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Influence of Zinc and Boron Fertilization on Grain and straw Nutrient Uptake in Rice (*Oryza Sativa L*) var. IET 5882

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ARTICLE DETAILS

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ABSTRACT

The influence of combined application of micro-nutrients, Zinc (Zn) and boron (B) along recommended dose of Nitrogen, Phosphorous and Potassium (NPK) markedly improved nutrient uptake of rice (Oryza Sativa L) under field experiment conducted during the kharif season for two consecutive years, at Sagara taluk, Shimoga district, Karnataka 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), RDF with ZnSO4(6-18kg/ha) + boron(4 kg/ha),,their combination were evaluated in a randomized complete block design with three replications.Plots receiving zinc, boron along with NPK fertilizers resulted in significantly higher accumulation of NPK and Zn and B in grain and straw attributes These results highlight the synergistic role of Zn and B with NPK in addressing micro-nutrient deficiencies, enhancing nutrient use efficiency, and boosting rice productivity in Zn- and B-deficient soils, with implications for sustainable intensification

1. Introduction

Rice is a staple crop feeding over half the world's population, but its productivity is often limited by micro-nutrient deficiencies, particularly zinc (Zn) and boron (B), in alkaline, sandy, or low-organic-matter soils(.Guo J ,2024) . Zinc (Zn) and boron (B) are essential micro-nutrients that significantly impact nutrient uptake, growth, and yield in rice *(Oryza sativa L.*) especially as intensive cropping and changing water management practices (like alternate wetting and drying) increasingly induce soil deficiencies. Their presence significantly influences the absorption and efficiency of primary macro-nutrients like nitrogen (N), phosphorus (P), and potassium (K)(.Erenoglu B , 2011). Nutrient uptake in rice is fundamentally driven by NPK, but Zinc (Zn) and Boron (B) are critical micro-nutrients that significantly boost overall nutrient uptake and yield, especially when applied with Zn and B aids vegetative growth, while B supports pollination and grain filling, with their combined application improving nutrient efficiency, correcting deficiencies (common in rice soils), and synergistically increasing N, P, and K absorption for better growth, quality, and higher productivity Balanced nutrition, including these micro-nutrients, ensures better utilization of macro-nutrients, leading to higher biomass and grain yield.

Zn is crucial for enzyme activation, protein synthesis, and hormone regulation, while B supports cell wall formation, pollen viability, and carbohydrate transport. Deficiencies lead to reduced nutrient uptake, stunted growth, and lower yields. Zinc deficiency is widespread in rice-growing areas, that it ranks next to N and P in many states (Takkar and Randhawa. 1980). Studies show that Zn application increases root elongation, tiller number, and panicle fertility. Combined Zn and B fertilization has shown synergistic effects, improving macro-nutrient absorption and grain quality. Applied boron may improve the utilization of applied nitrogen by cotton plants by increasing the translocation of N compounds into the boll (Miley et al.,1969). This review examines mechanisms, experimental evidence, and agronomic implications of Zn and B on rice nutrient uptake. (Bhutto MA ,2013)

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2. Materials and methods

2.1. Experimental Site and Design

A field experiment was conducted during the kharif seasons of two consecutive years to evaluate the effects of zinc (Zn) application alone and in combination with boron (B), along with the recommended dose of fertilizers (RDF; NPK) on nutrient uptake by Grain and straw of rice (Oryza sativa L.). The study was carried out in Sagara taluk, Shivamogga district (formerly Shimoga), Karnataka, India. The experimental site is situated at 14° 5' N latitude and 75° 5' E longitude, with an elevation of 600 meters above mean sea level1.

2.2. Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with seven treatments and three replications. The individual plot size was 3 m × 2.5 m1. 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.

At transplanting, 50% of the recommended dose of nitrogen (N: 60 kg/ha), along with the full dose of phosphorus (P : 80 kg/ha), potassium (K : 60 kg/ha), and treatment-specific doses of zinc (Zn) and boron (B), were applied as basal dose. These nutrients were supplied through urea, single super phosphate (SSP), muriate of potash (MOP), zinc sulphate ($ZnSO_4 \cdot 7H_2O$), and boric acid (H_3BO_3), respectively. The remaining 50% N was top-dressed in two equal splits (25% each) at the active tillering and panicle initiation stages.

