



## Effect of Zinc and Boron Application on Lycopene and Nutritional Qualities of Tomato

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### Authors' contributions

This work was carried out in collaboration among all authors. Author SM collected samples, performed analysis and wrote the first draft of the manuscript. Author RCD helped in manuscript preparation and performed the statistical analysis. Authors HMZ and MSA designed the study, supervise the work and corrected the final draft of the manuscript. All authors read and approved the final manuscript.

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### ABSTRACT

A pot experiment was conducted in the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh, to examine the effect of different levels of Zn and B on the major biochemical and nutritional quality of tomato fruits. The experiment was laid out in a completely randomized design (CRD) with 4 replications along with two treatment factors viz., (i) four levels of Zn- like control, Zn @ 4.0 kg ha<sup>-1</sup>, Zn @ 6.0 kg ha<sup>-1</sup> and Zn @ 8.0 kg ha<sup>-1</sup>; and (ii) three levels of B- like control, B @ 2.0 kg ha<sup>-1</sup> and B @ 3.0 kg ha<sup>-1</sup>. Among the biochemical parameters- lycopene, total acidity, and vitamin C contents in tomato fruits ranged from 3.24-3.76 mg 100 g<sup>-1</sup>, 0.26-0.36%, and 21.76-26.40 mg 100 g<sup>-1</sup> samples, respectively. The study results revealed that the highest amounts of lycopene and vitamin C were recorded from B @ 2.0 kg ha<sup>-1</sup>. Combined Zn and B applications showed a highly significant effect on total acidity, lycopene, and vitamin C contents of tomato fruits. Similarly, the application of Zn and B alone or in combination significantly affected the major nutrient contents of tomato fruits. The highest amounts of Ca, Mg, Na, K, and P were obtained from the application of Zn @ 4.0 kg ha<sup>-1</sup>, while the maximum amounts of Fe and Zn were recorded from Zn @ 8.0 kg ha<sup>-1</sup> treatment. However, the application of B alone

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significantly reduced the contents of Ca, P, S, Fe, and Zn in tomato fruits while the contents of Mg, K, and Na remained almost unchanged. Finally, the study results concluded that the combined application of Zn and B (@ 4.0 and 2.0 kg ha<sup>-1</sup>, respectively) had a significant effect on major nutrients and biochemical characters of tomato fruits.

**Keywords:** Micronutrients; lycopene; minerals; fruit quality.

## 1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a popular vegetable crop, and most people like it for its high nutritive values. It is a cheaper source of polyphenols and antioxidants. However, it is hopeful that the total production of tomato in Bangladesh is increasing day by day, which was 385 thousand M. tons in 2017-18 [1], but it is not enough to fulfil the demand of the countries' peoples. Thus, this vegetable's production needs to increase, and the nutritional quality of the produced fruits should emphasize getting the maximum health benefit, which the farmers usually ignore during its cultivation.

Micronutrients play an important role in not only plant growth but also different metabolic processes in the plant body such as photosynthesis, enzyme activity, respiration, cell development, nitrogen fixation and hormone synthesis, but they are required in small quantity for the plant body [2-3]. Micronutrient deficiencies are one of the major limiting factors for crop production and quality of crops. Furthermore, the application of micronutrients increases the efficiency of macronutrients. Therefore, the applications of micronutrient fertilizers have a significant role in achieving higher and sustainable crop yields. However, different research organizations in Bangladesh have conducted a good number of field experiments with micronutrients at different agro-ecological zones of the country, and most of them were concentrated on cereal crops [4-7]. However, research on the effect of micronutrients on vegetable crops is relatively more minor. However, in recent times, few field trials with micronutrients in vegetable cultivation have been made in Bangladesh [8-9].

High cropping intensity and use of mainly macronutrient fertilizers are the major limiting factors for the micronutrient deficiency in soils of Bangladesh, resulting in lower yields and quality of the crops. Moreover, our country's cropping intensity is very high, resulting in higher removal of the micronutrients from soils. Among the micronutrients, zinc (Zn) and boron (B) are already declared deficient in some soils of

Bangladesh [10]. There is some evidence that B and Zn play an important role in improving the quality of tomatoes and checking various diseases and physiological disorders [11]. According to Salam et al. [12], deficiencies of such micronutrient elements are among the major problems for the lower yield and quality of produced tomato fruits in Bangladesh. Furthermore, lycopene is present in tomatoes, one of the most potent antioxidants among the dietary carotenoids. Dietary intake of tomatoes and tomato products containing lycopene is associated with a decreased risk of cancer and cardiovascular disease [13]. Thus, the present research work was undertaken to evaluate the effect of different levels of Zn and B on lycopene and other nutritional qualities of tomatoes.

