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Effect of Graded Levels of Zinc and Boron on Growth, Yield and Chemical Properties of Soils under Paddy

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Field studies were conducted on application of zinc and boron to summer rice crop on Alfisols at Naganahalli village, Mysore district, Karnataka. The results showed that external application of zinc as $ZnSO_4$ @ 20 kg ha^{-1} and boron as borax @ 4 kg ha^{-1} significantly enhanced the plant height number of tillers $hill^{-1}$, grains per panicle, thousand grain weight, grain yield and straw yield of paddy. Further there was significant increase in major (N, P and K), secondary (S, Ca and Mg) and micronutrient (Zn, Cu, Fe, Mn and B) status of soils.

Introduction

Rice is the most important staple food crop of India and particularly Karnataka state. It is grown in India in an area of 43.86 m ha with a production of 104.80 m t with an average productivity of 2.65 t ha^{-1}. In Karnataka it is cultivated in an area of 1.30 m ha with an annual production of 3.66 m t in (Anon., 2015). The yield of rice has stagnated or on the decline as the micronutrients has emerged as yield limiting factors in soils of Karnataka. Further the soils of Karnataka are primarily deficient in zinc and boron and are one of the reasons for stagnation or decline in the yield of rice in southern part of Karnataka. Therefore, efforts are needed to maximize yield of rice by overcoming the deficiencies of these micronutrients (Hafeez *et al.*, 2013).

Now a day's micronutrients deficiency such as zinc and boron is widespread in rice growing areas of country that leads to substantial loss in yield and quality of grains. Soils deficient in micronutrients are not capable of nourishing crop plant successfully and therefore low yield and quality of crops are obtained. Among the micronutrients, zinc and boron play an important role in seed setting and yield of crops. Zinc is required for the biosynthesis of the plant growth regulator such as indole-3-acetic acid (IAA) (Fang *et al.*, 2008) and for carbohydrate and nitrogen metabolism which leads to high yield and yield components. Boron can influence photosynthesis and respiration and activate number of enzymatic systems of protein and nucleic acid metabolism in plants (Chowdhury *et al.,* 2010).For proper growth and development of crop plants, zinc and boron are essential micronutrients to improve the economic yield and quality of several crop plants (Pratima Sinha *et al.*, 2000).

Fertilizers particularly zinc and boron in addition to recommended dose of major nutrients is needed to increase yield, uptake and total content of essential nutrients in rice (Abbas *et al.*, 2013). Therefore, the experiment was undertaken with an objective to find out the effect of graded levels of zinc and boron on growth, yield and chemical properties of rice soils.

Materials and Methods

Field experiment was conducted on farmer's field at Naganahalli village, Mysore district, Karnataka during summer season, to study the effect of graded levels of zinc and boron on growth, yield and chemical properties of soils under paddy. A composite surface soil sample (0-15 cm depth) was collected for analysis before the commencement of the experiment.

The initial soil status of the experimental site is presented in Table 1. The experiment was laid out in randomised complete block design (RCBD) with sixteen treatments (16) and replicated thrice (3) with using Jaya variety of paddy.

Zinc and boron were added through $ZnSO_4$ and borax respectively at three levels viz., 10, 20 and 30 kg $ZnSO_4$ ha^{-1} and 2, 4 and 6 kg borax ha^{-1}. At transplanting, recommended dose of FYM, 50 per cent of the nitrogen, 100 percent of phosphorus and potassium were applied as complex 20:20:20 fertilizer. The remaining nitrogen was given in two equal split doses through urea, 25 per cent each at tillering and panicle initiation stages, respectively.

Twenty three days old rice seedlings were transplanted at a spacing of 20 x 10 cm with 2 to 3 seedlings per hill in well puddled and leveled plots. Plots were irrigated after two days of transplanting to maintain 2.0 cm level of submergence for eight days. Later, these plots were irrigated to maintain the water level to a height of 5 cm throughout the crop growth except last ten days to harvest.

Appropriate plant protection measures were taken during crop growth. Soil samples (0-15 cm depth) from individual plots were collected at panicle initiation stage and at harvest for analysis of physico-chemical properties of soil by standard method (Piper, 1966; Jackson, 1973; Walkley and Black, 1934; Subbaiah and Asija, 1956; Page *et al.*, 1982; Lindsay and Norwell, 1978 and Berger and Troug, 1939). The biometric observations like plant height at panicle initiation stage and yield parameters viz., number of tillers, number of grains $panicle^{-1}$, test weight (g), grain and straw yield were recorded plot wise. Post-harvest soil samples were collected from different treatments and analysed for nutrient status.