2.3. 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 experimental field was ploughed repeatedly under moist conditions and then puddled to achieve a fine tilth. Raised nursery beds measuring 5 m in length, 1 m in width, and 0.15 m in height were prepared. Prior to sowing, the recommended quantity of NPK fertilizers was incorporated as a basal dose into the nursery beds. Rice seeds were uniformly broadcast on the beds. Necessary plant protection and weed control measures were applied in the nursery as required. The main field was ploughed thrice under wet conditions, puddled, and levelled. Plots were demarcated according to the experimental design, with uniform levelling within each plot. Strong bunds (15 cm height × 30 cm width) were constructed around the plots to facilitate water retention. A thin film of standing water was maintained during initial establishment. Twenty-nine-day-old seedlings were transplanted at a spacing of 20 cm × 10 cm, with two seedlings per hill.

2.4 Post-Transplanting Crop Management

The experimental plots were kept weed-free through timely manual weeding. Standard plant protection measures were adopted to manage insect pests and diseases as and when necessary. Irrigation was provided intermittently to maintain approximately 5 cm of standing water throughout the crop growth period.

2.5 Data Collection

Uptake of macro nutrients viz.,Nitrogen ,Phosphorous, Potash, and micro nutrients Zinc and Boron in Grain and straw of Rice at the time of the harvesting from DAT were recorded from 10 randomly selected plants 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 nutrient uptake in grain and straw.

3 Result and Discussion

3.1 Nutrient uptake in Grain

At harvest, N,P,K,Zn and B uptake in grain differed significantly due to micronutrient levels. Application of RD of NPK ha + 18 kg of zinc ha-1+ 4 kg of Boron/ha (T7) caused significantly higher nitrogen(78.06 kg ha-1),Phosporus (34.41 kg ha-1)Potassium(62.07 kg ha-1),Zinc (174.41 g h-1) and Boron (58.96 g h-1) uptake in grain as Compared to all other treatments. This was followed by application of RD of NPK ha-1+ 12 kg of zinc ha-1+ 4 kg of Boron ha-1. Application of the RDF alone recorded significantly lower uptake of nitrogen in grain (66.84 kg ha-1) ,Phosphorous (22.22kg ha-1), Potasssium (53.22 kg ha-1), Zn (139.87 g ha-1) and Boron (31.46 g ha-1) in grain as compared to rest of the treatments.

3.2 Nutrient uptake in Straw

Application of RD of NPK ha"'+ 18 kg of zinc ha"'+ 4 kg of boron caused significantly higher Nitrogen (72.25 kg ha-1),Phosphorous (16.86 kg ha-1) Potassium (119.04 kg ha-1),Zinc (81.44 g ha-1) and Boron(31.91 g ha-1) uptake in straw as compared to all other treatments.

Table 1. Nitrogen, phosphorus and potassium uptake (leg ha^{-1}) in grain at harvest as influenced by micro-nutrient levels

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T1	66.84	25.22	53.22
T2	69.77	26.73	53.99
T3	72.03	28.14	55.03
T4	74.03	29.96	57.07
T5	73.03	28.92	56.70
T6	76.70	31.33	59.60
T7	78.06	34.41	62.07
S.Em±	0.30	0.07	0.13
CD at 5%	0.67	0.17	0.29

Table 2. Zinc and boron uptake (g ha^{-1}) in grain at harvest as influenced by micronutrient levels

Treatment	Available Zn	Available B
T1	139.87	31.46
T2	142.45	33.50
T3	149.07	34.27
T4	170.21	36.17
T5	150.73	50.12
T6	167.91	55.21
T7	174.41	58.96
S.Em±	0.51	0.36
CD at 5%	1.72	0.73

Table 3. Nitrogen, phosphorus and potassium uptake (kg ha^{-1}) in straw at harvest as influenced by micro-nutrient levels