## 2. MATERIALS AND METHODS

### 2.1 Preparation of Pot Experiment

To fulfil the objective, a pot experiment was carried out at the Net House, Department of Agricultural Chemistry, Bangladesh Agricultural University (BAU), Mymensingh, during the period from November 2017 to March 2018. Details of soils used for the experiment, along with the physicochemical properties already published in our previous report [9]. The experiment was conducted with the seedlings of tomato (*Lycopersicon esculentum*) var. *Ruma-VF*. The pots were prepared 15 days before transplanting the tomato seedlings and 8.0 kg powered soil was poured in each plastic bucket, keeping undisturbed before transplanting the tomato seedlings. The tomato seedlings were transplanted when they were 25 days old.

### 2.2 Treatments and Fertilizer Application

Zinc sulfate heptahydrate (ZnSO<sub>4</sub>.7H<sub>2</sub>O; contained 23% Zn) and boric acid (H<sub>3</sub>BO<sub>3</sub>; contained 17% B) were taken as the source of Zn and B for the experiment. The treatment combinations consist of two factors, such as- (i) different levels of Zn, viz., Zn<sub>0</sub> = Control, Zn<sub>4.0</sub> = Zn @ 4.0 kg ha<sup>-1</sup>, Zn<sub>6.0</sub> = Zn @ 6.0 kg ha<sup>-1</sup> and Zn<sub>8.0</sub> = Zn @ 8.0 kg ha<sup>-1</sup>; and (ii) different levels of B, viz. B<sub>0</sub> = Control, B<sub>2.0</sub> = B @ 2.0 kg ha<sup>-1</sup> and

$B_{3.0} = B @ 3.0 \text{ kg ha}^{-1}$  in a completely randomized design (CRD) with 4 replications. Urea, TSP, MoP and Gypsum were used for the experiment as per the recommendation of the Fertilizer Recommendation Guide [10], considering the high yield goal and medium soil fertility status. No manure was used in the experiment. Intercultural operations were done manually when necessary.

### 2.3 Tomato Fruits Harvesting

Tomato fruits were harvested during the early ripening stage when they attained red colour, and the first harvest of ripe tomato started 80 days after transplanting. After hand harvesting of fruits, all the samples were tagged and taken to the laboratory. Two uniform size and shape fruits of each treatment were selected for further chemical analyses.

### 2.4 Analysis of Biochemical Qualities of Tomato Fruits

Lycopene is responsible for the red colour of tomato fruits. Fully ripened tomato fruit samples were collected from each treatment and kept for 24 hrs at room temperature. These fruits were used for the determination of lycopene content. Extraction of the carotenoids present in the sample was performed using acetone and then taken up in petroleum ether following the method described by Sadasivam and Manickam [14]. To determine total titratable acidity and vitamin C, fully matured light yellow tomato fruit samples were also collected from each treatment. Total titratable acidity was estimated by the visual titration method by neutralizing the acid with 0.1M NaOH using 2 drops of phenolphthalein as an indicator. On the other hand, vitamin C content in tomato fruit was estimated based on the reduction of 2,6-dichlorophenol indophenol dye as outlined by Sadasivam and Manickam [14].

### 2.5 Estimation of Nutrient Elements in Tomato Fruits

Determination of major mineral elements (Ca, Mg, P, S, K, Na, Fe and Zn) was done in aqueous tomato fruit extract. For this purpose, one ripened tomato fruit sample collected from each treatment pot was cut into small pieces using a sharp stainless steel knife and dried in an electric oven at 50°C temperature for about 72 hrs. Then the samples were ground using a grinding mill, and powdered samples were used to prepare tomato fruit extract by wet oxidation

method as described by Singh et al. [15]. Among the nutrient elements, Ca and Mg were determined titrimetrically, P and S were measured by spectrophotometrically, and Na and K were estimated by flame photometrically as mentioned by Singh et al. [15]. Iron and Zn contents in the aqueous extract of tomato fruit were measured using an atomic absorption spectrophotometer (AAS) (Model: AA-7000, SHIMADZU, Japan). Hollow cathode lamp of Fe and Zn operating at 248.3 and 213.9 nm, respectively used as the radiation source, and the lamp current was set at 15 mA. The instrumental parameters were adjusted according to the manufacturer's recommendations.

