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Response of *Boro* Rice (cv. BRRI dhan89) Yield to Foliar Application of Micronutrients

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Abstract: Insufficient management of nutrients poses a significant obstacle to achieving sustainable rice production in tropical climates. To address this challenge, an investigation was conducted to find out the potential impact of micronutrients on enhancing the yield of *Boro* rice through foliar application. The study was structured using a randomized complete block design and replicated three times. Field trials were conducted with three micronutrients (Boron, Zinc and Copper) and involved seven treatments, namely control (NPK), NPK + Zinc, NPK + Boron, NPK + Zinc + Boron, NPK + Zinc + Copper, NPK + Boron + Copper, and NPK + Zinc + Boron + Copper. The addition of zinc, boron and copper led to a notable enhancement in the factors contributing to yield. The maximum number of total tillers hill^{-1} (11.29), effective tillers hill^{-1} (10.09), panicle length (24.69), grain panicle^{-1} (138.36), grain yield (5.43 t ha^{-1}) and straw yield (7.22 t ha^{-1}) was resulted when NPK + Zinc + Boron + Copper applied together. The least grain yield (3.64 t ha^{-1}) was produced in control (NPK) owing to lower number of effective tillers hill^{-1} (7.46), lower number of grain panicle^{-1} (118.46) and higher number of sterile spikelet panicle^{-1} (25.46). The findings suggested that the appliance of NPK combined with Zn, B and Cu yielded superior in BRRI dhan89.

Keywords: *Boro* rice; Foliar application; Micronutrients; Yield; BRRI dhan89.

INTRODUCTION

Rice (Oryza sativa) is of considerable significance as a primary food staple in worldwide. It ranks as the second most consumed product globally, following wheat (Rajamoorthy *et al.*, 2015). Agriculture constitutes an important role in Bangladesh's economy with a primary focus on rice cultivation which occupies approximately 75% of the arable land. The predominant crop cycle involves the cultivation of *Boro* and *T. Aman* rice. It contributes 91.12% to the overall cereal production. According to BBS (2022), the respective areas dedicated to *Aus*, *Aman* and *Boro* cultivation are 1.16 million hectares, 5.72 million hectares and 4.81 million hectares with corresponding yields of 3, 1.46, and 2.02 t ha^{-1}. The current imperative for Bangladesh's agricultural sector is to address the growing population's food requirements.

Micronutrient deficiency stands out as a major contributor to the declining yield trends linked to malnutrition in rice producing nations. Zinc assumes the third most vital role in plant nutrition after nitrogen and phosphorus. Zinc and boron deficiencies are common nutritional issues affecting crop plants (Roy *et al.*, 2022; Raku *et al.*, 2023). Factors affecting the internal distribution of zinc in crops include enhanced phloem mobility, root-to-shoot zinc translocation and the biochemical utilization of zinc (Hacisalihoglu and Kochian, 2003). Boron, a crucial mineral nutrient, triggers various physiological processes such as carbohydrate metabolism, translocation, pollen germination, pollen tube development, plasma membrane stimulation, anther development and the overall growth of flowers and seed fertility (Herera-Rodríguez *et al.*, 2010; Siddiky *et al.*, 2007; Wang *et al.*, 2003). A shortage in boron can result in reduced photosynthesis rates, stunted plant height and a decreased number of reproductive structures (Zhao and Oosterhuis, 2003; Bithy *et al.*, 2020). The growth features and total crop output display promise with the application of boron to leaves (Das *et al.*, 2022; Bithy *et al.*, 2021). Copper is essential for numerous biological processes and a deficiency in copper negatively impacts photosynthesis while increasing respiration rates (Olszewska *et al.*, 2008).

Traditional farming methods frequently utilize soil applied fertilizers to tackle nutrient deficiencies. The application of fertilizers to plant foliage can complement soil fertilization (Fageria *et al.*, 2009) and proves advantageous when a crop's needs surpass the available soil supply (Dey *et al.*, 2023). Recognizing the importance of micronutrients, the current study endeavored to investigate the impact of zinc, boron and copper on the yield of *cv.* BRRI dhan89.

