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EFFECTS OF FOLIAR APPLICATION OF ZINC AND BORON ON THE YIELD OF TOMATO

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Abstract

Zinc and Boron deficiencies in Bangladeshi soil is remarkable which is a major cause of yield loss of tomato. However, foliar spray of these micronutrients can be a cure of this problem. Field experiments were carried out during Rabi season of 2021-2022, 2022-2023 and 2023-2024 to evaluate the effect of foliar application of zinc (Zn) and boron (B) on the yield and yield attributes of tomato (var. BARI tomato21). Treatments included various combinations of Zn and B application at 300 ppm and 600 ppm. The experiment followed a Randomized Complete Block Design (RCBD) with three replications. The Zn and B were sprayed three times at 20, 40 and 60 days after transplanting (DAT). The treatment T_8, containing 600 ppm Zn and 300 ppm B foliar application showed the most significant impact on plant height (140.5 cm), number of branches per plant (3.23), number of fruits per plant (54.1), individual fruit weight (56.6 g) and marketable fruit yield (101.4, 88.8 and 91.3 t ha^{-1}, respectively in 2021-22, 2022-23 & 2023-24 cropping years). Over the span of three years, the T_8 treatment consistently outperformed other Zn-B combinations individual Zn or B application and the control in terms of fruit yield.

Keywords: Boron, Foliar application, Tomato, Yield, Zinc.

Introduction

Tomato (*Solanum lycopersicum*) is one of the most important vegetable crops in Bangladesh, contributing significantly to household nutrition and national agriculture. However, tomato production in the country is often constrained by nutrient-related challenges, particularly deficiencies of essential micronutrients such as zinc (Zn) and boron (B). These micronutrients play critical roles in plant growth and fruit development zinc is involved in various enzymatic activities and protein synthesis (Patel *et al.*, 2007), while boron is essential for cell wall formation (Dong *et al.*, 2018) as well as flower and fruit development (Rerkasem *et al.*, 2020). In many soils of Bangladesh, Zn and B deficiencies are widespread, leading to reduced crop vigor, lower yields, and poor fruit quality. To overcome these limitations, foliar application has emerged as an efficient method for supplying micronutrients directly to plants and enhances the yield and yield attributes of tomato crop. Previous studies suggest that foliar sprays of zinc and boron

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can significantly improve plant growth, fruit size, and overall yield of tomato (Bhujel et al., 2024). Therefore, evaluating the impact of foliar applications of zinc and boron on the yield and quality of tomato is essential for developing improved nutrient-management practices that enhance tomato productivity in Bangladesh (Sultana *et al.*, 2016).In this context, the present study was undertaken to assess the effects of different foliar concentrations of zinc and boron on the yield and yield attributes of tomato.

Materials and Methods

Description of the experimental site

Field experiments were set up during rabi season of consecutive three years from 2021-2024 at the Regional Agricultural Research Station (RARS) of BARI, Jashore. The site belongs to AEZ 11 i.e High Ganges River Floodplain. Before starting the first season trial, Soil samples from all treatments were collected at 0-15 cm depths. The soil samples were collected from the experimental field for analysis of soil properties (Tables 1 and 2). Soil texture was measured by hydrometer method (Black, 1965), soil bulk density (BD) was measured by core method (Karim *et al.*, 1988)), Soil pH was measured by a glass electrode pH meter (Ghosh *et. al.*, 1983), Soil Organic Carbon (SOC) was measured by the wet oxidation method (Jackson, 1973) and SOM was calculated by multiplying percent SOC with the van Bemmelen factor, 1.73 (Piper, 1942). Total N was measured by micro-Kjeldahl method (Bremner, and Mulvaney, 1982), available P by the 0.5 M $NaHCO_3$ (Olsen et al. 1954), exchangeable K by NH4OAc extraction (Black, 1965), available S by $CaCl_2$ extraction (Fox *et. al.*, 1964), available Zn by DTPA extraction (Lindsay and Norvell, 1978) and Available B content of soil was determined by the mono-calcium biphosphate $[Ca(H_2PO_4)_2]$ extraction method (Page *et al*., 1982). The analysis revealed that the textural class of the experimental soil was sandy clay loam with bulk density value was 1.40 g cm^{-3}. Soils were slightly alkaline in nature with low levels of SOM (1020%) and P (15.0 mg kg^{-1}). On the other hand, the soils had very low levels of N (0.60%), K (0.15 meq 100 g $soil^{-1}$), Zn (0.52 mg kg^{-1}) and B (0.16 mg kg^{-1}).