### 2.6 Statistical Analysis of Data

After collection, all data were analyzed (analysis of variance) with the help of the computer package MSTAT followed by F-test, and the mean differences of the treatments were adjudged by the least significant difference (LSD) test [16-17].

## 3. RESULTS AND DISCUSSION

### 3.1 Effect of Zn on Biochemical Properties of Tomato Fruits

There are highly significant differences in the lycopene content of tomato fruits by applying different levels of Zn (Fig. 1A). The average amount of lycopene varied from 3.24-3.76 mg 100 g<sup>-1</sup> tomato sample. The highest amount of lycopene was obtained by applying Zn @ 8.0 kg ha<sup>-1</sup>, and the lowest amount of lycopene recorded from the control treatment. In general, field-grown tomatoes have higher lycopene levels than controlled conditions or greenhouse-grown fruits [18]. Our results are in agreement with those of Salam et al. [12], who stated that the lycopene content of tomato fruits gradually increased with the increasing levels of B and Zn. Application of different levels of Zn significantly affected total acidity. It can be seen from Fig. 1B that the highest amount (0.36%) of acidity was recorded from the application of Zn @ 6.0 kg ha<sup>-1</sup> treatment, and the lowest acidity (0.26%) was obtained from the control treatment. According to Kazemi [19], increased addition of Fe and Zn in soils resulted in higher titratable acidity content in tomato fruits due to their role in carbohydrate metabolism and synthesis of related enzymes. Statistical analysis revealed significant differences in the vitamin C content of tomato fruits. The highest amount of vitamin C (26.40

mg 100 g<sup>-1</sup> sample) was obtained from the application of Zn @ 4.0 kg ha<sup>-1</sup>, which was statistically similar to the control treatment (26.08 mg 100 g<sup>-1</sup> sample) (Fig. 1C).

On the other hand, the lowest amount of vitamin C was recorded from the application of Zn @ 8.0 kg ha<sup>-1</sup>. Present study results revealed that higher application of Zn reduced ascorbic acid content in tomato fruits. This result is at par with the report of Abedy [20], who stated that the application of Zn has an important role in photosynthesis and related enzymes, which will lead to increased sugar and decreasing acid. However, Bhatt and Srivastava [21] stated the importance of Zn in ascorbic acid synthesis in tomato fruits.

### 3.2 Effect of B on Biochemical Properties of Tomato Fruits

The effect of different doses of B on the lycopene content of tomato fruits was highly significant at  $P < 0.01$  (Fig. 2A). The maximum amount of lycopene in tomato fruits (3.67 mg 100 g<sup>-1</sup> sample) was obtained from the application of B @ 2.0 kg ha<sup>-1</sup>. On the other hand, the minimum amount of lycopene (3.39 mg 100 g<sup>-1</sup> sample) was obtained from the control treatment. Salam et al. [12] also reported a similar observation, and they stated that increasing levels of B and Zn gradually increased the lycopene content of tomato fruits. It is apparent from Fig. 2B that the application of different levels of B considerably affected the total acidity of tomato fruits. The highest amount of total acidity (0.36%) was recorded from B @ 3.0 kg ha<sup>-1</sup>, which was statistically at par with the application of B @ 2.0 kg ha<sup>-1</sup>. In comparison, the lowest amount of total acidity (0.21%) was obtained from the control treatment. Lopez-Andreu et al. [22] also reported that the titratable acidity was lower in tomatoes grown under B deficient conditions. Application of B @ 2.0 kg ha<sup>-1</sup> significantly increased ascorbic acid content and titratable acidity at all stages of picking tomato fruits [23]. There were highly significant variations in the vitamin C content of tomato fruits due to the application of different levels of B (Fig. 2C). The amount of vitamin C in tomato fruits ranged from 21.54-26.16 mg 100 g<sup>-1</sup> sample. The highest amount of vitamin C was recorded from the application of B @ 2.0 kg ha<sup>-1</sup>, while the lowest amount of vitamin C was recorded from B @ 3.0 kg ha<sup>-1</sup> treatment. It was apparent from this study that the application of B @ 2.0 kg ha<sup>-1</sup> significantly increased the vitamin C content of tomato fruit. A similar result was also reported by Islam et al. [24] and Salam et al.

