



The Effects of Foliar Boron on the Growth and Yield of Maize

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Maize (*Zea mays* L.) is crucial for food security and rural economies in Bangladesh, yet its productivity is constrained by soil fertility depletion and abiotic stresses. This study assessed the efficacy of foliar boron (B) application on maize performance during the 2023-24 Rabi season at Bangladesh Open University's Agricultural Laboratory. Using a randomized complete block design with three replications, six B concentrations (0-30 mg L⁻¹) were foliar-applied at the six-leaf stage. Optimal growth responses - including maximum plant height (194.3 cm), dry matter accumulation (185.8 g), CGR (7.23 g m⁻² day⁻¹), and RGR (0.006 g g⁻¹ day⁻¹) - were recorded at 25 mg L⁻¹ B. Yield components showed progressive improvement, peaking at 30 mg L⁻¹ B with superior cob diameter, seed count (18.2% increase over control), 100-seed weight (12.5% enhancement), and record yields (5.65 t ha⁻¹ grain; 9.9 t ha⁻¹ stover). The results demonstrate that foliar B supplementation at 25-30 mg L⁻¹ significantly boosts maize productivity through improved physiological efficiency. These findings provide actionable insights for micronutrient management strategies to enhance maize profitability in Bangladesh's resource-limited farming systems, potentially increasing yields by 22-28% compared to conventional practices.

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1. INTRODUCTION

Maize (*Zea mays L.*) is one of the most important cereal crops globally and has immense potential in Bangladesh as a versatile crop that supports food security, livestock feed, and industrial uses. Despite its adaptability and growing importance, maize production in Bangladesh faces challenges such as soil fertility issues and nutrient imbalances. Among the essential micronutrients, boron plays a pivotal role in crop development, influencing cell division, pollen viability, nutrient translocation, and seed formation (Pereira, et al., 2021). Unfortunately, boron deficiency is widespread in Bangladeshi agricultural soils because of intensive farming, erratic rainfall, and improper fertilizer management, leading to reduced crop growth and yields (Islam, et al., 2018).

Foliar application of boron has emerged as an efficient and cost-effective method to address micronutrient deficiencies in maize. Unlike soil application, foliar feeding ensures the targeted delivery of boron, especially during critical growth stages, thereby improving its bioavailability (Bayar, et al., 2024). Studies from similar agro-climatic regions have demonstrated the potential of boron to enhance maize yield components, such as plant height, cob setting, grain weight, and overall productivity. However, systematic research on its effects in Bangladesh is limited, leaving significant scope for the optimization and adoption of boron-based interventions in maize cultivation.

With increasing population pressure and a growing demand for maize in livestock and poultry industries, optimizing maize yield is crucial for Bangladesh's agricultural sustainability (Uddin, et al., 2011, Begum, et al., 2010). The application of boron aligns with modern precision farming practices, promoting nutrient-use efficiency and environmental stewardship. This study investigated the effects of foliar boron application on the growth and yield of maize, with the aim of providing actionable insights for Bangladeshi farmers. By understanding the role of boron in enhancing productivity, this research seeks to contribute to sustainable agriculture and food security, ensuring economic benefits for smallholder farmers, while addressing the nation's rising maize demand.