Results and Discussion

Growth and yield parameters of paddy

The results presented in Table 2 indicate that application of recommended levels of major nutrient fertilizers (NPK) along with $ZnSO_4$ @ 20 kg ha^{-1} and Borax @ 4 kg ha^{-1} has significantly enhanced the plant height (87.21 cm) and was superior over all other treatments. Lower plant height of 64.67 cm was recorded in T_1 treatment (RDF + FYM). It is a well-known fact that boron is essential in enhancing carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism, root growth and stimulating other physiological processes of plant (Ashour and Reda, 1972). Since the soil was deficient in both DTPA Zn and B the paddy crop responded well and resulted in enhanced growth and yield. These results were in accordance with that of Balachandar *et al.,* (2003) and Jyoti Sharma *et al.,* (2013) who reported that increase in plant height of crop due to the application of boron and zinc. In this study, a synergistic effect of boron and zinc was found in increasing plant height of rice.

Significantly highest number of tillers $hill^{-1}$ (26.88 number of tillers $hill^{-1}$), number of grains per panicle (130.05 grains per panicle) and thousand grain weight (26.96 g) were recorded in T_{12} treatment which received RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was superior over all other treatments. The lowest number of tillers $hill^{-1}$ (12.61 number of tillers $hill^{-1}$), number of grains per panicle (100.42 grains per panicle) and thousand grain weight (21.87 g) was recorded in T_1 treatment which received RDF + FYM as compared to other treatments. The results very clearly indicated that the application of both the nutrients may increases the number of tillers per hill and also the need for application of boron at an early stage of the crop to increase the tiller numbers. These results were in accordance with that of Muhammad *et al.,* (2012).

A significant increase in grain and straw yield of rice was noticed over the RDF+FYM due to application of different levels of $ZnSO_4$ and borax. The highest grain (62.21 q ha^{-1}) and straw (88.33 q ha^{-1}) yield was recorded in the T_{12} treatment which received RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was significantly superior over all other treatments. The lowest grain (49.89 q ha^{-1}) and straw yield (64.40 q ha^{-1}) was recorded in T_1 (RDF+FYM) treatment. Application of Zn and B, when used alone as well as when applied in combination, resulted in significantly higher grain and straw yields than the control. The beneficial effect of B on enhancement of crop yield has been reported by Sharma (1995), Christos Dordas (2006) and Raghuveer Rao *et al.,* (2013). Similarly, the favorable effect of Zn on yield of different crops has also been well documented (Das, 1992, Subrahmaniyan *et al.,* 2001 and Bagewadi *et al.,* 2003). In this experiment, the crop yield increased to a much greater extent due to the combined use of Zn and B than their use alone. These results were in accordance with that of Muhammad *et al.,* (2012), Quddus *et al.,* (2011) and Jyoti Sharma *et al.,* (2013).

Chemical properties of soil

Soil pH, EC and OC

The results pertaining to soil chemical properties are presented in Table 3. There was no significant difference in soil pH, EC and OC content in soil at both stages of crop growth.

Available major and secondary nutrient status of soil at panicle initiation and at harvest stages of paddy

The status of major and secondary nutrient in soil as influenced by graded levels of zinc and boron in paddy are presented in Table 4 and Table 5. Increase in available nitrogen was noticed among treatments in both stages due to application of RDF with zinc and boron.

A significant increase in available nitrogen was noticed over RDF+FYM treatment due to combined application of NPK with Zn and B which form synergistic relationship and helps in increased available nitrogen in all treated plots. The available nitrogen in soil was higher at panicle initiation stage of crop and declined at later stage. This might be due to the uptake of N by the growing plants as described by Prakash *et al.,* (1994).

There was a significant increase in available phosphorus status of soil over RDF with borax treated plots in both stages. The boron had no relation with P compared to Zn.

But the combination of RDF with $ZnSO_4$ and Borax had slight increase in available P compared to initial value might be due to addition of P fertilizer and S in $ZnSO_4$ that helps in P availability.

The available P content was higher in initial stages of crop but declined at later stages. This may be due to uptake of P by growing plants and/or due to refixation of solubilized P.

These observations are in conformity with the findings of Dashrath Singh *et al.,* (1976).

Available potassium showed significant difference among treatments. Significantly higher potassium content was observed in T_{16} treatment (RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}) at both stages and followed by T_{13} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}) at both stages. RDF+FYM (T_1) recorded significantly lower available potassium at both stages. Rao and Shukla (1997) reported that increase in release rate of K on application of fertilizers resulted in larger decline of K in reserve pool of the soil.