[12], and they stated that the vitamin C content was higher in B+Ca and B+Zn treated tomato fruits than the control.

### 3.3 Interaction Effect of Zn and B on Biochemical Properties of Tomato Fruits

The combined application of Zn and B had an expressive effect on the total acidity of tomato fruits. The highest amount (0.57%) of total acidity was found when Zn @ 6.0 kg ha<sup>-1</sup> along with B @ 2.0 kg ha<sup>-1</sup>, and the lowest amount (0.14%) of acidity was obtained from the control treatment (Table 1). Kazemi [19] also reported the highest titratable acidity in tomato fruits when plants were treated with 100 mg L<sup>-1</sup> Zn + 200 mg L<sup>-1</sup> Fe. Interaction effects of Zn and B on the lycopene contents of tomato fruits were also significant. The average lycopene content of tomato fruits ranged from 2.86-4.16 mg 100 g<sup>-1</sup> sample due to the combined application of Zn and B. The highest amount of lycopene in tomato fruits was obtained from the application of B @ 3.0 kg ha<sup>-1</sup> without Zn.

On the other hand, the lowest amount of lycopene in tomato fruits was obtained from the application of Zn @ 6.0 kg ha<sup>-1</sup> without B (Table 1). These results are in agreement with those of Salam et al. [12], who reported that lycopene content of tomato fruits treated with B<sub>2.5</sub>Zn<sub>6.0</sub> was almost thrice (123.00 µg 100 g<sup>-1</sup>) compared to control (43.25 µg 100 g<sup>-1</sup>) treatment. Kazemi [19] obtained the highest amount of lycopene (2.25 mg 100 g<sup>-1</sup>) in tomato fruits when plants were treated with 100 mg L<sup>-1</sup> Zn + 200 mg L<sup>-1</sup> Fe. They also recommended foliar application of Zn and Fe to improve growth, flower yield, quality and chemical constituents in tomato plants. This result is in agreement with the present study also. The vitamin C content in tomato fruits expressively varied due to the interaction effects of Zn and B. The average vitamin C content in tomato fruit ranged from 17.97-27.55 mg 100 g<sup>-1</sup> sample. The highest amount of vitamin C in tomato fruits was obtained from the application of B @ 3.0 kg ha<sup>-1</sup> without Zn, and the lowest amount of vitamin C content in tomato fruit was obtained from the combined application of Zn @ 6.0 kg ha<sup>-1</sup> and B @ 2.0 kg ha<sup>-1</sup>. Dube et al. [25] recorded the highest ascorbic acid content in tomato with the soil application of zinc sulphate and borax @ 10 and 20 kg ha<sup>-1</sup>, respectively. However, the antioxidant content of tomatoes greatly influenced by the effects of variety, season, harvest time, maturity, as well as environmental factors such as light, temperature,

water and nutrient supply, which was reported nicely in a review article published by Dumas et al. [26].

### 3.4 Effect of Zn on Nutrient Elements of Tomato Fruits

The calcium content in the tomato fruits was significantly affected by the application of different levels of Zn. The highest amount of Ca (0.31%) in the tomato fruit was recorded from the application of Zn @ 4.0 kg ha<sup>-1</sup>, and the lowest amount of Ca (0.24%) was obtained from both Zn @ 6.0 and 8.0 kg ha<sup>-1</sup> treatments (Table 2). Paul and Shaha [27] stated that citrus fruits are not considered good sources of Ca, but some fruits may contain an appreciable amount of Ca. However, they obtained 27.0±1.2 mg% Ca in tomato fruits collected from the northern region of Bangladesh. The content of Mg in the tomato fruit varied significantly by the application of different levels of Zn. The highest amount of Mg (0.18%) in the tomato fruits was recorded from Zn @ 4.0 and 8.0 kg ha<sup>-1</sup> treatments. The lowest Mg (0.14%) in the tomato fruit was recorded from the control treatment (Table 2). The Na and K contents in the tomato fruit did not vary significantly by the application of Zn. However, the range of Na and K in tomato fruits was 0.14 - 0.15% and 0.245 - 0.261%, respectively. The P and S contents in the tomato fruits were significantly affected by applying different levels of Zn. The highest amounts of P (0.34%) and S (0.39%) in the tomato fruits were recorded from the application of Zn @ 4.0 and 6.0 kg ha<sup>-1</sup>, respectively.