2. MATERIALS AND METHODS

The experiment was conducted at the Agricultural Laboratory in the School of Agriculture and Rural Development (SARD), Bangladesh Open University, Gazipur, during the Rabi season from November 2023 to March 2024. The soil texture consists of 11.28% clay, 26.72% silt, and 62% sand. The soil of the experimental site was clay loam in texture and the physicochemical properties of the surface soil (0–20 cm) were as follows: pH, 7.13; Organic matter, 2.08; EC, 135 (Msm^{-1}) total N, 0.095%; total P, 12.41 mg kg^{-1} ; total K, 17.10 mg kg^{-1} ; total S, 17.13 mg kg^{-1} ; total Zn, 0.553 mg kg^{-1} , total B, 0.234 mg kg^{-1} . The experiment was designed as a randomized complete block design (RCBD) with three replications. The treatments consisted of five foliar boron levels of 0, 10, 15, 20, 25, and 30 mg L^{-1} ; Boron from the source of boric acid (H_3BO_3) was foliar sprayed at six leaf stages of maize with the help of a knapsack sprayer. The maize variety 'BARI hybrid maize- 7' was used in this experiment. Maize seeds were collected from the Bangladesh Agricultural Research Institute (BARI) in Gazipur, Bangladesh. The seedbed was prepared using a power tiller, plowed twice, followed by a rotavator required for maize cultivation. The subplot had a width of 2m and a length of 1.5m, which accommodated four rows. Plant and row distances were maintained at 20 cm and 35 cm, respectively. The recommended doses of fertilizers were 120–60–40 $\text{kg N} - \text{P}_2\text{O}_5 - \text{K}_2\text{O}$. The sources of $\text{N} - \text{P}_2\text{O}_5 - \text{K}_2\text{O}$ were Urea, Triple Super Phosphate (TPS), and Muriate of Potash (MP). TSP, MP, and half of the Urea were used as the basal dose during land preparation. The remaining Urea was applied as a top dressing 35 d after sowing. The experimental plots were irrigated using surface irrigation according to the requirements of the crop and weather conditions. Four irrigations were applied along with the natural seasonal precipitation. Weeds were manually eradicated during the crop cycle; the first weeding was conducted after twenty-five days and the second after forty-five days of maize emergence. All other cultural practices, that is, thinning, herbicide, and insecticide application, were kept uniform for all experimental units. Plants were harvested at maturity to record plant height, dry matter, stem diameter, crop growth rate (CGR), relative growth rate (RGR), yield, and yield components. Crop growth rate (CGR) and Relative growth rate

(RGR) were calculated from the following formula expressed by (Yoshida, 1981) and (Hunt, 1978, Hunt, 1982).

Crop growth rate (CGR): The crop growth rate refers to the increase in biomass per unit of time following the formula of (Yoshida, 1981) and (Hunt, 1978).

$$CGR = \frac{W_2 - W_1}{T_2 - T_1}$$

where W_1 and W_2 are the biomass (total dry weight) at T_1 and T_2 , respectively. $(T_2 - T_1)$ = Time difference between two consecutive harvests.

Relative growth rate (RGR): The crop growth rate refers to the relative increase in biomass per unit time, following the formula of (Hunt, 1982).

$$RGR = \frac{\ln W_2 - \ln W_1}{T_2 - T_1}$$

where W_1 and W_2 are the biomass (total dry weight) at T_1 and T_2 , respectively. $(T_2 - T_1)$ = Time difference between two consecutive harvests. Where represents the natural logarithm.

The recorded data were collected and tabulated for statistical analyses. Analysis of variance (ANOVA) and parameter means were compared using the Statistix-10.0. Mean differences between treatments were determined by least significant differences (LSD) at the 5% significance level.

3. RESULTS

Research concerning the effect of boron on the growth and yield of maize was conducted under

field conditions. Significant differences were observed among the treatments for the different growth parameters of maize, viz. plant height ($F = 205.4$, $P < 0.0001$ and $df = 5, 17$), dry matter ($F = 205.4$, $P < 0.0001$ and $df = 5, 17$), CGR ($F = 282.43$, $P < 0.0001$ and $df = 5, 17$), and RGR ($F = 99999.99$, $P < 0.0001$ and $df = 5, 17$) as compared with their respective controls; however, there was no significant difference among the treatments, except for stem diameter ($F = 1.99$, $P = 0.152$ and $df = 5, 17$) as compared with the control (Table 1). The highest plant height, dry matter, CGR, and RGR were investigated for the 25 mg L⁻¹ boron with average mean values of 194.3 cm, 185.8 g, 7.23 and 0.006, respectively (Table 1). The highest stem diameter was observed when 15 mg L⁻¹ boron was applied, with an average mean value of 1.43 cm (Table 1). The lowest plant height, dry matter, stem diameter, CCR and RGR were observed for control with average mean values of 172.5 cm, 172.2 cm, 1.20 cm, 5.27 and 0.005, respectively (Table 1).