MATERIALS AND METHODS

Experimentation

The research site was situated at latitude of 24° 75' North and a longitude of 90° 50' East with an average height of 18 meters surplus sea level (AEZ-9). The ground in the research part exhibits a predominantly neutral pH of 6.8, accompanied by low levels of unprocessed material and fertility. The ground of the research plot belongs to Old Brahmaputra alluvial zone. The field trials involved the cultivation of BRRI dhan89 rice variety along with three micronutrients (Boron, Zinc and Copper) and included seven treatments: control (NPK), NPK + Zinc, NPK + Boron, NPK + Zinc + Boron, NPK + Zinc + Copper, NPK + Boron + Copper, and NPK + Zinc + Boron + Copper. The micronutrients were applied at rates of 2 kg ha^{-1} for Zinc, Boron and Copper, using fertilizers such as $ZnSO_4.7H_2O$ (8.7 kg ha^{-1}), $Na_2B_4O_7$ (37 kg ha^{-1}) and $CuSO_4.5H_2O$ (7.8 kg ha^{-1}) during the panicle initiation stage of rice through foliar application. The N, P and K fertilizers were applied at recommended rates of 92 kg ha^{-1}, 23 kg ha^{-1} and 75 kg ha^{-1}, respectively. The study was structured using a randomized complete block design and replicated thrice resulting in a total of 21 plots. All plot had a size of 5 m^2 (2.5 m × 2.0 m).

Crop Husbandry

BRRI dhan89 was chosen as the experimental crop for the research. The seeds of this rice variety were sourced from the Agronomy Field Laboratory at Bangladesh Agricultural University, Mymensingh. The gravity method is employed to choose robust and weighty seeds. Following selection, the chosen seeds underwent a 24 hour soaking period in a water filled bucket and were then transferred to a jute bag. Seeds begin to germinate after 48 hours and sow after 72 hours in the nursery. For the experimental plots, urea, triple superphosphate, and muriate of potash were applied at rates of 200, 115 and 125 kg ha^{-1}. All fertilizers, except urea were administered prior to the completion of the last soil preparation. Conversely, urea was employed at three distinct time schedules: 15, 30 and 45 days following the transplanting process. Micronutrients such as Zn, B and Cu were applied at rates of 2 kg ha^{-1} each, in the form of $ZnSO_4.7H_2O$ (8.7 kg ha^{-1}), $Na_2B_40_7$ (37 kg ha^{-1}) and $CuSO_4.5H_2O$ (7.8 kg ha^{-1}). These micronutrient fertilizers were applied at the panicle initiation stage of rice, which occurred 60 days after transplanting. Seedlings that were 40 days old were uprooted from the nursery in the early morning of the transplanting day and arranged at intervals of 25 cm by 15 cm within each cluster, with two seedlings per hill. Adequate irrigation was provided as needed to maintain sufficient moisture in the field, and excess water was drained 15 days before harvest.

Data Collection

The harvest occurred when the seeds reached full maturity, characterized by 90% of them displaying a golden yellow colour. Excluding border hills the data on various vegetation characteristics was documented through the random selection of five hills as of every plot. The produce from each plot was segregated, appropriately labelled, and sent to the location for threshing. A pedal thresher was then used to pound the beans. The seeds were cleaned, weighed, and their grain yield was noted. The straws were cleaned, dried, and weighed to determine the yield. Subsequently, the paddy and straw production in $plot^{-1}$ were transformed into t ha^{-1}. Information regarding yield components and yields were collected on various sampling days and during harvest, involving the random selection of five plant samples from each plot.