Table.1 Initial physical and chemical properties of the experimental site

Particulars		Content
Physical properties		
Particle size distribution	Sand (%)	78.00
	Silt (%)	7.50
	Clay (%)	14.50
	Texture	Sandy loam
Bulk density (Mg m^{-3})		1.53
Particle density (Mg m^{-3})		2.70
Pore space (%)		44.00
Maximum water holding capacity (%)		37.20
Chemical properties		
pH (1:2.5)		7.38
EC (dSm^{-1} at 25^0 C)		0.29
Organic Carbon (%)		0.51
Availabe N (kg ha^{-1})		287.28
Available P_2O_5 (kg ha^{-1})		17.58
Available K_2O (kg ha^{-1})		206.04
CEC [Cmol (P$^+$) kg^{-1}]		14.80
Exchangeable Ca [Cmol (P$^+$) kg^{-1}]		5.86
Exchangeable Mg [Cmol (P$^+$) kg^{-1}]		2.50
Available S (mg kg^{-1})		14.40
DTPA – Extractable Zn (mg kg^{-1})		0.92
DTPA – Extractable Cu (mg kg^{-1})		1.20
DTPA – Extractable Fe (mg kg^{-1})		3.24
DTPA – Extractable Mn (mg kg^{-1})		2.01
Hot water soluble B (mg kg^{-1})		0.69

Table.2 Effect of graded levels of zinc and boron on growth and yield (q ha^{-1}) of paddy at Naganahalli, Mysore district, Karnataka

Treatments	Plant height (cm)	Number of tillers $hill^{-1}$	No.of grains / panicle	Thousand grain weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1: Rec. NPK + FYM (No Zn and B application)	64.67	12.61	100.42	21.87	49.89	64.40
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	73.11	17.65	108.03	23.02	50.74	70.16
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	78.47	20.66	119.36	24.68	52.25	74.99
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	75.40	19.87	117.67	23.40	51.15	71.13
T_5: RDF + Borax @ 2 kg ha^{-1}	73.31	17.21	112.00	23.20	52.39	75.64
T_6: RDF + Borax @ 4 kg ha^{-1}	77.67	20.93	120.33	25.14	54.25	80.08
T_7: RDF + Borax @ 6 kg ha^{-1}	75.65	20.22	119.84	24.16	53.42	79.46
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	78.10	21.44	120.86	23.57	54.58	77.38
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	80.44	23.67	121.77	25.20	55.14	81.10
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	81.85	23.45	122.20	24.71	56.70	84.53
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	83.18	22.32	127.59	25.32	60.94	86.25
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	87.21	26.88	130.05	26.96	62.21	88.33
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	85.87	23.85	129.14	26.33	61.63	87.43
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	84.57	23.46	123.50	24.98	60.35	84.27
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	81.11	22.46	122.67	24.52	59.36	83.82
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	80.66	21.58	122.01	23.25	58.75	81.61
S.Em±	0.88	0.51	1.67	0.37	1.18	0.35
C.D. at 5 %	2.64	1.53	5.00	1.12	3.55	1.05

Table.3 Effect of graded levels of zinc and boron on soil reaction (pH), electrical conductivity (EC) and organic carbon content of soil at different growth stages of paddy at Naganahalli, Mysore district, Karnataka

Treatments	pH		EC (dSm^{-1})		OC (%)	
	Panicle initiation stage	Harvest stage	Panicle initiation stage	Harvest stage	Panicle initiation stage	Harvest stage
T_1: Rec. NPK + FYM (No Zn and B application)	7.37	7.34	0.31	0.29	0.66	0.61
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	7.19	7.20	0.33	0.30	0.63	0.58
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	7.17	7.18	0.34	0.32	0.60	0.55
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	7.10	7.12	0.35	0.33	0.59	0.52
T_5: RDF + Borax @ 2 kg ha^{-1}	7.25	7.22	0.30	0.29	0.57	0.54
T_6: RDF + Borax @ 4 kg ha^{-1}	7.22	7.20	0.32	0.31	0.62	0.57
T_7: RDF + Borax @ 6 kg ha^{-1}	7.15	7.13	0.33	0.32	0.59	0.55
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	7.26	7.23	0.34	0.33	0.58	0.54
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	7.24	7.20	0.35	0.34	0.57	0.53
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	7.20	7.17	0.36	0.33	0.54	0.51
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	7.24	7.21	0.34	0.32	0.57	0.55
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	7.21	7.18	0.37	0.35	0.55	0.52
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	7.19	7.15	0.38	0.36	0.55	0.51
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	7.18	7.16	0.35	0.33	0.56	0.53
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	7.14	7.13	0.37	0.35	0.53	0.51
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	7.08	7.04	0.39	0.36	0.52	0.50
S.Em±	0.05	0.03	0.01	0.01	0.02	0.02
C.D. at 5 %	NS	0.10	0.04	0.03	0.06	0.05