Significant differences were also observed among the treatments in the yield parameters of maize viz. cob diameter ($F = 4.75$, $P = 0.0127$ and $df = 5, 17$), seeds/row ($F = 8.25$, $P = 0.0014$, $df = 5, 17$), 100 seed wt. ($F = 7.35$, $P = 0.0023$, and $df = 5, 17$), seed yield ($F = 7.87$, $P = 0.0017$ and $df = 5, 17$), stover yield ($F = 4.58$, $P = 0.014$ and $df = 5, 17$), and harvest index ($F = 4.74$, $P = 0.0127$ and $df = 5, 17$) compared with their respective controls (Tables 2 and 3). The yield parameters of cob/plant ($F = 1.51$, $P = 0.256$, $df = 5, 17$), cob length ($F = 0.79$, $P = 0.576$, $df = 5, 17$), and row/cob ($F = 1.00$, $P = 0.45$, and $df = 5, 17$) were not significantly different from their respective controls (Table 2).

Table 1. Effect of boron on some growth characteristics of maize

Treatments (mg L ⁻¹)	Plant height (cm)	Dry matter (g)	Stem diameter (cm)	CGR	RGR
Control	172.5d ± 0.7	172.2b ± 2.0	1.20b ± 0.1	5.27e ± 0.1	0.005a ± 0.0
10	180.8c ± 0.3	173.1b ± 1.2	1.37ab ± 0.0	5.69d ± 0.0	0.006a ± 0.0
15	183.7b ± 0.6	175.8b ± 1.8	1.43a ± 0.0	6.42b ± 0.0	0.006a ± 0.0
20	193.6b ± 0.6	183.5a ± 0.9	1.40ab ± 0.1	7.12a ± 0.0	0.006a ± 0.0
25	194.3a ± 1.0	185.8a ± 1.0	1.40ab ± 0.0	7.23a ± 0.1	0.006a ± 0.0
30	182.8b ± 0.3	175.7b ± 0.6	1.23b ± 0.1	6.23c ± 0.0	0.006a ± 0.0
df	5,17	5,17	5,17	5,17	5,17
F Value	205.4	205.4	1.99	282.43	99999.99
P Value	0.0001	0.0001	0.152	0.0001	0.0001

The data points represent the mean of three replicates for each treatment. Treatments with different letters indicate significant differences ($p < 0.05$) based on least significant difference (LSD) tests and one-way ANOVA

Table 2. Effect of boron on yield components of maize

Treatments (mg L ⁻¹)	Cob/plant	Cob length (cm)	Cob diameter (cm)	Seeds/row	Row/cob
Control	1.00a± 0.0	13.4a± 0.6	13.0b± 0.2	23.7c± 1.3	13.7a ± 0.0
10	1.05a± 0.0	14.1a± 0.9	13.1b± 0.1	29.7b± 1.2	14.0a ± 0.0
15	1.11a± 0.0	14.7a± 0.8	13.2b± 0.3	31.0ab± 1.2	14.0a ± 0.0
20	1.15a± 0.0	14.8a ± 0.1	13.6ab± 0.2	29.7b ± 0.9	14.0a ± 0.0
25	1.17a± 0.0	15.0a ± 0.8	14.2a ± 0.3	33.3ab ± 2.0	14.0a ± 0.0
30	1.03a± 0.0	15.3a ± 0.9	14.3a ± 0.3	33.7a± 1.7	14.0a ± 0.0
df	5,17	5,17	5,17	5,17	5,17
F Value	1.51	0.79	4.75	8.25	1.00
P Value	0.256	0.576	0.0127	0.0014	0.45

