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Research Article

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Effect of graded levels of zinc and boron on nutrient content and uptake by grain and straw of paddy

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Summary

A field experiment was taken during summer at Naganahalli village, Mysore district, Karnataka to study the graded levels of zinc and boron on nutrient content and uptake by grain and straw of paddy. Among the treatments, T_{12} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) recorded significantly higher nutrients (N, P, Ca, Mg, Zn, Cu and B) content and uptake by grain and straw of paddy compared to all other treatments. The potassium and sulphur content and uptake were significantly high in T_{16} treatment (RDF + $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 6 kg ha^{-1}) but, the potassium uptake was significantly high in T_{13} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 6 kg ha^{-1}). The RDF+FYM (T_1) treatment showed significantly higher Fe and Mn content but their uptake was significantly high in T_{12} (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) and T_3 (RDF + $ZnSO_4$ @ 20 kg ha^{-1}) treatment by grain and straw of paddy.

Key words : Content, Uptake, Grain, Straw, Treatment, Significantly

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Introduction

Rice is the most important staple food crop in the world as well as in India. It serves as a major source of calories for about 60 per cent of the world population. Globally, it occupies an area of 147 m ha with production of 525 m t. Rice is grown 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 India and 1.30 m ha with an annual production of 3.66 m t in Karnataka (Anonymous, 2015). Rice crop needs seventeen essential nutrients which are supplied through the soil, in the form of fertilizers and manures. Dash *et al*. (2015) reported that balanced nutrition based on soil test value is the key to sustain rice productivity and to improve soil productivity. A suitable combination of micronutrients is the most important single factor that affects the productivity of the crops.

The zinc and boron are required for the basic processes of plant life. Zinc participate in the synthesis of tryptophan which is a precursor of indol acetic acid (IAA) and is required for plant growth, nitrogen metabolism, starch and chlorophyll synthesis and AT Pase activity, as well as the transport of assimilates (Deise *et al.*, 2012). Shelp (1993) and Marschner (1995) reported that boron plays an important role in meristem tissue cell division, petal and leaf bud formation, sugar and hydrocarbon metabolism and their transfer, pollen budding and seed formation. Boron is responsible for the integrity of the cell membrane, cell wall synthesis and lignification (Goldbach *et al.*, 2001).

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 grain with respect to protein and fat contents. Little is known about the effect of applying these micronutrients on the production and nutritional value of paddy. Fertilizers particularly zinc and boron in addition to recommended dose of major nutrients is needed to increase uptake and total content of nutrients in rice (Abbas *et al.*, 2013). Therefore, by studying zinc and boron interaction in the grain, we can find its indirect effects that improvement of the harvest qualitatively and quantitatively, while enriching the grain of paddy (Farshid Aref, 2011b). Also, it has been shown that if we use grains rich in these elements, we can improve the harvest qualitatively and quantitatively. Therefore, the present experiment was undertaken with an objective to find out the effect of graded levels of zinc and boron on nutrient content and uptake by paddy.

Resource and Research Methods

The experiment was taken in red shallow, moderately deep and deep soils of farmer's field at Naganahalli village, Mysore district, Karnataka during summer season, to study the effect of graded levels of zinc and boron on nutrient contents and uptake by grain and straw of 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 A. The experiment was laid out in Randomized Complete Block Design with sixteen treatments and replicated thrice with using Jaya variety of paddy.

The application of zinc and boron 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 nitrogen, 100 per cent 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.