Table.4 Effect of graded levels of zinc and boron on available major nutrient status (kg ha^{-1}) of soil at different growth stages of paddy at Naganahalli, Mysore district, Karnataka

Treatments	Available N		Available P_2O_5		Available K_2O	
	Panicle initiation stage	Harvest stage	Panicle initiation stage	Harvest stage	Panicle initiation stage	Harvest stage
T_1: Rec. NPK + FYM (No Zn and B application)	289.93	280.50	17.82	17.70	210.38	206.72
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	297.53	287.83	18.78	18.39	212.66	207.00
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	305.21	296.18	18.47	18.08	214.95	210.27
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	299.80	291.65	18.03	17.82	217.46	212.63
T_5: RDF + Borax @ 2 kg ha^{-1}	297.64	287.55	16.08	15.73	218.33	214.27
T_6: RDF + Borax @ 4 kg ha^{-1}	301.78	293.68	16.71	16.11	220.48	217.30
T_7: RDF + Borax @ 6 kg ha^{-1}	303.05	294.64	17.03	16.56	219.06	214.37
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	309.38	298.53	18.63	17.92	219.42	214.92
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	312.19	304.77	19.35	18.44	222.03	216.31
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	316.98	307.47	19.82	18.77	223.28	216.28
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	317.78	304.90	21.39	19.36	220.37	212.24
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	322.89	312.03	22.12	20.89	222.48	217.13
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	322.89	309.50	22.04	19.72	224.57	217.78
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	322.18	311.88	20.93	19.39	220.60	212.60
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	318.49	311.27	20.89	19.00	223.09	216.71
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	313.57	308.33	20.26	18.98	225.66	218.28
S.Em±	2.58	1.21	0.32	0.18	1.47	1.46
C.D. at 5 %	7.74	3.64	0.97	0.53	4.39	4.36

Table.5 Effect of graded levels of zinc and boron on secondary nutrient status of soil at different growth stages of paddy at Naganahalli, Mysore district, Karnataka

Treatments	Ca [Cmol (P$^+$) kg^{-1}]		Mg [Cmol (P$^+$) kg^{-1}]		Available S (mg kg^{-1})	
	Panicle initiation stage	Harvest stage	Panicle initiation stage	Harvest stage	Panicle initiation stage	Harvest stage
T_1: Rec. NPK + FYM (No Zn and B application)	5.87	5.83	2.40	2.29	16.81	16.04
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	5.90	5.85	2.54	2.36	20.41	19.92
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	5.98	5.91	2.57	2.41	21.21	20.33
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	5.95	5.88	2.52	2.34	22.82	21.27
T_5: RDF + Borax @ 2 kg ha^{-1}	6.01	5.93	2.44	2.30	17.32	17.05
T_6: RDF + Borax @ 4 kg ha^{-1}	6.06	5.98	2.48	2.33	18.19	17.79
T_7: RDF + Borax @ 6 kg ha^{-1}	6.03	5.95	2.50	2.37	19.10	18.73
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	6.04	5.96	2.53	2.35	20.65	19.51
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	6.07	5.97	2.56	2.38	22.07	21.11
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	6.09	6.00	2.59	2.41	22.60	21.77
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	6.12	6.03	2.61	2.40	22.26	21.20
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	6.15	6.07	2.64	2.42	23.01	22.42
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	6.18	6.10	2.66	2.44	22.88	21.87
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	6.08	5.99	2.49	2.41	22.51	21.35
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	6.10	6.02	2.47	2.39	23.03	22.50
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	6.13	6.05	2.41	2.37	23.69	22.73
S.Em±	0.02	0.02	0.04	0.04	0.39	0.47
C.D. at 5 %	0.06	0.05	0.11	NS	1.18	1.42

Table.6 Effect of graded levels of zinc and boron on micronutrient status (mg kg^{-1}) of soil at different growth stages of paddy at Naganahalli, Mysore district, Karnataka