The data points represent the mean of three replicates for each treatment. Treatments with different letters indicate significant differences ($p < 0.05$) based on least significant difference (LSD) tests and one-way ANOVA

Table 3. Effect of boron on yield of maize

Treatments (mg L ⁻¹)	100SW (g)	Seeds yield (t/ha)	Stover yield (t/ha)	HI%
Control	28.7d ± 0.3	4.60c ± 0.0	8.2c ± 0.4	33.9c ± 0.4
10	30.7cd ± 0.9	5.24b ± 0.1	8.6cd ± 0.3	34.8cd ± 0.2
15	33.0abc ± 0.6	5.23b ± 0.1	9.4ab ± 0.4	35.2ab ± 0.5
20	32.3cd ± 1.2	5.22b ± 0.2	9.1abc ± 0.2	35.5ab ± 0.4
25	34.7a ± 0.6	5.43ab ± 0.2	9.8a ± 0.3	36.1a ± 0.5
30	34.9a ± 1.2	5.65a ± 0.1	9.9a ± 0.3	36.1a ± 0.3
df	5, 17	5, 17	5, 17	5, 17
F Value	7.35	7.87	4.58	4.74
P Value	0.0023	0.0017	0.014	0.0127

The data points represent the mean of three replicates for each treatment. Treatments with different letters indicate significant differences ($p < 0.05$) based on least significant difference (LSD) tests and one-way ANOVA

The individual treatment of boron 30 mg L⁻¹ performed the highest result of most of the yield parameters viz. cob length, cob diameter, 100 seed wt., seed yield and stover yield with average mean values of 15.3 cm, 14.3 cm, 33.7, 34.0 g, 5.65 t/ha and 9.9 t/ha, respectively (Tables 2 & 3). All treatments except were not significantly different in the case of row/cob, with the highest mean value of 14.0 (Table 2). The highest harvest index was observed for individual treatments with 30 mg L⁻¹ boron (Table 3).

4. DISCUSSION

Foliar application of boron significantly improved maize plant height, particularly when optimal concentrations were applied at the growth stages. Data on plant height changed because of different foliar applications of boron, while plots were treated with 25 mg L⁻¹ boron. The plant height was 21.8 cm taller than that of the non-treated plants. The application of boron may contribute to the increase in plant height, as it lengthens the plant's inter-nodal length by increasing the number of cells. Additionally, boron plays a role in cell differentiation and cell

wall production, fostering plant growth, and root and shoot elongation (Haghi, et al., 2016). According to (Bayar, et al., 2024), foliar application of boron significantly enhances the height of maize plants, specifically at a concentration of 1%. In the present study, the dry matter yield of shoots and roots varied among the test cultivars. A concentration of 20 ppm of boron greatly enhanced dry matter production in both shoots and roots. (Rahim, et al., 2004) reported a significant increase in dry weight per plant in maize, which aligns with the findings of the current study, indicating that boron application greatly enhanced maize growth. The application of boron at a rate of 15 kg/ha significantly increased the dry matter yield of sorghum hybrids compared with lower concentrations (Alkhamisi, et al., 2017). This suggests that adequate boron levels are essential for maximizing forage yield, especially in environments with variable salinity.

Boron deficiency in cereal crops, as noted by (Lal, et al., 2022), frequently leads to decreased dry matter yield owing to morphological abnormalities, impaired photosynthesis, and

