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Effect of combined zinc and Boron fertilization with NPK on growth, and productivity of Rice (*Oryza sativa* L) var. lET 5882

Aparna Hamsa [1] Vinay V Hegde [2]

[1]Dept.Environmental science First Grade College, Vijayanagar, Bangalore, India

[2]Dept.Computer Sciences Engg, RV College of Engineering, Bangalore, India

Abstract : The combined effect of Zinc (Zn) and Boron (B) fertilization with Nitrogen, Phosphorus, and Potassium (NPK) on rice (*Oryza sativa L.*) var.IET 5882, was investigated in a field experiment conducted during the kharif season for two years, at Sagara taluk, Shimoga district, Kamataka state,India Seven treatments, including control, recommended dose of fertilizer (RDF, 120 : 80 : 60 N,P, K kg/ha), and RDF with $ZnSO_4$ (6–18 kg/ha),$ZnSO_4$(6-18kg/ha) + Boron(4 kg/ha),their combination were evaluated in a randomized complete block design with three replications. Combined Zn and B with NPK significantly enhanced growth and yield parameters, with plant height (126.66 cm), tiller count(23.66), number of leaves(63.59)., compared to NPK alone at harvesting time. Grain yield increased by 65.76 (q/ha), driven by higher panicle density , grains weight/panicle 4.16 (g), grain weight/hill 26.10(g) and 1000-grain weight 25.16 (g). These results highlight the synergistic role of Zn and B with NPK in addressing micronutrient deficiencies, enhancing nutrient use efficiency, and boosting rice productivity in Zn- and B-deficient soils, with implications for sustainable intensification.

IndexTerms - Rice, micronutrients, NPK, Zn, B, RDF.

I. INTRODUCTİON

Rice (*Oryza sativa* L.) is a staple crop highly responsive to balanced fertilization. The general trend with regard to balanced fertilization which is being followed presently is the application of major nutrients alone leading to cropping up of micro-nutrient deficiencies, among which Zinc, Boron and Fe have gained considerable recognition owing to their widespread deficiencies have been reported in the cultivation of rice in India

The term micro-nutrient refers to the relative quantity of a nutrient that is required for plant growth. It does not mean that they are less important to plants than other nutrients. They are just as important in plant nutrition as the major nutrients. They simply occur in plants and soils in much smaller concentrations. Plants grown on micro-nutrient-deficient soils can exhibit similar reductions in plant growth and yield as major nutrients.

Micro-nutrient deficiencies started emerging with the adoption and spread of intensive agriculture. Imbalanced use of macro and micro-nutrient fertilizers, reduced recycling of crop residues, and bumper harvests in the past three decades have induced secondary and micro-nutrient deficiencies .In several areas with intensive cropping, Zinc (Zn) deficiency appeared initially and subsequently the deficiencies of Boron (B), Iron (Fe), Manganese and Molybdenum (Mo) were recorded. with deficiencies in micro-nutrients like Zinc (Zn) and Boron (B) often limiting growth, nutrient uptake, and yield in many soils, particularly alkaline or calcareous ones. While Nitrogen (N), Phosphorus (P), and Potassium (K) form the macro-nutrient backbone, integrating Zn and B addresses micro-nutrient gaps, enhancing overall plant performance. Studies show that combined Zn and B application alongside NPK not only corrects deficiencies but also synergistically boosts nutrient efficiency, reduces losses, and improves productivity without compromising grain quality.

The severity of these deficiencies depended on the soil conditions and the crop grown. Among micronutrients, Zn deficiency seems to be the most critical micronutrient deficiency in crop production and human beings (WHO, 2002; Alloway, 2004)

Zinc deficiency is widespread in rice-growing areas, that it ranks next to N and P in many states ap (Takkar and Randhawa. 1980) .Studies show that Zn application increases root elongation, tiller number, and panicle fertility. In a field trial on calcareous soils, soil-applied $ZnSO_4$ at 5 kg/ha boosted grain yield by 25% compared to controls . Foliar Zn sprays (0.5%) enhanced Zn uptake efficiency, reducing luxury consumption .

Boron supports cell wall integrity and pollen tube growth, with deficiencies causing sterile florets , Boron is not a constituent of enzymes in plant, nor is there evidence that it directly affects enzyme activities. There is a long list of possible roles of boron including sugar transport, cell wall synthesis, lignifications, cell wall structure integrity, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid (lAA) metabolism, phenol metabolism, and as part of the cell membranes.

The assessment of boron nutrition and its requirement by various crops have been extensively studied and reviewed by Gupta (1983), Bergmann (1984), Sharrock (1984), Francois (1986) and many other researchers. It has been found that boron is necessary for plant growth.