Table A : Initial physical and chemical properties of the experimental site

Particulars		Content
Physical properties		
	Sand (%)	78.00
Particle size	Silt (%)	7.50
distribution	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
Avail. N (kg ha^{-1})		287.28
Avail. P_2O_5 (kg ha^{-1})		17.58
Avail. K_2O (kg ha^{-1})		206.04
CEC [c mol (p$^+$) kg^{-1}]		14.80
Exch. Ca [c mol (p$^+$) kg^{-1}]		5.86
Exch. Mg [c mol (p$^+$) kg^{-1}]		2.50
Avail. 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

The plant samples were collected from each plot and were dried in hot air oven at 65°C for 24 hours. Dried samples were powdered and stored in plastic containers for analysis. Powdered grain and straw samples were predigested with HNO_3 for a period of twelve hours then treated with diacid (HNO_3: $HClO_4$ in 10:4 ratio) mixture and digested on sand bath till white residue was obtained. Cooled and the volume was made upto 100 ml using 6N HCl. The samples were analysed for nutrient composition of grain and straw by standard method (Piper, 1966; Jackson, 1973 and Jones and Case, 1990).

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Effect of graded levels of zinc and boron on major nutrients content of paddy grain and straw :

The N, P and K content in grain and straw increased due to application of levels of zinc and boron with RDF (Table 1). Significantly higher N and P content in grain and straw was recorded in T_{12} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) compared to T_1 treatment (RDF + FYM). The similar findings were obtained by Aydn and Sevinc (2006). There was significant increase in N and P concentration with increasing levels. The effect of Zn on N concentration may be dilution effect, while the effect of B on N concentration may be a synergistic relationship between these nutrients (Hosseini *et al.*, 2007).

The potassium content in grain and straw were significantly high in T_{16} treatment (RDF + $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 6 kg ha^{-1}) compared to RDF+FYM due to increased levels of application of Zn and B (Aydn and Sevinc, 2006). Hosseini *et al.* (2007) reported that, boron application increased K concentration irrespective of Zn supply. This may be due to synergistic interaction between B and K. Similar results were also reported in wheat (Yadav and Manchanda, 1979) and Lentil (Singh and Singh, 1983).

Effect of graded levels of zinc and boron on secondary nutrients content of paddy grain and straw :

The secondary nutrients content of paddy grain and straw is given in Table 2. Higher Ca and Mg content in grain and straw were recorded in T_{12} treatment (RDF + $ZnSO_4$@20 kg ha^{-1}+borax@4 kg ha^{-1}) which were significantly superior than T_1 (RDF+FYM) and followed by T_{13} (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 6 kg ha^{-1}) and T_{14} (RDF + $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 2 kg ha^{-1}) treatment. The combination of these nutrients will form good synergistic relationships in plants to contribute maximum concentration in both grain and straw.

Significantly higher S content in grain and straw was recorded in T_{16} (RDF + $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 6 kg ha^{-1}) followed by T_{15} (RDF + $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 4 kg ha^{-1}) and T_{13} (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 6 kg ha^{-1}) treatment. The lower S content was recorded in T_1treatment (RDF+FYM) in grain and straw. Usually higher S content in grain and straw was noticed in $ZnSO_4$ treated plots as compared to untreated plots. However, the levels and methods of B application were found to have no effect on S contents in grain and straw.

Table 1 : Effect of graded levels of zinc and boron on major nutrients content (%) in grain and straw of paddy at harvest

Treatments	Nitrogen content		Phosphorus content		Potassium content	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Rec. NPK + FYM (No Zn and B application)	1.26	0.78	0.15	0.10	0.39	0.82
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	1.33	0.81	0.16	0.11	0.48	1.01
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	1.40	0.86	0.19	0.13	0.52	1.07
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	1.38	0.82	0.21	0.12	0.55	1.10
T_5: RDF + Borax @ 2 kg ha^{-1}	1.28	0.80	0.20	0.11	0.43	0.87
T_6: RDF + Borax @ 4 kg ha^{-1}	1.34	0.85	0.23	0.12	0.46	0.92
T_7: RDF + Borax @ 6 kg ha^{-1}	1.29	0.81	0.26	0.14	0.50	0.96
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	1.38	0.84	0.24	0.13	0.51	1.06
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	1.43	0.87	0.27	0.15	0.54	1.10
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	1.45	0.89	0.29	0.17	0.58	1.16
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	1.47	0.90	0.24	0.12	0.52	1.09
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	1.55	0.95	0.30	0.18	0.55	1.12
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	1.52	0.92	0.27	0.16	0.57	1.16
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	1.54	0.94	0.25	0.13	0.53	1.12
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	1.50	0.89	0.21	0.11	0.55	1.14
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	1.48	0.82	0.19	0.11	0.58	1.18
S.E.±	0.02	0.02	0.01	0.01	0.02	0.02
C.D. (P=0.05)	0.07	0.07	0.04	0.03	0.05	0.06