Treatment	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
T1	60.30	10.33	102.77
T2	62.38	11.60	106.63
T3	65.37	12.65	108.42
T4	68.65	13.40	113.74
T5	66.36	12.67	110.10
T6	70.61	15.11	116.39
T7	72.25	16.86	119.04
S.Em±	0.43	0.22	0.21
CD at 5%	0.94	0.50	0.46

Table 4. Zinc and boron uptake (g ha^{-1}) by straw as influenced by micronutrient levels

Treatment	Available Zn	Available B
T1	60.16	17.71
T2	65.42	20.67
T3	72.15	21.85
T4	79.57	23.87
T5	68.19	27.70
T6	74.12	30.12
T7	81.44	31.91
S.Em±	0.44	0.39
CD at 5%	0.75	0.71

The application of zinc (Zn) and boron (B) micronutrients has been shown in numerous studies to enhance the uptake and accumulation of macronutrients nitrogen (N), phosphorus (P), and potassium (K) in rice grain and straw. This effect is particularly pronounced in micronutrient-deficient soils common in rice-growing regions, such as calcareous, alkaline, or flooded paddies, where Zn and B deficiencies limit overall nutrient efficiency. Increase in NPK concentration by applying zinc and boron was probably be due to the improvement of enzymatic function and the metabolic processes of the plant which ultimately might have increased the uptake of major plant nutrients and consequently the yield (Panda and Nayak, 1974.) The results showed that all the applied doses of zinc and zinc + boron significantly increased the Zn and boron content. The increased nutrient uptake (N,P,K,Zn and Boron) in grain and straw might be owing to the increased enzymatic activity and organic recycling of the plant nutrients in response to available zinc and Boron supply along with NPK fertilizers to plants and biochemical and physiological functions of boron in plants. Zn and B play critical roles in plant physiology that indirectly boost macronutrient absorption and utilization: Zinc activates enzymes involved in N metabolism, improves root development for better nutrient foraging, and enhances photosynthetic efficiency, leading to greater overall biomass and nutrient demand. Boron supports cell wall integrity, pollen tube growth, and sugar transport, which facilitate better translocation of nutrients within the plant. Synergistic interactions occur when Zn and B are applied together with NPK fertilizers. For instance, Zn improves N use efficiency, while B alleviates P deficiency symptoms and aids K regulation in guard cells. These micro-nutrients correct deficiencies that otherwise restrict root elongation, tillering, and panicle fertility, resulting in healthier plants capable of absorbing more NPK from soil or applied fertilizers. All the levels of applied zinc and combination of zinc + boron was significantly different from one another showing the ability of zinc and boron to enhance the availability of soil Zn and B which might be due to the improvement of enzymatic function and the metabolic processes of the plant that ultimately increased the uptake of zinc and boron. Similar results were reported by Devarajan and Ramanathan (1995); Singh et al.(1996).

4. Conclusion

Zinc and Boron, though required in trace amounts, play pivotal roles in rice physiology, including enzyme activation, cell wall integrity, pollen viability, and synergistic interactions that facilitate the uptake and translocation of macro-nutrients and other micro-nutrients in both grain and straw. The application of zinc and boron fertilizers significantly enhanced nutrient concentrations and total uptake in rice grain and straw, leading to improved grain yield, straw biomass, and overall crop productivity, particularly in soils prone to deficiencies common in intensive rice cultivation systems. These findings underscore the prevalence of zinc and boron deficiencies in rice-growing regions and highlight the efficacy of targeted fertilization strategies—often through soil or foliar applications to mitigate limitations on nutrient dynamics and sustain rice yields. Integrated micro-nutrient management, incorporating soil testing and balanced fertilization, is essential for optimizing nutrient use efficiency, enhancing grain nutritional quality, and supporting sustainable rice production amid increasing cropping intensity and soil depletion. The combined application of zinc (Zn) and boron (B) with NPK fertilization significantly enhanced Nutrient uptake by grain and straw in rice. The synergy of Zn and B with NPK mitigated micro-nutrient deficiencies, reduced nutrient losses, and enhanced use efficiency, particularly in Zn- and B-deficient soils. These findings underscore the importance of balanced micro-nutrient and macro-nutrient management for sustainable rice production, with soil-specific adjustments recommended to optimize rates and avoid toxicity.

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