On the other hand, the lowest amount of P was obtained from the application of Zn @ 8.0 kg ha<sup>-1</sup>, which might be due to the competitive effect between Zn and P in the uptake of ions (Zn decreases P content) as stated by Kazemi [19]. Total Zn content in tomato fruits was significantly influenced by the application of different levels of Zn. The highest amount of Zn (0.29 ppm) content in the tomato fruits was recorded from the application of Zn @ 6.0 and 8.0 kg ha<sup>-1</sup> treatments. The lowest amount of Zn (0.25 ppm) was recorded from the control treatment. This result is in agreement with the findings of Gurmani et al. [28], who reported that Zn concentration in leaf, fruit and root increased with the increasing level of applied Zn. Iron content in the tomato fruits was significantly affected by the application of different doses of Zn. The highest amount of Fe (1.42 ppm) was recorded from Zn @ 8.0 kg ha<sup>-1</sup>, while the lowest amount of Fe

(1.06 ppm) was recorded from the control, which is statistically similar to the application of Zn @ 4.0 kg ha<sup>-1</sup> treatment.

### 3.5 Effect of B on Nutrient Elements of Tomato Fruits

Boron fertilization is frequently used in agricultural production. Many researchers previously reported the positive effect of B on different crops, i.e. on tomato [12], wheat [29], sunflower [30], pepper and cucumber [31]. Based on such investigations, Ekinici et al. [32] reported that different B applications increased the nutrient content, plant growth, and yield of different plant species. However, the effect of different doses of B on the Ca content of tomato fruits was significant. The highest amount of Ca (0.28%) in tomato fruit was recorded from the control treatment, and the lowest (0.25%) amount of Ca was recorded from both B @ 2.0 and 3.0 kg ha<sup>-1</sup> treatments (Table 3). However, Davis et al. [33] reported that foliar and/or soil application of B increased the tissue concentrations of N, Ca, K, and B in tomato shoot and fruit. The highest amounts of P (0.33%) and S (0.38%) were recorded from the control treatment, and the lowest amount was recorded from the application of B @ 3.0 kg ha<sup>-1</sup> (Table 3).

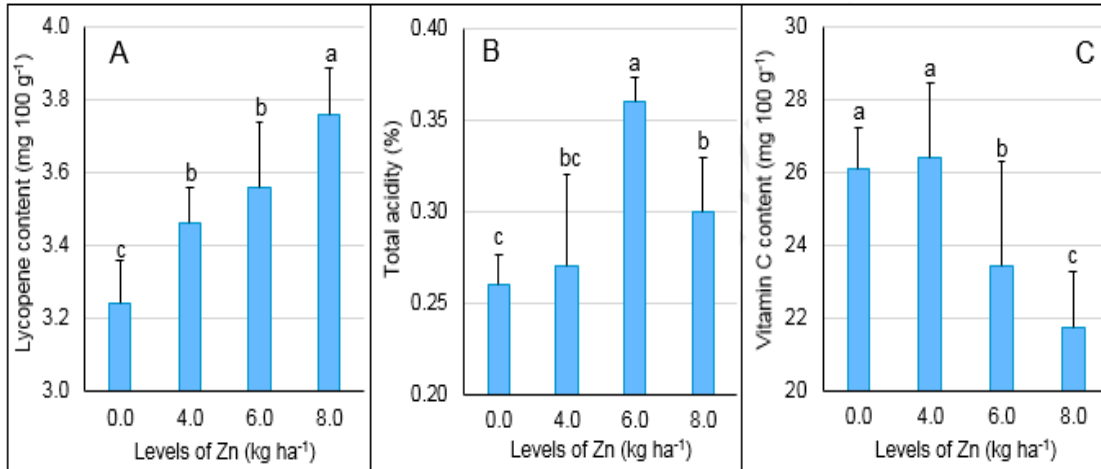
On the other hand, there was no significant effect of B in the Mg, Na, K and Zn content of the tomato fruit. But, according to Rajaie et al. [34], increments in B addition to soil significantly increased the concentration of N, P and K in the lemon shoot. However, the application of B observed a highly significant effect in the content of Fe of tomato fruits. The highest amount of Fe (1.35 ppm) was recorded from the control treatment, while the lowest amount of Fe (1.06 ppm) in tomato fruits was recorded from the application of B @ 3.0 kg ha<sup>-1</sup>. Thus, it can be summarized that the application of B did not positively influence the Fe content of tomato fruits. This result is at par with the findings of Aref [35], who stated that B use did not affect Fe uptake in the corn grain at any level.