Effect of graded levels of zinc and boron on micronutrients content in grain and straw of paddy:

The micronutrients content in grain and straw of paddy is presented in Table 3. Significantly higher Zn (24.90 mg kg^{-1} and 39.89 mg kg^{-1}) and B (3.75 mg kg^{-1} and 1.87 mg kg^{-1}) content in grain and straw were

Table 2 : Effect of graded levels of zinc and boron on secondary nutrients content (%) in grain and straw of paddy at harvest

Treatments	Calcium content		Magnesium content		Sulphur content	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Rec. NPK + FYM (No Zn and B application)	0.25	0.32	0.10	0.12	0.10	0.08
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	0.30	0.40	0.13	0.15	0.12	0.11
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	0.36	0.52	0.16	0.20	0.14	0.13
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	0.32	0.46	0.14	0.17	0.16	0.15
T_5: RDF + Borax @ 2 kg ha^{-1}	0.31	0.43	0.11	0.13	0.11	0.09
T_6: RDF + Borax @ 4 kg ha^{-1}	0.35	0.51	0.13	0.17	0.13	0.12
T_7: RDF + Borax @ 6 kg ha^{-1}	0.33	0.45	0.11	0.15	0.15	0.13
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	0.36	0.53	0.14	0.17	0.13	0.12
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	0.38	0.57	0.17	0.20	0.16	0.15
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	0.40	0.62	0.19	0.23	0.19	0.17
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	0.40	0.63	0.18	0.20	0.15	0.13
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	0.45	0.70	0.23	0.24	0.18	0.16
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	0.43	0.66	0.19	0.21	0.21	0.18
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	0.42	0.63	0.20	0.23	0.18	0.16
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	0.39	0.61	0.18	0.20	0.21	0.19
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	0.36	0.57	0.16	0.18	0.23	0.20
S.E.±	0.02	0.01	0.01	0.01	0.02	0.01
C.D. (P=0.05)	0.05	0.04	0.04	0.04	0.05	0.04

Table 3 : Effect of graded levels of zinc and boron on micronutrients content (mg kg^{-1}) in grain and straw of paddy at harvest

Treatments	Zn	Cu	Fe	Mn	B	Zn	Cu	Fe	Mn	B
	Grain					Straw				
T_1: Rec. NPK + FYM (No Zn and B application)	21.51	15.02	193.50	64.16	2.38	23.00	14.73	192.81	60.13	1.47
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	23.33	19.85	189.98	63.13	2.42	28.36	17.43	187.47	59.01	1.50
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	24.04	18.91	186.92	61.69	2.56	30.33	17.28	184.81	58.91	1.57
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	23.71	17.67	183.86	59.28	2.50	27.18	16.19	180.58	56.16	1.53
T_5: RDF + Borax @ 2 kg ha^{-1}	20.93	18.63	188.82	57.52	2.96	26.60	17.31	186.43	54.37	1.60
T_6: RDF + Borax @ 4 kg ha^{-1}	22.53	19.06	183.83	57.08	3.17	27.14	17.93	182.08	52.42	1.72
T_7: RDF + Borax @ 6 kg ha^{-1}	20.74	19.28	179.58	54.65	3.04	26.65	18.66	178.25	51.64	1.65
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	21.22	17.83	187.55	52.56	3.01	26.63	16.85	184.48	49.46	1.63
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	22.19	18.68	184.39	51.29	3.10	29.50	18.19	181.33	47.45	1.66
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	24.49	22.03	179.88	49.52	3.17	32.66	20.45	177.65	46.43	1.70
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	22.11	18.92	178.89	50.18	3.60	31.76	18.08	176.46	48.17	1.82
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	24.90	22.04	177.83	49.13	3.75	39.89	20.23	173.71	45.53	1.87
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	24.64	19.54	176.24	48.88	3.32	39.44	18.69	171.59	44.13	1.77
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	22.36	18.37	176.05	48.54	3.13	32.71	17.16	170.56	43.05	1.67
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	21.61	17.93	172.01	48.06	2.99	30.45	16.57	169.85	42.79	1.64
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	20.14	17.18	169.89	47.75	2.86	28.26	16.17	168.06	42.27	1.59
S.E.±	0.66	0.44	2.06	0.64	0.07	0.64	0.60	1.37	1.72	0.02
C.D. (P=0.05)	1.98	1.31	6.16	1.91	0.22	1.91	1.81	4.11	5.15	0.06