Treatments and design

The experimental design was Randomized Complete Block Design (RCBD) with three replications of each treatment. The seedlings were raised in a seedbed and 30-days old tomato seedlings were transplanted into a 4- row 10 m^2 (4.0 m × 2.5 m) plot with planting spacing of 60 cm × 50 cm. The experiment included nine treatments with two micronutrients (Zn and B), applied through foliar spray as needed to thoroughly wet the entire plants in the plots, either individually or in combination, along with a control, at concentrations of 300 ppm and 600 ppm for each micronutrient. The treatments were as T_1 = control (no spray), T_2 = Foliar application of 300 ppm Zn at 20, 40 and 60 DAT, T_3 = Foliar application of 600 ppm Zn at 20, 40 and 60 DAT, T_4 = Foliar application of 300 ppm B at 20, 40 and 60 DAT, T_5 = Foliar application of 600 ppm B at 20, 40 and 60 DAT, T_6 = Foliar application of 300 ppm Zn + Foliar application of 300 ppm B at 20, 40 and 60 DAT, T_7 = Foliar application of 300 ppm Zn + Foliar application of 600 ppm B at 20, 40 and 60 DAT, T_8 = Foliar application of 600 ppm Zn + Foliar application of 300 ppm B at 20, 40 and 60 DAT and T_9 = Foliar application of 600 ppm Zn + Foliar application of 600 ppm B at 20, 40 and 60 DAT.

Table 1. Particle size distribution, textural class and bulk density of initial soil of the experimental field, RARS, Jashore

Soil depth (cm)	Particle size distribution			Textural class	Bulk density g cm^{-3}
	Sand%	Silt%	Clay%		
0-15	52.00	25.28	22.72	Sandy clay loam	1.40

Table 2. Initial soil nutrients status of the experimental field, RARS, Jashore

Soil depth (cm)	pH	SOM	Total N	Available level of nutrients				
		(%)		K	P	S	Zn	B
				meq 100 g $soil^{-1}$	mg kg^{-1}			
0-15	7.6	1.20	0.060	0.15	15.0	18	0.52	0.16
Interpretation	Slightly alkaline	Low	Very low	Very low	Low	Medium	Very low	Very low

Solution preparation

Prepared 1 liter of 300 ppm Zn solution by dissolving 1.32 grams of $ZnSO_4 \cdot 7H_2O$ in distilled water and made the volume up to 1 liter. Similarly, by dissolving 2.64 grams of $ZnSO_4 \cdot 7H_2O$ was in 1-liter distilled water for 600 ppm Zn solution. In addition, 2.65 grams of Borax ($Na_2B_4O_7 \cdot 10H_2O$) was dissolved in 1-liter distilled water for 300 ppm B solution. Likewise, 5.30 grams of Borax ($Na_2B_4O_7 \cdot 10H_2O$) was dissolved in 1-liter distilled water for 600 ppm B solution.

Fertilizer dose and method of application

The micronutrients were supplied in the form of borax and zinc sulphate, which are the sources of boron and zinc, respectively. Zinc and boron were applied through foliar spray, either individually or in combination, three times at vegetative stages (20 DAT), flowering stage (40 DAT) and early fruiting stage (60 DAT). A 300 ppm Zn and B foliar spray in tomato required 600 L ha^{-1}, total 180 g of Zn and B was needed per hectare. Similarly, 1200 L ha^{-1} solution was needed for 600 ppm Zn and B solution where a total 360 g Zn and B was needed for 1 hectare of land. Zinc and boron were applied through foliar spray as needed to thoroughly wet the entire plants in the plots. On the other hand, a blanket dose of cow dung (10 t ha^{-1}), urea (300 kg ha^{-1}), TSP (200 kg ha^{-1}), and MoP (210 kg ha^{-1}) were applied. During final land preparation, the full amounts of cow dung and TSP, along with half of the MoP, were applied to soil. The remaining half of MoP and the entire urea were applied in two equal installments: the first at 15 DAT and the second at flowering stage (45 DAT).