### 3.6 Interaction Effect of Zn and B on Nutrient Elements of Tomato Fruits

The interaction effect of Zn and B on Ca and Mg contents in tomato fruits were statistically significant. The average Ca content in tomato fruits ranged from 0.18-0.37%, while the mean Mg content varied from 0.11-0.20% due to the combined application of Zn and B. Both the

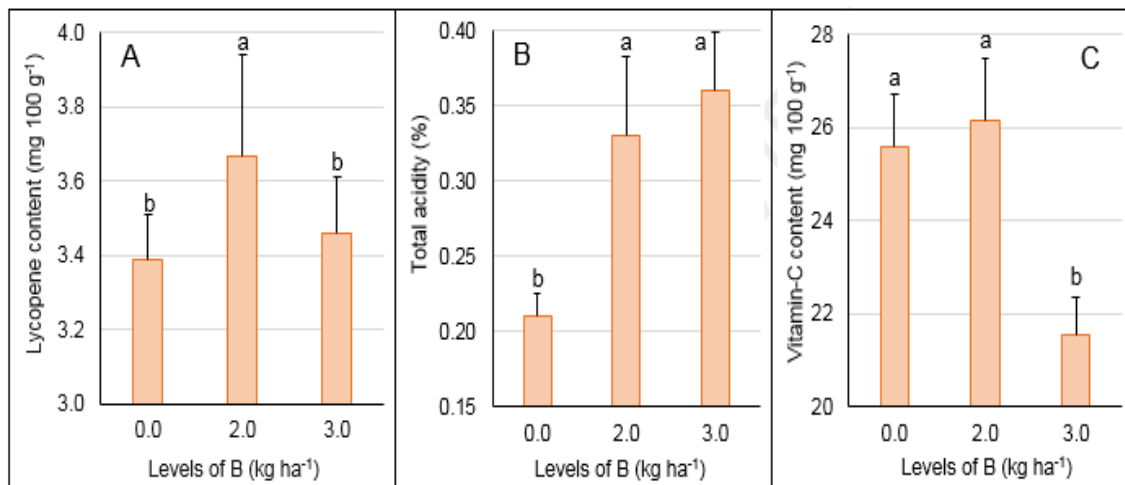
highest amounts of Ca and Mg were recorded from the application of Zn @ 8.0 kg ha<sup>-1</sup> without B (Table 4). The combined effects of Zn and B on Na and K concentrations in tomato fruits were not statistically significant. The average value of Na and K content in tomato fruits ranged from 0.13-0.17% and 0.236-0.263%, respectively (Table 4). However, Loneragan and Webb [36] reported that an antagonistic relationship

between Zn and other cationic micronutrients appears due to competition at the absorption sites of plant roots. The interaction effect of Zn and B on P and S contents of tomato fruits was statistically significant. The average values of P ranged from 0.27-0.40% and the highest value was recorded from the application of Zn @ 8.0 kg ha<sup>-1</sup> without B.



**Fig. 1. Effect of different levels of zinc (Zn) application on lycopene (A), titratable total acidity (B) and ascorbic acid (C) contents of tomato fruits**

Each value is the mean for four replicates, and vertical bars indicate the standard deviation. Means with different letters indicate significant difference between values at  $P < 0.01$  (LSD Fisher's test)



**Fig. 2. Effect of different levels of boron (B) application on lycopene (A), titratable total acidity (B) and ascorbic acid (C) contents of tomato fruits**

Each value is the mean for four replicates, and vertical bars indicate the standard deviation. Means with different letters indicate significant difference between values at  $P < 0.01$  (LSD Fisher's test)