recorded in T_{12} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) compared to T_1 treatment (RDF+FYM). Hosseini *et al*. (2007) reported that, irrespective of Zn supply, B concentration was markedly increased with increasing B application. When no B was applied, Zn elevated B concentration. Sinha *et al.* (2000) observed that Zn fertilization increased B in the leaves of mustard plants supplied with low or adequate B reduced it when B was excessive.

Significantly higher Cu (22.04 mg kg^{-1} and 20.45 mg kg^{-1}) content in grain and straw was observed in T_{12} (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) and T_{10} treatment (RDF + $ZnSO_4$ @ 10 kg ha^{-1} + borax @ 6 kg ha^{-1}) by the application of zinc and boron compared to T_1treatment (RDF+FYM). Farshid Aref (2011a) reported that, the effect of Zn-B interaction on the plant Cu concentration showed the use of B in any Zn levels had no effect on the Zn concentration in plant. At B levels, the application of Zn increased the Cu content, but at other B level, the use of Zn had no effect on the Cu content in plants.

The iron and manganese content in grain and straw was significantly low in combined treatments of zinc and boron compared to RDF+FYM. Higher content of Fe (193.50 mg kg^{-1} and 192.81 mg kg^{-1}) and Mn (64.16 mg kg^{-1} and 60.13 mg kg^{-1})in grain and straw was recorded in T_1 (RDF+FYM) compared to other treatments. Farshid Aref (2012) reported that, Zn and B application at all levels and combined application showed low Fe content in plants. The reduction in Mn content in plant by Zn and B application may be due to dilution effect or antagonistic relationship between Zn and Mn and B and Mn.

Effect of graded levels of zinc and boron on major nutrients uptake by grain and straw of paddy :

Uptake of major nutrients by paddy grain and straw are furnished in Table 4. Significantly higher N uptake by grain and straw of paddy were recorded in T_{12}treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) and lower uptake was recorded in T_1treatment (RDF +FYM) in grain and straw. Jiang *et al*. (1994) reported that, an increase in uptake of N because of the application of B in groundnut. Shrivastava *et al*. (1993) reported the beneficial effect of Zn on N uptake in cotton. However, application of boron along with zinc resulted in much higher N uptake values as compared to application of boron alone.