Statistical Analysis

The average of all treatments was computed, and an analysis of variance was performed for each studied trait was performed with Statistix 10 package. The dissimilarities along with treatment were assessed through the application of using Duncan's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant Height

There is notable diversity in plant height observed across various treatments (Table 1). The maximum height of plant (102.55cm) was calculated when NPK + Zn + B + Cu are applied followed by NPK + Zn + B application (99.11 cm) and the shortest plant (90.60cm) was calculated in control (NPK). Earlier research indicated a significant impact of micronutrient supplementation (Zn + B + Cu) on plant height. The range of plant height among nutrient treated plants varied from 92 to 121 cm. The highest positive response was observed with Zn + B (Arif *et al.*, 2012). According to Rashid *et al.* (2006), a deficiency in boron results in a decrease in leaf photosynthesis rate and plant height. The appliance of 1 kg of boron ha^{-1} led to a notable increase in plant height (BINA, 1993). Singh et al. (2020) noted that the use of zinc as a foliar spray in combination with NPK resulted in an increase in plant height. Sarwar *et al.* (2016) explored the impact of boron application on rice plant height, finding a significant enhancement. The research highlighted the well established

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role of boron in improving various aspects of plant physiology, including carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism and root growth.

Total Tillers Hill^{-1}

The impact of diverse treatments on the overall count of tillers hill^{-1} showed statistical significance (Table 1). The uppermost number of total tillers hill^{-1} (11.29) was resulted in application of NPK + Zn + B + Cu followed by NPK + Zn + B application (10.54) and lowest one (8.31) was resulted in control treatment (NPK). The number of tillers plant^{-1} in the group of treated rice plants ranged from 8 to 12.16. The rice plants treated with Zn + B exhibited a higher tiller response hill^{-1} compared to the control (Bhattacharjee *et al.*, 2002). Mitra and Jana (1991) found that the appliance of 20 kg of boron ha^{-1} led to a major enlarge in the number of total tillers hill^{-1}. Reddy *et al.* (2020) who noted a rise in the number of tillers hill^{-1} by adhering to the recommended fertilizer dosage along with zinc application.

Effective Tillers Hill^{-1}

The statistical significance of the overall effective tiller count hill^{-1} varied among different treatments (Figure 1a). The maximum number of effective tillers hill^{-1} (10.09) was found with NPK + Zn + B + Cu and the minimum number of effective tillers hill^{-1} (7.46) was spotted in control (NPK). Mitra and Jana (1991) stated that application of boron increases effective tillers hill^{-1}. Boron contributes to the growth of roots, the initiation of fruit and the development of seeds. Elevated zinc levels in the grain can be sustained by applying zinc in the rhizosphere along with a consistent supply, coupled with a higher number of productive tillers hill^{-1} (Jena *et al.*, 2006). Mustafa et al. (2011) also observed that the increase in productive tillers hill^{-1} could be attributed to the sufficient zinc supply which may have enhanced the absorption and availability of other essential nutrients. This in turn, led to an improvement in plant metabolic processes, ultimately resulting in an increased number of effective tillers hill^{-1}.

Non-Effective Tillers Hill^{-1}

Various treatments had a non considerable impact on the number of non-effective tillers hill^{-1} (Table 1). The uppermost result (1.54) was resulted when NPK + Zn + B were applied combined and the minimum one (0.85) was recorded in control (NPK). Therefore, the impact of fertilizer management did not result in a significant effect on the number of ineffective tillers hill^{-1}. The increased count of ineffective tillers per hill could be attributed to a potential deficiency in micro-nutrients (specifically zinc, boron and copper). This insufficiency in these nutrients might hinder the enhancement of productive tillers in rice cultivation.

Panicle Length

Various treatments had a notable impact on the length of the panicle (Table 1). The highest length of the panicle (24.69cm) was recorded while NPK + Zn + B + Cu fertilizers were applied followed by application of NPK + Zn + B (23.98), NPK + B + Cu (23.38) and NPK + B (23.34). Conversely, the lowest one (21.75cm) was recorded when micronutrients were not applied (NPK). The application of Zn, B and MT treatments led to a notable and varied augmentation in panicle length, ranging from 24 to 30.40 cm. It was noted that the plant subjected to Zinc and Boron treatment showed the most significant growth in panicle length, achieving a measurement of 30.40 cm, surpassing the control group (Bhattacharjee *et al.*, 2002). Arif *et al.* (2012) observed a noteworthy increase in panicle length, ranging from 24 to 30.40 cm, due to the application of Zn, B and MT (Microtone). Providing sufficient zinc to rice led to an enhancement in panicle length. Boron is crucial in expediting the development and elongation of panicles in rice plants (Liew *et al.*, 2012). According to Dobermann and Fairhurst (2000), a deficiency in boron, especially during the panicle formation stage, significantly diminishes panicle formation in rice plants, consequently reducing panicle length.