II.MATERİALS AND METHODS

Experimental Site and Design

A field experiment was conducted to study the impact of zinc and combination of Zinc and Boron along with recommended dose of fertilizers (RDF), viz., NPK on growth, yield of rice (*Oryza sativa* L.) during kharif seasons for two years, at Sagara taluk, Shimoga district, Kamataka state,India.The experimental site is located between 14° 5' north latitude and 75° 5' east longitudes and at an altitude of 600 meters above the mean sea level.

Treatments

The experiment was laid out in Randomized Block Design comprising of 7 treatments and 3 replications. Each treatment plot size is 3m × 2.5m.

Seven treatments were evaluated to assess the combined effects of Zinc (Zn) and Boron (B) with Nitrogen, Phosphorus, and Potassium (NPK) fertilization:

T1: Control ((RDF, 120 : 80 : 60 NPK kg/ha)

T2: RDF+ Zinc (Zinc sulphate) at 6 kg/ ha

T3: RDF + Zinc (Zinc sulphate) at 12kg/ ha

T4: RDF + Zinc (Zinc sulphate) at 18 kg/ ha

T5: RDF + Zinc (Zinc sulphate) at 6 kg/ ha+ boron (boric acid) at 4 kg/ ha

T6: RDF + Zinc (Zinc sulphate) at 12 kg/ ha+ boron (boric acid) at 4 kg/ ha

T7: RDF + Zinc (Zinc sulphate) at 18 kg/ ha+ boron (boric acid) at 4 kg/ ha

Among the recommended dose of fertilizer 50% of nitrogen (60 kg/ha) and full dose of phosphorous(80 kg/ha) and full dose of potash(60 kg/ ha) was applied in the form of urea , single super phosphate and muriate of potash as a basal dose at the time of sowing. The remaining 50% of nitrogen was applied astop dress 30 days after sowing.The cerop was harvested treatment wise at meturity stage.

Crop Management

The rice variety (lET 5882, semi dwarf (105-110 cm), grains are coarse bold with average yield of 35-55 q/ha. Suitable for rain fed lands) was used.

The soil was ploughed repeatedly under moist condition and then puddle by ploughing to a fine tilt. The raised beds of 5 m length, 1 m width and 5 m height were prepared. Before sowing the seeds, recommended quantity of NPK fertilizers were incorporated as a basal dose. Seeds were uniformly spread on the nursery beds. The plant protection and weed control measures were undertaken in nursery when needed.

The main field was ploughed in wet condition, three times puddle and levelled. The plots were laid out as per requirement and levelled within the plots. Strong bunds of 15 cm height and 10 cm width were formed. A thin film of water was maintained. Among the nutrients fifty per cent nitrogen and full dose of phosphorus, potassium and different dosages of zinc and boron were applied as basal dose at the time of transplanting as per the treatments in the form of urea, single super phosphate, muriate of potash, zinc sulphate and boric acid respectively. The remaining 50 per cent nitrogen was applied in two splits at tillering (25 %) and panicle initiation stage (25 %). Twenty nine days old seedlings were transplanted at the spacing of 20-10 cm using only two seedlings/ hill.

After care

Regular hand weeding was done to keep the experimental plot weed free. Regular plant protection measures were taken to control pests and diseases. Irrigation was given to maintain water around five cm depth in each plot.

Data Collection

Growth Parameters

Plant height, tiller number, number of leaves/hill were recorded at 30, 60, and 90 ,at the time of harvest from DAT from 10 randomly selected plants per plot. Leaf area index (LAI) was measured using a portable leaf area meter at the panicle initiation stage.

Productivity (Yield and Yield Components)

Yield components, including number panicles/hill,panicle length (cm), number of tillers hill^{-1} grain weight/panicles and 1000-grain weight (g), were measured from 10 randomly selected hills per plot.

Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using [software, e.g., SPSS v.25]. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at a 5% significance level ($p < 0.05$). Correlation analyses were performed to evaluate growth, and yield parameters.

III RESULTS AND DISCUSSION

Effects on Growth parameters

Plant height (cm)

Maximum plant height was recorded in treatment combination of T7**:** RDF + Zinc (Zinc sulphate) at 18 kg/ ha+ boron (boric acid) at 4 kg ha^{-1} 126.66 cm at the harvesting stage, followed by T6 RDF + Zinc (Zinc sulphate) at 12 kg/ ha+ boron (boric acid) at 4 kg ha^{-1} 121.50 cm). This is attributed to the increased availability of Zn and B,which enhanced the metabolic activity which in turn might have influenced the plant growth. These results are in conformity with the works of Khattak and Paraveen (1985) who observed the dwarfism and growth reduction in zinc deficient plants (Jackson and Chapman, 1975).