disrupted metabolic processes, emphasizing the essential role of boron in ensuring optimal plant growth. This micronutrient significantly affects the crop growth rate (CGR) of maize, a key factor in plant development. Maintaining sufficient boron levels enhances growth, yield, and overall productivity. In this study, the application of 25 mg L⁻¹ boron significantly increased the maize CGR. Additionally, foliar application of 0.3% boron achieved a CGR of 22.1 g/m²/day during a specific growth phase, demonstrating its efficacy in promoting sweet corn growth (Kumar, et al., 2023). Studies have shown that foliar application of boron can increase the number of cobs per plant, particularly in reproductive processes such as flowering, pollen tube growth, and seed formation. In maize, foliar application of boron significantly influences various growth parameters, including cob formation per plant (Haque, 2024). Boron is essential for pollen tube elongation and viability. The current study demonstrated that higher doses of boron increased the number of cobs per plant and cob length, although these improvements were not statistically significant. However, 30 mg L⁻¹ of boron showed the best performance in cob setting per plant and cob length. In contrast, boron significantly influenced kernel setting per cob, with 30 mg L⁻¹ identified as the most advantageous dose. A sufficient supply ensures effective pollination and fertilization, leading to a better kernel set on the cobs. (Dresselhaus, et al., 2011) reported that boron plays a key role in pollen tube elongation, which directly affects successful cob setting in maize. Adequate boron availability supports proper pollen tube growth, allowing it to reach the female gametophyte effectively, which is critical for double fertilization. Without sufficient boron, pollen tubes may fail to grow properly, leading to fertilization issues, lower seed set, and reduced cob formation. Other studies on pine trees (*Picea meyeri*) have shown that boron is crucial for pollen germination and pollen tube growth. When boron is deficient in the growth medium, pollen germination rates are significantly lower, and the pollen tubes that have grown exhibit abnormal development (Wang, et al., 2003). Regarding the foliar spray of boron application, 100 seed weight, seed yield, stover yield, and harvest index significantly increased with increasing doses of boron. Among them, 30 mg L⁻¹ of foliar boron showed the highest results, which were statistically similar to that of 25 mg L⁻¹ of boron. The increase in boron intake led to an increase in grain weight because higher boron availability enhanced enzyme activation, which resulted in an increase in the

partitioning of nutrients from leaves to grains and an increase in grain weight. This process contributed to the overall improvement in crop yield, demonstrating the significant role of boron in plant development and nutrient distribution. Regarding the foliar application of boron at different concentrations, (Bayar, et al., 2024) revealed that the application of 1% boron produced the maximum thousand-grain weight. The increase in seeds per cob is attributed to the application of boron, which improves the seed-filling process by enhancing seed setting and thereby reducing male sterility often observed under boron-deficient conditions (Tahir, et al., 2018). These results are consistent with the findings of (Sultana, et al., 2015), who reported that an improvement in seeds per cob was achieved through boron application. Similar results were reported by (Phonglosa, et al., 2019), indicating that foliar application of boron increases the number of seeds per cob. A significant and higher stover yield was observed with the application of 30 mg L⁻¹, which may be attributed to the increased biomass build-up from having more leaves and yield features, such as a higher number of seeds per cob. This consistent application of boron led to enhanced uptake of major nutrients, resulting in improved photosynthetic activity and greater vegetative growth in plants. Accelerated growth due to proper metabolic activity results in a higher stover yield. These findings are consistent with those reported previously (Kumar, et al., 2023). The application of boron (B) had a significant positive effect on the harvest index of maize, enhancing both yield and quality. Research has indicated that foliar application of boron at 25 mg L⁻¹ and 30 mg L⁻¹ leads to improved growth parameters and yield components, ultimately increasing the harvest index. Studies have indicated that applying a 1% boron solution could have led to an increase in the harvest index by 12.77% to 13.31% compared to untreated plots, as reported by (Bayar, et al., 2024).

5. CONCLUSION

This study highlights the critical role of boron in enhancing maize growth, yield, and productivity through foliar application. Optimal concentrations, such as 25 mg L⁻¹ and 30 mg L⁻¹, improved the growth and yield indicators of maize. These findings emphasize the importance of boron in boosting growth parameters, such as the crop growth rate (CGR) and harvest index, supporting sustainable agricultural practices. Consistent results across studies validate the

efficacy of boron in promoting maize growth and maximizing yield.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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