Grains Panicle^{-1}

The various micronutrient treatments had a significant impact on the number of grains panicle^{-1} (Figure 1b). The uppermost result (138.36) was observed in NPK + Zn + B + Cu application which was statistically similar with application of NPK + Zn + Cu (135.39) and the minimum grains panicle^{-1} (118.46) was found in while only NPK fertilizers were used (control). The appliance of zinc, boron and copper significantly influenced the number of grains per plant, ranging from 119 to 147.3 in the treated group of rice plants. Specifically, rice plants treated with 33% zinc at a rate of 6 kg/acre exhibited the highest response, with 47.36 grains per plant, surpassing the control (Khattak, 1995).

Number of Sterile Spikelets

In this research, various micronutrient treatment had a statistically significant impact on the quantity of sterile spikelets of *boro* rice (Table 1). The maximum number of sterile spikelets panicle^{-1} (25.46) was found in controlled treatment (NPK) which was identical to application with NPK + B (21.25) treated rice plants and the minimum number of sterile spikelets panicle^{-1} (6.66) was observed in NPK + Zn + B + Cu treated rice plants. The utilization of zinc fertilization, along with boron (B) and copper (Cu), significantly reduced the proportion of sterile grains in the conducted research. Previous studies have indicated that applying zinc foliar enhances the viability of pollen grains, leading to a reduction in sterility percentage in rice (Khan *et al.*, 2009).

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Table 1. Effect of micronutrients on yield and yield contributing characters of *Boro* rice *cv.* BRRI dhan89

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Non effective tillers hill^{-1} (no.)	Panicle length (cm)	Sterile spikelets (no.)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
T_1	90.60e	8.31d	0.85	21.75c	25.46a	19.57c	8.42d	43.21b
T_2	94.92cd	8.70cd	0.90	23.07bc	16.45bc	20.69bc	9.93c	43.55b
T_3	94.57d	9.18cd	0.85	23.34ab	21.25ab	19.96bc	10.54c	46.07a
T_4	99.11ab	10.54ab	1.54	23.98ab	9.89de	20.61bc	11.79b	43.23b
T_5	95.94bcd	9.82bc	1.09	22.62bc	17.85b	20.50bc	11.34b	44.81ab
T_6	98.36bc	9.83bc	1.46	23.38ab	12.66cd	21.33b	11.48b	43.19b
T_7	102.55a	11.29a	1.20	24.69a	6.66e	23.51a	12.66a	42.94b
Sig. level	**	**	NS	**	**	**	**	**
CV%	2.18	7.13	8.94	3.65	8.36	4.17	3.35	2.66

Here in the column having similar letter does not differ significantly as per DMRT at 1% level of probability. Here, T_1: Control (NPK), T_2: NPK + Zn, T_3: NPK + B, T_4: NPK + Zn + B, T_5: NPK + Zn + Cu, T_6: NPK + B + Cu, T_7: NPK + Zn + B + Cu