Data collection and analysis

Ten plants from each plot during the harvest were selected randomly to collect the data on plant height, number of branches per plant, total and marketable fruits per plant, single fruit weight, and fruit yield per hectare. These data were statistically analyzed using Statistix 10 software. The mean values were calculated, and analysis of variance for each treatment was performed using the F-test. Differences between treatments were assessed using the Least Significance Difference (LSD) test at a 5% significance level (Gomez and Gomez, 1984).

Results and Discussion

Effects of zinc and boron on growth parameters

Spraying zinc and boron as a foliar application significantly increased the plant height of tomato. The tallest plant (140.5 cm) was observed in T_8 treatment (600 ppm Zn and 300 ppm B foliar application) during 2023-2024 year which is 26.9% higher than T_1 control treatment (Table 3). The T_8 treatment was statistically comparable to the T_7, T_6, and T_9 treatments. The number of branches per plant exhibited a similar pattern. The T_8 treatment recorded the highest number of branches per plant (3.23), followed by T_9 (3.03) and T_7 (3.02), as shown in Table 3 and the T_8 exhibited a 38.6% increase relative to the control. Our findings align closely with those of several other researchers. Sharma (1999) reported the tallest plants (70.6 cm) and the highest branch count (5.9) with 20 kg ha^{-1} of borax, while the control had the shortest plants (59 cm) and fewest branches (4.8). Hamsaveni *et al*. (2003) observed a significant height increase (140.7 cm) in tomatoes with a 0.5% boron spray at 50% flowering. Hussain *et al*. (1989) found the greatest height improvement with 0.1% zinc and boron foliar spray. Bhatt *et al*. (2004) achieved 9.61 branches per plant due to 100 ppm each of boron and zinc. Barche *et al*. (2011) recorded the highest height (80.4 cm) and branch count (34.7) with H_3BO_3 and $ZnSO_4$ at 250 ppm. Ejaz *et al*. (2011) showed 6% zinc and 5% boron sprays significantly improved plant height and branches of tomato plants.

Effects of zinc and boron on the yield and yield attributes of tomato

Foliar application of Zn and B positively influenced tomato growth and yield. It also remarkably influenced the total and marketable fruit count per plant as well as the individual fruit weight. During 2023-2024, the T_8 treatment yielded the highest total number of fruits per plant (54.1), followed by the T_9 treatment (51.5 fruits). This represented a 36.9% increase for T_8 compared to the control treatment (T_1), which recorded 39.5 fruits, as detailed in Table 3. The T_8 treatment also produced the maximum number of marketable fruits (41.5), closely followed by T_9 (39.0). In contrast, the control treatment resulted in the lowest number of marketable fruits (27.9). The highest individual fruit weight was observed in the T_8 treatment (56.6 g), which was comparable to T_9 (54.4 g). Moreover, the yield per plant in the T_8 treatment was significantly higher at 2.75 kg compared to the other treatments. Our findings are consistent with many previous research results. Barche *et al.* (2011) highlighted the superior yield from combined boron (H_3BO_3) and zinc ($ZnSO_4$) sprays at 250 ppm, increasing fruit yield per plant (1.18 kg) and total yield (20 t ha^{-1}). Ali *et al.* (2013) confirmed similar findings, noting the maximum yields from boron and zinc sprays (5 g per 100 ml each). Singh and Tiwari (2013) observed optimal yields using boric acid, zinc sulphate, and copper sulphate at 250 ppm each. Singh *et al*. (2014) reported tomato yields of 23.1 t ha^{-1} with boron (0.2%) and zinc (0.4%) compared to the 14.5 t/ha control. Shnain *et al*. (2014) documented the highest fruit clusters (7.17), fruits per plant (88.3), and total yield (113.6 t ha^{-1}) with boron and zinc sprays (1.25 g per litre each). Combined application of micronutrients consistently demonstrated more effective than individual micronutrient treatments.