Tillers/hill

Data on number of tiller/hill as influenced by micronutrient levels in rice. At harvest, number of tillers/hill differed significantly due to micronutrient levels. Application of RDF + 18 kg of zinc ha"+ 4 kg of Boron ha^{-1} (T7) Produced significantly higher number of tillers hill^{-1} (23.66) and was on par with application of RDF + 12 kg of zinc ha^{-1}+ 4 kg of Boron ha"' (T6- 21.67). Application of RDF alone recorded significantly lower number of tillers hill^{-1} (Tl- 8.67) as compared to the rest of the treatments. minimum with control (4.66 to

8.67). The increase in tillering might be attributed to improved enzymatic activity and auxin metabolism in plants by adequate supply of micronutrient levels (Zn and B). These findings are in line with Salam and Subramanian (1993), Hosseiny and Maftoun. (2008)

Number of Leaves hill

Application of RD of NPK ha^{-1}+ 18 kg of zinc ha^{-1}+ 4 kg of Boron ha^{-1} (T7) produced significantly higher number of leaves hill'" (63.59) as compared to all other treatments. Application of RDF alone recorded significantly lower number of tillers $hill^{-1}$ (Tl- 8.67) as compared to the rest of the treatments.

Combined Zn and B fertilization with NPK promotes vigorous vegetative growth in rice by improving root development,plant height, tillering, number of leaves,might be because Zn aids in enzyme activation (e.g., carbonic anhydrase for photosynthesis) and hormone synthesis (e.g., auxin for cell elongation), while B supports cell wall integrity and pollen viability, reducing sterility. This is attributed to the increased availability of Zn and B, which enhanced the metabolic activity which in turn might have influenced the plant growth. These results are in conformity with the works of Khattak and Paraveen (1985) who observed the dwarfism and growth reduction in zinc deficient plants (Jackson and Chapman, 1975). Tillering capacity is one of the most important components responsible for increased crop production. The more the number of tillers per plant, the better would be the crop stand and consequently the higher yield. The data regarding the number of tillers per plant (Table 4) indicated that variations in tillers per plant by different treatments were significant at 5% level of probability.

Table 1 : Plant Height(cm) at different growth stages

Treatments	Days after transplanting			
	30	60	90	At Harvest
T1	38.66	85.50	96.83	96.16
T2	43.90	91.23	102.13	108.90
T3	48.68	101.53	113.46	114.46
T4	52.53	108.76	117.93	118.46
T5	49.93	102.16	114.10	114.83
T6	52.10	109.76	120.70	121.50
T7	54.93	114.46	126.00	126.66
S.Em ±	0.67	0.78	0.60	0.65
CD at 5%	1.466	1.705	1.318	1.427

Table 2: Number of tillers hill $^{-1}$ different growth stages

Treatments	Days after transplanting			
	30	60	90	At Harvest
T1	4.66	8.66	9.67	8.67
T2	6.33	11.66	12.67	13.33
T3	8.67	17.33	18.66	19.32
T4	10.32	18.66	21.33	20.66
T5	9.66	17.66	19.65	20.00
T6	11.00	19.00	22.66	21.67
T7	11.33	19.33	23.00	23.66
S.Em ±	0.47	0.83	0.68	0.58
CD at 5%	1.026	1.469	1.494	1.277

Table 3: Number of leaves hill $^{-1}$ at different growth stages

Treatments	Days after transplanting			
	30	60	90	At Harvest
T1	15.07	33.41	40.70	35
T2	17.87	40.51	54.48	44.83
T3	21.18	46.44	56.71	49.04
T4	26.84	52.28	66.03	60.18
T5	23.73	48.77	57.73	51.33
T6	27.66	54.37	67.86	60.62
T7	29.36	57.39	71.70	63.59
S.Em ±	0.52	0.48	0.53	0.67
CD at 5%	1.146	1.065	1.137	1.462

Effects on Productivity

Number of panicle and Length of Panicle (cm).