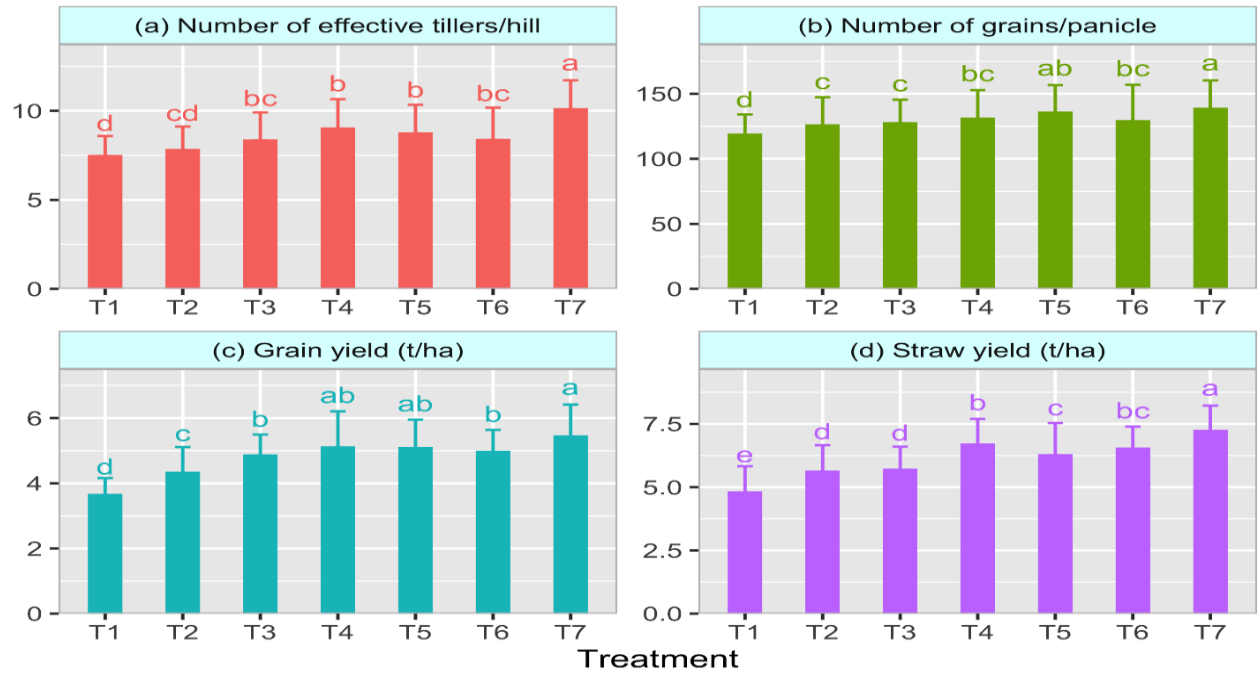

Figure 1. Effect of micronutrients on yield and yield contributing characters of *Boro* rice

Here, T_1: Control (NPK), T_2: NPK + Zn, T_3: NPK + B, T_4: NPK + Zn + B, T_5: NPK + Zn + Cu, T_6: NPK + B + Cu, T_7: NPK + Zn + B + Cu

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1000-Grain Weight

Various micronutrient treatments had a significant impact on the weight of 1000 grains (Table 1). The maximum result (23.51 g) was calculated when NPK + Zn + B + Cu applied together and the minimum one (19.57 g) was calculated in control treatment (NPK). The application of zinc, boron and copper significantly enhanced various yield parameters, including the 1000-grain weight. In plants treated with micronutrients, the mass of 1000 kernels ranged from 14 to 20 grams. Specifically, the Zn treated plants exhibited a 33% increase in mass, reaching a maximum of 20 g/1000 kernels. The combination of Zn and B resulted in a mass of 19.33 g/1000 kernels, while the control group recorded a mass of 10 g/1000 kernels (Arif *et al.,* 2012). Mitra and Jana (1991) found the similar result for weight of 1000 seeds. Saleem *et al.* (2011) determined that a residual effect at a 2 kg B ha^{-1} rate led to a significantly higher 1000-grain weight compared to the 1 kg boron ha^{-1} rate and it was equivalent to the 3 kg boron ha^{-1} rate. Ashraf *et al.* (2004), who found an increase in the 1000-grain weight of rice with higher levels of residual boron fertilizer.

