T_{10}	RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}	307	27.0	157	24.14	331	28.1	166	24.58
T_{11}	RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}	292	26.3	154	23.25	325	28.0	158	24.38
SEm (±)		3.54	0.90	2.97	0.59	3.80	0.07	1,25	0.03
CD (P = 0.05)		10.45	2.67	8.92	1.78	11.40	0.21	4.16	0.09

Table 2: Effect of FYM, S, Zn and B on yield and economics of rice-rice cropping system.(pooled of two years).

Treatments		Total Grain yield (t ha^{-1})	Total straw yield (t ha^{-1})	Gross return (`₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
				Total	Total	Mean
T_1	RFD (N-P_2O_5-K_2O) @ 80-40-40kg ha^{-1}	15.69	19.73	95021	46021	0.94
T_2	RFD + FYM @ 5 t ha^{-1}	19.63	24.62	117808	65808	1.26
T_3	RFD + Zn SO_4 @ 25 kg ha^{-1}	20.16	25.04	120875	70750	1.40
T_4	RFD + Zn EDTA @ 1 kg ha^{-1}	16.89	22.33	101850	52060	1.04
T_5	RFD + S @ 30 kg ha^{-1}	17.44	22.73	105035	54235	1.06
T_6	RFD + B @ 1 kg ha^{-1}	16.37	21.94	98793	49143	0.98
T_7	RFD + Zn EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1}	19.06	24.23	114494	62904	1.21
T_8	RFD + Zn-EDTA @ 1 kg ha^{-1} + B @ 1 kg ha^{-1}	17.98	23.34	108213	57773	1.14
T_9	RFD + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}	18.45	23.65	110930	58980	1.14
T_{10}	RFD + $ZnSO_4$ @ 25 kg ha^{-1} + B @ 1 kg ha^{-1}	22.96	27.56	137318	86543	1.70
T_{11}	RFD + Zn-EDTA @ 1 kg ha^{-1} + S @ 30 kg ha^{-1} + B @ 1 kg ha^{-1}	20.86	25.56	124965	72725	1.38
SEm (±)		2.11	1.63	-	-	-
CD (P = 0.05)		6.27	4.89	-	-	-

Table 3: Effect of FYM, S, Zn and B on grain yield (t ha^{-1}) over seasons 2010 & 2011.

Treatments		Kharif			Rabi			Total grain yield
		2010	2011	Pooled	2010	2011	Pooled	
T_1	RFD	3.59	3.55	3.57	4.34	4.22	4.28	15.69
T_2	RFD+FYM	4.35	4.53	4.44	5.36	5.39	5.38	19.63
T_3	RFD+$ZnSO_4$	4.52	4.68	4.60	5.46	5.51	5.48	20.16
T_4	RFD+Zn-EDTA	3.87	3.85	3.86	4.59	4.58	4.59	16.89
T_5	RFD+S	3.92	4.07	3.99	4.76	4.70	4.73	17.44
T_6	RFD+B	3.71	3.70	3.71	4.52	4.44	4.48	16.37
T_7	RFD+Zn-EDTA+S	4.24	4.40	4.32	5.22	5.20	5.21	19.06
T_8	RFD+Zn-EDTA+B	3.99	4.15	4.07	4.89	4.94	4.92	17.98
T_9	RFD+S+B	4.06	4.23	4.14	5.07	5.09	5.08	18.45
T_{10}	RFD+ $ZnSO_4$+B	5.19	5.36	5.28	6.14	6.28	6.21	22.96
T_{11}	RFD+Zn-EDTA+S+B	4.69	4.86	4.77	5.69	5.63	5.66	20.86
SEm (±)		0.06	0.06	0.06	0.05	0.06	0.05	2.11
CD (P = 0.05)		0.18	0.18	0.17	0.16	0.16	0.16	6.27

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