Table 3. Effects of zinc and boron as foliar spray on the yield contributing characters of tomato during 2023-24

Treat.	Plant height (cm)	No. of branches/plant	Total number of fruits/plant	Marketable fruits/plant	Individual fruit weight (g)	Fruit yield/plant (kg)
T_1	110.7 d	2.33 f	39.5 e	27.9 g	37.2f	1.79 d
T_2	114.9 d	2.40 ef	42.0 e	29.9 fg	41.8 e	1.93 cd
T_3	116.3 cd	2.60 de	47.1 cd	30.9 efg	45.3de	2.22 bc
T_4	119.5 cd	2.67 d	46.1 d	33.9 cde	44.6 de	2.22 bc
T_5	126.6 bc	2.93 bc	48.1 bcd	35.3 cd	48.1 cd	2.12 bcd
T_6	133.1 ab	2.77 cd	47.9bcd	32.7 def	51.4 bc	2.34 b
T_7	133.3 ab	3.02 ab	50.5 abc	36.7 bc	52.4 b	2.22 bc
T_8	140.5 a	3.23 a	54.1 a	41.5 a	56.6 a	2.75 a
T_9	132.9 ab	3.03 ab	51.5 ab	39.0 ab	54.4 ab	2.39 b
LSD	10.91	0.25	3.8	3.4	4.14	0.35
CV%	5.03	5.28	4.63	5.71	4.99	9.07

Legend: T_1 = control (no spray), T_2 = Foliar application of 300 ppm Zn at 20, 40 and 60 DAT, T_3 = Foliar application of 600 ppm Zn at 20, 40 and 60 DAT, T_4 = Foliar application of 300 ppm B at 20, 40 and 60 DAT, T_5 = Foliar application of 600 ppm B at 20, 40 and 60 DAT, T_6 = Foliar application of 300 ppm Zn + Foliar application of 300 ppm B at 20, 40 and 60 DAT, T_7 = Foliar application of 300 ppm Zn + Foliar application of 600 ppm B at 20, 40 and 60 DAT, T_8 = Foliar application of 600 ppm Zn + Foliar application of 300 ppm B at 20, 40 and 60 DAT and T9 = Foliar application of 600 ppm Zn + Foliar application of 600 ppm B at 20, 40 and 60 DAT.

Over three years of observation, tomato yields increased with foliar sprays of zinc and boron at different concentrations. Significant yield differences were seen among treatments, with the highest yield recorded in the T_8 treatment (foliar application of 600 ppm Zn + 300 ppm B). In the first year, the highest yield (101.4 t ha^{-1}) was obtained from T_8 (600 ppm Zn + 300 ppm B foliar application) treatment which was statistically comparable to T_7 (300 ppm Zn + 600 ppm B foliar application) and T_9 (600 ppm Zn + 600 ppm B foliar application) treatments. In the 2nd year, the highest yield (88.7 t ha^{-1}) of tomato was found in T_8 treatment which was statistically similar with T_4 and T_9 treatments (84.5 t ha^{-1}). The 2nd year showed slightly lower yields, possibly due to late sowing. In the 3rd year, the T_8 treatment produced the highest tomato yield which was identical and followed by T_9 (89.9 t ha^{-1}), T_3 (91.5 t ha^{-1}), T_2 (84.6 t ha^{-1}), T_5 (83.6 t ha^{-1}), T_2 (84.6 t ha^{-1}) and T_6 (81.1 t ha^{-1}). The T_8 treatment achieved yields of 101.4, 88.7, and 91.3 t ha^{-1} in the first, second, and third years, respectively, representing 34%, 18%, and 25% increases over the control yields of 75.4, 75.0, and 73.3 t ha^{-1}. The BARI tomato-21 variety also showed a 26% yield increase with foliar applications of Zn and Boron (Ullah *et al*., 2015). Foliar application of 600 ppm Zn and 300 ppm B optimized plant physiological functions. Zinc is crucial for carbonic anhydrase enzyme synthesis, aiding CO_2 transport in photosynthesis (Alloway, 2008), enhancing photosynthetic efficiency and strengthening the antioxidant system in tomatoes (Faizan and Hayat, 2019).