Grain Yield

The experimental treatments showed notable differences in terms of the amount of grains produced (Figure 1c). The maximum grain yield (5.43 t ha^{-1}) was resulted in appliance of NPK + Zn + B + Cu micronutrients followed by NPK + Zn + B (5.10 t ha^{-1}) and NPK + Zn + Cu (5.08 t ha^{-1}) applications. The minimum grain yield (3.64 t ha^{-1}) was obtained in control treatment (NPK). The variation in results can be attributed to the diverse implementation of treatments. The higher crop yield may be attributed to the minimal occurrence of sterile spikelets panicle^{-1}. The application of Zn + B + Cu demonstrated a noteworthy and favorable impact on the yield of *boro* rice. In comparison to the control treatment, all Zn + B + Cu treatments exhibited significantly elevated grain yields, ranging from 7% to 28% (Ahmad *et al.,* 2012). The simultaneous application of iron, boron and zinc via foliar absorption led to a notable augmentation in the levels of these elements within the rice grain (Jin *et al.,* 2008). Micronutrient deficiencies, particularly in boron and zinc are becoming increasingly prevalent globally, exerting significant adverse effects on both crop yield and quality (Rafique *et al.,* 2008). According to Arif *et al.* (2012), the insufficiency of micronutrients, which are needed in small amounts, results in reduced crop growth and yield. The enhanced grain yield can be ascribed to the improved performance of growth and yield parameters, facilitated by the sufficient availability of essential micro-nutrients such as zinc, boron and copper (Cu) in the soil. These micro-nutrients, particularly Zn, B and Cu, positively influenced physiological processes, leading to the accumulation of photosynthesis in the economically significant parts, i.e., the grains. Previous studies by Suresh and Salakinkop (2016), Tabassum *et al.* (2013) support this statement.

Straw Yield

The variations in straw production were varied among the experimental treatments (Figure 1d). The uppermost straw yield (7.22 t ha^{-1}) was found in appliance of NPK + Zn + B + Cu and the minimum straw yield (4.78 t ha^{-1}) was originated in control treatment (NPK). The lowest yield occurred when no treatment was applied (absolute control), while the maximum yield was observed with the appliance of Zn + B + Cu treatment (Jahiruddin *et al.,* 1995). The research conducted by Aslam and Qureshi (1998) revealed a rise in the production of straw in paddy fields when applying boron. Saleem *et al.* (2011) documented that the greatest straw yield occurred when 3 kg of boron per hectare was applied, surpassing the control. The increase in paddy straw yield can be attributed to the enhancement of membrane function by boron, which positively influences the transport of essential metabolites for normal growth and development. Additionally, the activities of membrane-bound enzymes, contributing to a higher rice straw yield, were noted (Gupta, 1993).

Biological Yield

Various micronutrient treatments had a significant impact on the biological yield (Table 1). The uppermost biological yield (12.66 t ha^{-1}) was found in while NPK + Zn + B + Cu all these are applied combined and the least biological yield (8.42 t ha^{-1}) were recorded in control treatment (NPK). The differences observed could be attributed to the implementation of various treatments. According to Rashid *et al.* (2006), a lack of boron leads to a reduction in the leaf photosynthesis rate and the overall production of dry matter. The outcome aligned with the results of previous studies by Mustafa *et al.* (2011) which indicated that the additional use of zinc increased the biological yield of rice.

Harvest Index

Micronutrients were not impacted significantly on the harvest index (Table 1). The uppermost result (46.07%) was found in NPK + B treatment followed by the application of NPK + Zn + Cu (44.81%) and the least one (42.94 %) was found in appliance of NPK + Zn + B + Cu.

CONCLUSION

Exploring the influence of micronutrients on the development and productivity of rice, it can be inferred that the most favorable outcomes for *Boro* rice *cv.* BRRI dhan89, in terms of grain yield, effective tillers hill^{-1}, grains panicle^{-1} and thousand grain weights are achieved through the combined application of zinc, boron and copper in combining with nitrogen, phosphorus and potassium fertilizers. The findings indicated that utilizing a combination of NPK along with zinc, boron and copper produced better outcomes in enhancing the growth and yield of BRRI dhan89.

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Conflict of Interest

The authors certify that they have no financial or other competing interests to disclose with relation to the current work.

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