**Table 1. Interaction effect of Zn and B application on the major biochemical properties of tomato fruits**

Treatments	Total acidity (%)	Lycopene (mg 100 g <sup>-1</sup> )	Vitamin C (mg 100 g <sup>-1</sup> )
Zn <sub>0</sub> ×B <sub>0</sub>	0.14h	3.81bc	27.42a
Zn <sub>4.0</sub> ×B <sub>0</sub>	0.31bcde	3.04de	26.22abc
Zn <sub>6.0</sub> ×B <sub>0</sub>	0.33bcd	2.86e	24.60bc
Zn <sub>8.0</sub> ×B <sub>0</sub>	0.23fg	3.05de	26.15abc
Zn <sub>0</sub> ×B <sub>2.0</sub>	0.34bc	4.16a	27.55a
Zn <sub>0</sub> ×B <sub>3.0</sub>	0.25efg	3.19d	25.51abc
Zn <sub>4.0</sub> ×B <sub>2.0</sub>	0.21gh	2.87e	25.18abc
Zn <sub>4.0</sub> ×B <sub>3.0</sub>	0.31bcde	3.79bc	27.22ab
Zn <sub>6.0</sub> ×B <sub>2.0</sub>	0.57a	4.02ab	17.97d
Zn <sub>6.0</sub> ×B <sub>3.0</sub>	0.26defg	3.82bc	23.52c
Zn <sub>8.0</sub> ×B <sub>2.0</sub>	0.36b	3.68c	23.67c
Zn <sub>8.0</sub> ×B <sub>3.0</sub>	0.29cdef	3.78bc	18.09d
LSD <sub>(0.05)</sub>	0.07	0.25	2.69
Level of significance	**	**	**
CV%	14.14	4.27	6.52

\*\* means significant at 1% level of probability; Means with different letters in column indicate significant difference between values.

**Table 2. Effect of different doses of Zn application on major nutrient contents of tomato fruits**

Treatments	Major nutrient element							
	% Ca	% Mg	% Na	% K	% P	% S	Zn (ppm)	Fe (ppm)
Zn <sub>0</sub>	0.25b	0.14b	0.14	0.253	0.30b	0.36bc	0.25c	1.07c
Zn <sub>4.0</sub>	0.31a	0.18a	0.15	0.261	0.34a	0.36c	0.27b	1.06c
Zn <sub>6.0</sub>	0.24b	0.14b	0.15	0.246	0.30b	0.39a	0.29a	1.21b
Zn <sub>8.0</sub>	0.24b	0.18a	0.14	0.245	0.29b	0.37b	0.29a	1.42a
LSD <sub>(0.05)</sub>	0.03	0.02	0.01	0.27	0.02	0.01	0.02	0.12
Level of significance	**	**	NS	NS	**	**	**	**
CV%	12.56	17.06	10.58	11.04	7.14	3.00	2.92	9.90

NS= not significant; \*\* means significant at 1% level of probability. Means with different letters in column indicate significant difference between values

**Table 3. Effect of different doses of B application on major nutrient contents of tomato fruits**

Treatments	Major nutrient element							
	% Ca	% Mg	% Na	% K	% P	% S	Zn (ppm)	Fe (ppm)
B <sub>0</sub>	0.28a	0.16	0.15	0.248	0.33a	0.38a	0.27	1.35a
B <sub>2.0</sub>	0.25b	0.16	0.14	0.254	0.29b	0.37a	0.27	1.16b
B <sub>3.0</sub>	0.25b	0.16	0.14	0.251	0.29b	0.35b	0.28	1.06c
LSD <sub>(0.05)</sub>	0.02	0.02	0.01	0.23	0.01	0.02	0.69	0.10
Level of significance	**	NS	NS	NS	**	**	NS	**
CV%	12.56	17.06	10.58	11.04	7.14	3.00	2.92	9.90

NS= not significant; \*\* means significant at 1% level of probability. Means with different letters in column indicate significant difference between values.