Significantly higher P uptake by grain and straw were recorded in T_{12}treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) and it significantly superior

Table 4 : Effect of graded levels of zinc and boron on major nutrients uptake (kg ha^{-1}) by grain and straw of paddy at harvest

Treatments	Nitrogen		Phosphorus		Potassium	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Rec. NPK + FYM (No Zn and B application)	62.96	50.23	7.48	6.44	19.62	52.59
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	67.32	56.59	8.29	7.48	24.36	70.63
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	73.32	64.40	9.75	9.75	27.17	80.24
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	70.76	58.43	10.57	8.54	28.13	78.25
T_5: RDF + Borax @ 2 kg ha^{-1}	67.06	60.51	10.65	8.32	22.70	66.06
T_6: RDF + Borax @ 4 kg ha^{-1}	72.70	68.33	12.48	9.34	24.96	73.94
T_7: RDF + Borax @ 6 kg ha^{-1}	68.73	64.10	13.71	11.39	26.89	76.28
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	75.51	65.11	12.92	9.80	27.84	81.77
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	78.85	70.36	15.07	12.44	29.78	89.21
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	82.40	74.86	16.44	14.37	33.08	97.77
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	89.58	77.25	14.42	10.64	31.48	93.72
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	96.43	83.79	18.66	16.19	34.22	99.22
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	93.68	80.66	16.85	13.70	35.13	101.71
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	92.70	79.14	15.29	10.67	32.19	94.66
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	89.05	74.47	12.66	9.22	32.65	95.56
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	86.95	67.19	11.16	8.76	34.27	96.02
S.E.±	1.43	1.77	0.76	0.67	0.86	1.57
C.D. (P=0.05)	4.30	5.30	2.28	2.00	2.57	4.71

over all other treatments. Lower P uptake was reported in T_1 treatment (RDF+FYM) in grain and straw. Frashid Aref (2011b) reported that, the application of Zn and B at all levels and in combination had increased the uptake of P in both grain and straw compared to RDF +FYM.

Significantly higher potassium uptake by grain and straw were recorded in T_{13} (RDF +$ZnSO_4$@ 20 kg ha^{-1} + borax @ 6 kg ha^{-1}) treatment but lower K uptake was recorded in T_1 (RDF+FYM). Use of zinc caused significantly higher K uptake when applied alone or in combination with borax. Similar effect was observed when B was applied to the soil along with zinc. Application of borax along with zinc sulphate recorded significantly higher uptake of K as compared to their application alone. Longanathan and Krishnamoorthy (1977) and Golakia and Patel (1986) have reported that, an increase in K uptake due to application of B in groundnut. Shrivastava *et al*. (1993) reported similar result when zinc was applied to the soil in cotton. A synergistic effect of B and Zn on K uptake had been reported by Lopez *et al*. (2002).

Effect of graded levels of zinc and boron on secondary nutrients uptake by grain and straw of paddy :

The secondary nutrients uptake by grain and straw of paddy is presented in Table 5. Calcium uptake was significantly varied due to levels of zinc and boron application. Higher Ca uptake by grain and straw were recorded in T_{12} (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) treatment and was significantly superior than other treatments. Lowest Ca uptake was recorded in T_1 (RDF+FYM) in grain and straw. Application of B resulted in better uptake of Ca when applied alone or in combination with Zn except at very high level of soil application. Increase in uptake of Ca by B application had been reported by Suruvasi *et al*. (1986).

Significantly higher Mg uptake by grain and straw were recorded in T_{12} (RDF + $ZnSO_4$ @ 20 kg ha^{-1}+ borax @ 4 kg ha^{-1}) treatment. Lowest Mg uptake was recorded in T_1 (RDF+FYM) in grain and straw. The optimum doses performed better than higher doses when borax was applied either alone or in combination with $ZnSO_4$. Application of zinc did not indicate a favorable effect when applied along with B at any of the level. The results are in accordance with those of Suruvasi *et al*. (1986).