Table 4. Effect of zinc and boron as foliar spray on the fruit yield of tomato over the years

Treatments	Fruit yield (t ha^{-1})		
	2021-22	2022-23	2023-24
T_1	75.4 e	75.0 c	73.3 b
T_2	77.2 de	75.5 c	84.6 ab
T_3	76.8 de	83.3 b	91.5 a
T_4	85.8 cd	84.5 ab	81.9 ab
T_5	89.0 bc	80.6 b	83.6 ab
T_6	91.1 bc	81.3 b	81.1 ab
T_7	96.6 ab	83.2 b	72.3 b
T_8	101.4 a	88.7 a	91.3 a
T_9	98.0 ab	84.5 ab	89.9 a
LSD	9.5	5.1	2.1
CV%	6.23	3.57	9.41

Legend: T_1 = control (no spray), T_2 = Foliar application of 300 ppm Zn at 20, 40 and 60 DAT, T_3 = Foliar application of 600 ppm Zn at 20, 40 and 60 DAT, T_4 = Foliar application of 300 ppm B at 20, 40 and 60 DAT, T_5 = Foliar application of 600 ppm B at 20, 40 and 60 DAT, T_6 = Foliar application of 300 ppm Zn + Foliar application of 300 ppm B at 20, 40 and 60 DAT, T_7 = Foliar application of 300 ppm Zn + Foliar application of 600 ppm B at 20, 40 and 60 DAT, T_8 = Foliar application of 600 ppm Zn + Foliar application of 300 ppm B at 20, 40 and 60 DAT and T_9 = Foliar application of 600 ppm Zn + Foliar application of 600 ppm B at 20, 40 and 60 DAT.

Correlation matrix of yield and yield components

The correlation analysis revealed significant positive associations among all measured growth and yield attributes (Table 5). Plant height exhibited strong correlations with number of branches per plant (r = 0.82), total number of fruits per plant (r = 0.84), individual fruit weight (r = 0.83), and fruit yield per plant (r = 0.75), indicating its contribution to overall plant productivity. Number of branches per plant showed very strong correlations with total number of fruits per plant (r = 0.97) and marketable fruits per plant (r = 0.97), suggesting that branching is a major determinant of fruit-bearing capacity.

Total number of fruits per plant displayed the strongest correlations with individual fruit weight (r = 0.97) and fruit yield per plant (r = 0.92). Likewise, marketable fruits per plant was highly correlated with total fruits (r = 0.94), individual fruit weight (r = 0.92), and fruit yield per plant (r = 0.86). Individual fruit weight also showed a strong association with fruit yield per plant (r = 0.90), emphasizing its direct influence on yield.

Fruit yield per plant demonstrated the strongest correlation with fruit yield per hectare (r = 0.88), confirming that yield per plant is a reliable predictor of overall productivity. Fruit yield per hectare also correlated positively with total number of fruits per plant (r = 0.85) and number of branches (r = 0.81), although the correlation with plant height was relatively weaker (r = 0.46).

Table 5. Pearson correlation matrix of tomato yield and yield contributing characters during 2023-24 as affected by zinc and boron foliar spray

Parameters	Plant height	No. of branches/plant	Total number of fruits/plant	Marketable fruits/plant	Individual fruit weight	Fruit yield/plant	Fruit yield (t/ha)
Plant height	1						
No. of branches/plant	0.82	1					
Total number of fruits/plant	0.84	0.97	1				
Marketable fruits/plant	0.78	0.97	0.94	1			
Individual fruit weight	0.83	0.95	0.97	0.92	1		
Fruit yield/plant	0.75	0.85	0.92	0.86	0.90	1	
Fruit yield (t/ha)	0.46	0.81	0.85	0.79	0.78	0.88	1

Conclusion

Foliar application of zinc and boron notably improved tomato growth and yield. The T_8 treatment (foliar application of 600 ppm Zn + 300 ppm B) consistently produced the highest fruit yield and including the greatest number of fruits per plant, the most marketable fruits, and the heaviest individual fruit. Over a 3-year period, the T_8 treatment demonstrated consistent yield increases of 34%, 18%, and 25% compared to the control. These results highlight the beneficial effects of micronutrient application on tomato yield, suggesting that optimal levels of zinc and boron can significantly improve tomato production.

Conflicts of interest

The authors declare no conflicts of interest regarding publication of this paper.

Authors' contribution

N.U. Mahmud, N. Salahin and K.U. Ahammad conceptualized the study and designed the experiments. N. Salahin and N.U. Mahmud collected and analyzed the data as well as interpreted the results. Roknuzzaman drafted the text. N. Salahin and M.S. Kobir reviewed the results and finalized the manuscript.

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