**Table 4. Interaction effects of Zn and B on the major nutrient contents of tomato fruits**

Treatments	Major nutrient element							
	% Ca	% Mg	% Na	% K	% P	% S	Zn (ppm)	Fe (ppm)
Zn <sub>0</sub> ×B <sub>0</sub>	0.18d	0.14bcde	0.14	0.260	0.32b	0.37bc	0.92e	0.21e
Zn <sub>4.0</sub> ×B <sub>0</sub>	0.30bc	0.11e	0.15	0.258	0.30bcde	0.36c	1.14cd	0.25d
Zn <sub>6.0</sub> ×B <sub>0</sub>	0.28bc	0.17abc	0.14	0.241	0.27e	0.37c	1.15bcd	0.29bc
Zn <sub>8.0</sub> ×B <sub>0</sub>	0.37a	0.20a	0.17	0.260	0.40a	0.41a	0.96de	0.30ab
Zn <sub>0</sub> ×B <sub>2.0</sub>	0.30bc	0.16abcd	0.14	0.263	0.28cde	0.36c	1.09de	0.24d
Zn <sub>0</sub> ×B <sub>3.0</sub>	0.26c	0.19ab	0.14	0.260	0.33b	0.31d	1.12cde	0.28c
Zn <sub>4.0</sub> ×B <sub>2.0</sub>	0.32ab	0.12de	0.15	0.237	0.28cde	0.37c	1.30bc	0.31a
Zn <sub>4.0</sub> ×B <sub>3.0</sub>	0.20d	0.17abc	0.15	0.248	0.30bcde	0.42a	1.34b	0.31a
Zn <sub>6.0</sub> ×B <sub>2.0</sub>	0.20d	0.12cde	0.14	0.251	0.31bcd	0.37bc	0.98de	0.24d
Zn <sub>6.0</sub> ×B <sub>3.0</sub>	0.26c	0.19ab	0.14	0.236	0.32bc	0.38b	2.22a	0.28c
Zn <sub>8.0</sub> ×B <sub>2.0</sub>	0.20d	0.19ab	0.13	0.246	0.27de	0.36c	1.08de	0.30ab
Zn <sub>8.0</sub> ×B <sub>3.0</sub>	0.28bc	0.17abc	0.14	0.253	0.27de	0.36c	0.98de	0.31a
LSD <sub>(0.05)</sub>	0.05	0.04	0.02	0.47	0.03	0.02	0.20	0.01
Level of significance	**	*	NS	NS	**	**	**	**
CV%	12.56	17.06	10.58	11.04	7.14	3.00	2.92	9.90

NS= not significant; \* and \*\* means significant at 5% and 1% level of probability, respectively. Means with different letters in column indicate significant difference between values

On the other hand, the highest amount of S (0.42%) in the tomato fruits was recorded from the application of Zn @ 4.0 kg ha<sup>-1</sup> and B @ 3.0 kg ha<sup>-1</sup>, while the lowest amount of S (0.31%) was obtained from the application of B @ 3.0 kg ha<sup>-1</sup> without Zn. Yang et al. [37] reported that the combined application of boron with molybdenum or zinc resulted in higher rapeseed yield and quality than the single application of boron with molybdenum or zinc. The combined application of Zn and B significantly affected the Zn and Fe contents of tomato fruits. The highest amount of Zn (2.22 ppm) was obtained from the application of Zn @ 6.0 kg ha<sup>-1</sup> and B @ 3.0 kg ha<sup>-1</sup> treatment, and the lowest amount of Zn was recorded from the control treatment (Table 4). However, Mousavi et al. [38] stated that Zn transmission of plant roots to shoot reduces by high concentrations of P. Thus, Zn uptake by plants reduces by increasing phosphorus in soil. The highest amount of Fe (0.31 ppm) in the tomato fruits was recorded from the application of Zn @ 4.0 kg ha<sup>-1</sup>, and B @ 3.0 kg ha<sup>-1</sup> and the lowest amount (0.21 ppm) was recorded from the control treatment (Table 4). But according to Aref [35], both the single and interaction effects of Zn and B on the Fe concentration in the grain were insignificant.

#### 4. CONCLUSION

The present study results concluded that the application of Zn and B helped in improving the biochemical and nutritional quality of tomato.

Lycopene level increased by increasing level of Zn and B. However, vitamin C and total acidity content also increased by applying Zn and B up to a certain level as Zn @ 4.0 kg ha<sup>-1</sup> and B @ 2.0 kg ha<sup>-1</sup>. Application of Zn @ 4.0 kg ha<sup>-1</sup> and B @ 2.0 kg ha<sup>-1</sup> positively influence on nutrient contents on tomato fruits. Thus, this study results recommend the application of Zn @ 4.0 kg ha<sup>-1</sup> and B @ 2.0 kg ha<sup>-1</sup> to improve the quality of tomato fruits as well as to maintain good soil health conditions. However, this study also recommends field trials to evaluate the performance of Zn and B applications in improving tomato fruit quality in different areas of Bangladesh.

#### CONSENT

It is not applicable.

#### ETHICAL APPROVAL

It is not applicable.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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