The suphur uptake by paddy grain and straw increased with increased zinc and boron application and was significantly high in T_{16} treatment (RDF+ $ZnSO_4$ @ 30 kg ha^{-1} + borax @ 6 kg ha^{-1}). The Uptake of S was significantly higher in $ZnSO_4$ treated plots as compared to those that are not treated. However, the levels and methods of B application had no effect on S uptake by

Table 5 : Effect of graded levels of zinc and boron on secondary nutrients uptake (kg ha^{-1}) by grain and straw of paddy at harvest

Treatments	Calcium		Magnesium		Sulphur	
	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Rec. NPK + FYM (No Zn and B application)	12.31	20.61	5.16	7.93	5.11	5.37
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	15.39	28.06	6.50	10.73	5.92	7.72
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	18.81	38.99	8.36	15.14	7.32	9.75
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	16.20	32.72	7.16	12.05	8.18	10.67
T_5: RDF + Borax @ 2 kg ha^{-1}	16.07	32.52	5.76	9.83	5.94	7.06
T_6: RDF + Borax @ 4 kg ha^{-1}	18.81	40.84	7.05	13.88	7.05	9.53
T_7: RDF + Borax @ 6 kg ha^{-1}	17.45	35.49	5.70	12.18	8.01	10.06
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	19.65	41.01	7.64	12.90	7.10	9.23
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	20.95	46.23	9.19	16.14	8.64	12.05
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	22.68	52.41	10.72	19.33	10.77	14.65
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	24.37	54.62	10.97	16.96	9.14	11.24
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	28.20	61.83	14.31	20.87	10.99	14.13
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	26.50	58.00	11.91	18.76	12.94	16.03
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	25.15	53.37	11.87	19.10	10.86	13.20
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	23.15	51.41	10.50	16.49	12.27	15.65
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	20.95	46.24	9.20	14.42	13.51	16.59
S.E.±	0.91	1.19	0.84	1.17	0.95	1.05
C.D. (P=0.05)	2.73	3.58	2.53	3.52	2.84	3.16

the crop. The positive effect of $ZnSO_4$ to S uptake could be attributed to supply of S from the fertilizers. Similar results have been reported by Dineshkar and Bhabhulkar (1998) and Sahrawat *et al*. (2008).

Effect of graded levels of zinc and boron on micronutrients uptake by grain and straw of paddy:

The Table 6 represents the micronutrients uptake by grain and straw of paddy. Zinc (154.91 g ha^{-1} and 352.38 g ha^{-1}) uptake by grain and straw of paddy was significantly higher in T_{12} treatment(RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) and it was significantly superior than other treatments. Application of $ZnSO_4$ significantly increased Zn uptake in grain and straw when applied alone or along with borax. Similar results have been reported by Farshid Aref (2011a).

Significantly higher Copper (137.12 g ha^{-1} and 178.69 g ha^{-1}) uptake by grain and straw was observed in T_{12} treatment (RDF + $ZnSO_4$ @ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) and it was superior over all other treatments. Application of $ZnSO_4$ significantly increased Cu uptake when applied alone or along with B. Golakia and Patel (1986) has also reported increase in uptake of Cu by the application of B and Zn.

Iron (1106.36 g ha^{-1} and 1534.38 g ha^{-1}) uptake by grain and straw was significantly higher in T_{12} treatment (RDF + $ZnSO_4$@ 20 kg ha^{-1} + borax @ 4 kg ha^{-1}) over other treatments. The lower levels of borax caused significantly higher iron uptake by the crop than the higher levels. However, application of $ZnSO_4$ with borax in all levels increases the Fe uptake by the crop. Farshid Aref (2012) has reported an increase in Fe uptake when B was applied along with zinc.

Manganese (322.33 g ha^{-1} and 441.77 g ha^{-1}) uptake by grain and straw was significantly higher in T_3 treatment (RDF+$ZnSO_4$ @ 20 kg ha^{-1}) and superior over other treatments. The results would indicate that the uptake of Mn could be further reduced by still higher doses of Zn and B, possibly leading to a decline in crop yield.