Panicle number and panicle length were an important yield component of rice which contributes towards the yield of the crop. There was significant variation in number of panicles under the various treatments .The maximum number of panicle/hill were recorded with application of RDF with Zn at 18 kg ha^{-1} + boron at 4 kg ha^{-1} and was followed by RDF with Zn at 12 kg ha^{-1} + boron at 4 kg ha^{-1} .The least number of panicles hill^{-1} were with control . Increase in panicle hill^{-1} might be due to adequate supply of Zn along with boron that might have increased the availability and uptake of other essential nutrients and thereby resulting in the improvement of crop growth. The results support the findings of Hemadez et al. (1988)

Number of effective tillers/plant

Tillering capacity is one of the most important components responsible for increased crop production. The more the number of tillers per plant, the better would be the crop stand and consequently the higher yield. The data regarding the number of tillers per plant indicated that variations in tillers per plant by different treatments were significant at 5% level of probability. All the zinc, zinc+boron treatments increased the number of tillers per plant significantly over control. The maximum number of tillers/plant was recorded in the treatment receiving 18 kg Zn ha"^ + 4 kg B ha"' along with RDF (T7- 11.33 to 21.67) and minimum with control (4.66 to 8.67). The increase in tillering might be attributed to improved enzymatic activity and auxin metabolism in plants by adequate supply of micronutrient levels (Zn and B). These findings are in line with Salam and Subramanian (1993), Hosseiny and Maftoun. (2008)

Grain Yield (q/ha)

Grain yield is an important yield component which affects the weight of produce of cereals per unit area. Statistical analysis showed that the variation among the different Zn and Zn + B treatments was significant. All the zinc and Zn+B treatments increased the grain yield significantly over control. The maximum grain yield was obtained with RDF with Zn at 18 kg ha" + boron at 4 kg ha-1 (T7- 65.76 q ha-1) and it was followed by RDF with Zn at 12 kg ha-1 + boron at 4 kg ha"' (63.78 q ha-1) and RDF with Zn at 18 kg ha' (62.17 q ha-1) . Application of the RDF alone recorded significantly lower grain yield of 52.97 q ha-1as compared to rest of the treatments.The increased yield with application of zinc and boron was due to the higher magnitude of the yield component like more number of tillers, better panicle length, grain weight/ panicle, grain weight /hill and 1000 grain weight. And it was further supported by positive correlation between grain yield and growth and yield component. Such effects have also been reported by Agarwal et al (1997); Gupta and Kala (1992); Singh era/. (1996).

Table 4: **Total Number of Panicles hill^{-1} and Panicle Length (cm) and number of tillers hill^{-1} as influenced by Micronutrient levels**

Treatments	Total Number of Panicles hill^{-1}	Panicle Length(cm)	Number of tillers hill^{-1}
T1	10.16	12.37	8.67
T2	11.11	14.44	13.33
T3	12.07	17.03	19.32
T4	13.39	20.15	20.66
T5	12.40	19.07	20.00
T6	14.17	23.51	21.67
T7	15.15	26.03	23.66
S.Em ±	0.16	0.13	0.58
CD at 5%	0.353	0.291	1.277

Table 5: **Number of grains /hill, grain weight/ panicle, 1000 grain weight, grain yield (q ha^{-1})as influenced by micronutrient levels**

Treatments	Number of grains hill $^{-1}$	Grain weight panicle $^{-1}$ (g)	1000 grain weight(g)	Grain weight hill $^{-1}$ (g)	Grain yield (q ha^{-1})
T1	1079.50	2.02	19.36	19.70	52.97
T2	1154.70	2.28	20.22	20.81	56.57
T3	1210.55	2.82	21.30	22.23	58.43
T4	1308.67	3.30	24.26	24.95	62.17
T5	1240.33	2.99	22.30	22.85	59.45
T6	1367.23	3.69	24.93	25.45	63.17
T7	1406.09	4.16	25.16	26.10	65.76
S.Em ±	1.15	0.04	0.10	0.08	0.28
CD at 5%	2.53	0.09	0.21	0.18	0.61

IV. CONCLUSION

Micro nutrients are as important as the primary and secondary nutrients in plant nutrition. However, the amounts of micronutrients required for optimum nutrition are much lower. Micronutrient deficiencies are widespread because of increased nutrient demands from the more intensive cropping practices. Soil tests and plant analyses are excellent diagnostic tools to monitor the micronutrient status of soils and crops. Visual deficiency symptoms of these nutrients also are well recognized in most economic crops. Application of micronutrients along with RDF has influenced higher grain through better growth and yield component and better utilization of applied nutrients.

The combined application of zinc (Zn) and boron (B) with NPK fertilization significantly enhanced rice growth, and productivity of the Rice crop. The synergy of Zn and B with NPK mitigated micronutrient deficiencies, reduced nutrient losses, and enhanced use efficiency, particularly in Zn- and B-deficient soils. These findings underscore the importance of balanced micronutrient and macronutrient management for sustainable rice production, with soil-specific adjustments recommended to optimize rates and avoid toxicity.

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