Treatments	Zn	Cu	Fe	Mn	B	Zn	Cu	Fe	Mn	B
	Panicle initiation stage					Harvest stage				
T_1: Rec. NPK + FYM (No Zn and B application)	1.31	1.38	4.67	2.16	0.63	1.21	1.31	4.62	2.12	0.60
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	2.84	1.33	4.37	2.13	0.66	2.73	1.25	4.22	2.08	0.63
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	3.03	1.28	4.21	2.10	0.72	2.94	1.21	4.13	2.05	0.68
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	2.95	1.24	4.11	2.08	0.67	2.81	1.19	4.02	2.05	0.65
T_5: RDF + Borax @ 2 kg ha^{-1}	2.23	1.66	4.27	2.10	0.75	2.10	1.55	4.21	2.03	0.72
T_6: RDF + Borax @ 4 kg ha^{-1}	2.70	1.77	4.12	2.07	0.82	2.57	1.70	4.08	2.01	0.77
T_7: RDF + Borax @ 6 kg ha^{-1}	2.40	1.84	4.01	2.04	0.88	2.29	1.77	3.96	1.97	0.83
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	2.98	2.10	4.18	2.08	0.78	2.79	1.96	4.13	2.05	0.74
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	3.07	2.24	4.04	2.06	0.85	2.91	2.19	3.89	2.00	0.80
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	3.12	2.18	3.81	2.06	0.90	3.01	2.10	3.78	2.01	0.84
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	3.50	2.12	3.85	2.05	0.92	3.30	2.04	3.63	2.00	0.82
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	3.88	2.05	3.67	2.03	0.97	3.62	1.96	3.56	1.98	0.90
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	3.69	1.93	3.36	2.00	0.94	3.45	1.81	3.29	1.98	0.88
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	3.61	2.03	3.31	2.01	0.90	3.35	1.94	3.25	1.96	0.84
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	3.47	1.94	3.30	1.99	0.87	3.30	1.86	3.25	1.93	0.82
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	3.29	1.83	3.27	1.97	0.78	3.16	1.71	3.24	1.90	0.72
S.Em±	0.15	0.04	0.09	0.01	0.02	0.12	0.05	0.20	0.02	0.02
C.D. at 5 %	0.45	0.11	0.28	0.04	0.05	0.35	0.15	0.61	0.05	0.06

Status of calcium and magnesium was significantly influenced by the application of graded levels of zinc and boron at both the stages. Further significantly higher exchangeable Ca and Mg were noticed in T_{13} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}) followed by T_{12} treatment at both stages but at harvest Mg showed non-significance. Lower exchangeable Ca and Mg was recorded in T_1 treatment (RDF+FYM) at both stages. The combination of these nutrients could form synergistic relationship contributed for higher availability of these nutrients in soil. The exchangeable calcium and magnesium content of soil was higher at initial stage of the crop and declined at later stage. This may be attributed to uptake of calcium and magnesium by the growing plants as reported by Prakash *et al.,* (1994).

The available S was influenced significantly by treatment effect in both stages. The plots treated with $ZnSO_4$ had significantly higher content of available S than those which were not treated with $ZnSO_4$. The reason for this could be attributed to the release of S from $ZnSO_4$ to the soil. After utilization of part of the released S from $ZnSO_4$, the leftover of it might have contributed to the soil available pool. Since the levels of applied B were slightly low, but the B had significant effect on soil available sulphur.

Micronutrient status of soil at panicle initiation and at harvest stages of paddy

The status of micronutrient in soil as influenced by graded levels of zinc and boron in paddy are presented in Table 6. In respect of available Zn and hot water soluble B, the T_{12} (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}) treatment had significantly higher available Zn and B than T_1 treatment (RDF+FYM) and followed by T_{13} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}). However, the levels of Zn and B had significant effect on available Zn and B of soil at both stages. The difference in the quantities of applied Zn and B might be the reason for this and have good relation with synergistic in interaction.

Significantly higher Cu was recorded in T_9 treatment (RDF + $ZnSO_4$@ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}) followed by T_{10} treatment (RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}). Lowest Cu in soil was recorded in T_4 treatment (RDF+ $ZnSO_4$ @ 30 kg ha^{-1}) at both the stages. This might be due to antagonistic interaction of zinc and copper in soil (Tisdale *et al.,* 1985).

The application of FYM revealed significant increase in Fe and Mn content in soil at both stages. The combined application of different levels of Zn and B treated plots showed low Fe and Mn content. Tisdale *et al.,* (1985) reported that decreased availability of Fe and Mn in soils may be due to antagonistic interaction between zinc and manganese and boron and iron and manganese in soil.

It can be concluded that application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} recorded significantly higher growth and yield of rice compared to other treatments. At both stages of crop, the significant increase in major, secondary and micronutrient status of soils was noticed among treatments due to application of RDF with graded levels of zinc and boron compared to RDF+FYM treatments.

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