Boron (23.35 g ha^{-1} and 16.55 g ha^{-1}) uptake by grain and straw was significantly higher in T_{12} treatment (RDF+$ZnSO_4$@ 20 kg ha^{-1}+borax @ 4 kg ha^{-1}) compared to all other treatments. There was an increase in B uptake with increase in B application, both in the presence and absence of applied Zn. Application of $ZnSO_4$ did not have a favorable effect on B uptake particularly when applied along with B. It is reported that the toxicity effect of B is suppressed by zinc and increased B levels increased the concentration of B in plant tissues to a greater extent in the absence of applied zinc.

Conclusion :

The application of recommended dose of fertilizer with $ZnSO_4$ @ 20 kg ha^{-1} and borax @ 4 kg ha^{-1} recorded significantly higher nutrient content and uptake by paddy compared to other treatments but higher S content and

Table 6 : Effect of graded levels of zinc and boron on micronutrients uptake (g ha^{-1}) by grain and straw of paddy at harvest

Treatments	Zn	Cu	Fe	Mn	B	Zn	Cu	Fe	Mn	B
	Grain					Straw				
T_1: Rec. NPK + FYM (No Zn and B application)	107.32	74.92	965.44	320.10	11.87	148.12	94.88	1241.68	387.21	9.49
T_2: RDF + $ZnSO_4$ @ 10 kg ha^{-1}	118.38	100.71	964.02	320.36	12.30	198.97	122.27	1315.26	414.04	10.55
T_3: RDF + $ZnSO_4$ @ 20 kg ha^{-1}	125.61	98.79	976.64	322.33	13.39	227.46	129.58	1385.85	441.77	11.80
T_4: RDF + $ZnSO_4$ @ 30 kg ha^{-1}	121.28	90.39	940.49	303.25	12.81	193.36	115.19	1284.49	399.50	10.86
T_5: RDF + Borax @ 2 kg ha^{-1}	109.66	97.63	989.27	301.38	15.53	201.20	130.96	1410.10	411.22	12.08
T_6: RDF + Borax @ 4 kg ha^{-1}	122.24	103.40	997.26	309.68	17.20	217.33	143.61	1458.08	419.75	13.80
T_7: RDF + Borax @ 6 kg ha^{-1}	110.79	103.01	959.26	291.92	16.22	211.73	148.27	1416.32	410.32	13.14
T_8: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}	115.83	97.30	1023.69	286.91	16.45	206.09	130.41	1427.55	382.73	12.59
T_9: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 4 kg ha^{-1}	122.36	103.00	1016.74	282.83	17.08	239.27	147.52	1470.54	384.82	13.44
T_{10}: RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 6 kg ha^{-1}	138.86	124.91	1019.92	280.76	17.97	276.08	172.84	1501.72	392.48	14.40
T_{11}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 2 kg ha^{-1}	134.75	115.29	1090.12	305.80	21.96	273.93	155.97	1521.95	415.46	15.67
T_{12}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1}	154.91	137.12	1106.36	305.65	23.35	352.38	178.69	1534.38	402.14	16.55
T_{13}: RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 6 kg ha^{-1}	151.86	120.43	1086.17	301.27	20.44	344.83	163.41	1500.23	385.83	15.50
T_{14}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 2 kg ha^{-1}	134.92	110.84	1062.44	292.96	18.91	275.65	144.61	1437.31	362.75	14.10
T_{15}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 4 kg ha^{-1}	128.26	106.46	1021.13	285.28	17.73	255.24	138.92	1423.76	358.68	13.75
T_{16}: RDF + $ZnSO_4$ @ 30 kg ha^{-1} + Borax @ 6 kg ha^{-1}	118.32	100.93	998.10	280.51	16.82	230.62	131.93	1371.45	344.98	12.98
S.E.±	3.70	2.49	10.78	3.61	0.44	5.03	4.78	10.46	12.26	0.16
C.D. (P=0.05)	11.08	7.47	32.31	10.83	1.33	15.09	14.33	31.36	36.75	0.47

uptake by grain and straw was significantly recorded in recommended dose of fertilizer with $ZnSO_4$@ 30 kg ha^{-1} and borax @ 6 kg ha^{-1}.

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