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Optimization of Zinc and Boron Levels for Better Growth and Yield of Tomato (*Lycopersicon esculentum* Mill.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author SM performed pot experiment, collected data, performed the statistical analysis and wrote the first draft of the manuscript. 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 at the net house of the Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh during the period of November, 2017 to March, 2018 to optimize different levels of Zn and B for better growth and yield attributes of tomato (cv. *Ruma VF*). The experiment included two factors [factor- A viz., control (Zn_0), Zn @ 4.0 kg ha^{-1} (Zn_4), Zn @ 6.0 kg ha^{-1} (Zn_6) and Zn @ 8.0 kg ha^{-1} (Zn_8) and factor B viz., control (B_0), B @ 2.0 kg ha^{-1} (B_2) and B @ 3.0 kg ha^{-1} (B_3)], which was laid out in a completely randomized block design with 4 replications, thus total number of pots were 48. Zinc sulphate and boric acid were applied as the source of Zn and B that were applied during pot preparation along with recommended doses of N, P, K and S. The study revealed that application of different doses of Zn increased number of flower clusters $plant^{-1}$ at 80 days after transplanting, fruit length, fruit diameter, number of fruits $plant^{-1}$ and yield of tomato up to 4.0 kg ha^{-1}. Similarly, application of B @ 2.0 kg ha^{-1} produced the highest number of flower clusters $plant^{-1}$, fruit length and fruit diameter. On the other hand, the highest number of fruits $plant^{-1}$ and yield of tomato were obtained by the application of B @ 3.0 kg ha^{-1}

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which was statistically similar to the application of B @ 2.0 kg ha^{-1}. Combined application of Zn and B, @ 4.0 and 2.0 kg ha^{-1}, respectively appeared as the best practice for better growth and yield of tomato, and therefore it may be recommended to boost up tomato productivity.

Keywords: Zinc; boron; growth; yield; tomato.

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a major vegetable crop grown all over the world and also a popular vegetable in Bangladesh due to its taste and nutritional status. The best growing areas of tomato in Bangladesh are Chittagong, Comilla and Rajshahi [1] and it ranks fourth in respect of production and third in respect of area [2]. The production of tomato in our country in 2017-18 was 385 thousand metric tons whereas it was only 190 thousand metric tons in 2009-10 [3]. Although the production of tomato in Bangladesh is increasing day by day but it is not enough to fulfill the demand of the peoples; thus, every year the country needs to import tomato. The most logical way to increase the total production at the national level from our limited land resources is to increase yield per unit area. Application of micronutrients particularly Zn and B seem to be one of the important practices to boost up tomato production in micronutrient deficient areas of Bangladesh, because micronutrients play important role in growth and different metabolic processes in plant. Although the micronutrients are required in small quantity but they perform significant roles in plants growth and development. Micronutrient deficiencies are one of the major limiting factors for crop production in Bangladesh. Zinc and B are already declared deficient in some soils of Bangladesh. It is reported that Zn and B play an important role in improving the growth, yield and quality of tomato in addition to checking various diseases and physiological disorders [4].

High cropping intensity and use of only macronutrient fertilizers are the major limiting factors for the micronutrient deficiency in Bangladesh resulting lower crop yields. In general, Ganges floodplain, coastal saline soils and the area covered by different high yielding varieties (HYV) crops including rice are deficient in Zn, which indicates that although Zn requirement of a crop is very small, still its application cannot be overlooked [5]. Application of Zn and B increased the yield of transplanted aman rice by 11 and 8%, respectively [6]. Furthermore, in wheat, 21% yield increase due to application of B. It has been reported that 2.5 kg B and 6 kg Zn along with 20 tons cowdung per hectare is congenial for Gazipur soils of Bangladesh to improve tomato quality and soil health [7-8]. Besides, the cropping intensity, low organic matter content is another limiting factor for micronutrient deficiency in Bangladesh soils. At least 2% organic matter should be present in the soil for successful crop production but 90% soils of Bangladesh contained 0.5-1.0% organic matter [9]. Considering these facts in mind, the present research work was conducted to optimize different levels of Zn and B on growth and yield of tomato.

2. MATERIALS AND METHODS

2.1 Experimental Site and Soil

The 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. The soil was collected from the Genetics and Plant Breeding Farm of BAU, Mymensingh, which belongs to the agro-ecological zone of Old Brahmaputra Floodplain (AEZ-9). The physicochemical properties of the soil used for the experiment are: pH- 7.18, EC-150 µS cm^{-1}, organic matter- 1.13%, available P-12.6 µg g^{-1}, exchangeable K- 54.7 µg g^{-1}, available S- 10.9 µg g^{-1} and available Zn- 12.2 µg g^{-1}. However, N and B contents in soil were not determined.

2.2 Preparation of Pots

Plastic pots were prepared 15 days prior to transplant of the tomato seedlings. The collected soil was dried, ground and subsequently sieved by 2 mm stainless steel sieve. All kinds of weeds, stubbles and residues were removed and 8.0 kg powered soil was poured in each pot and kept undisturbed up to transplanting of the tomato seedlings.

2.3 Treatments for the Experiments

Zinc sulfate ($ZnSO_4.7H_2O$) and boric acid (H_3BO_3) were used as a source of Zn and B, which contained 23% Zn and 17% B, respectively and applied during final pot preparation. The experiment included two factors, viz. factor- A: control (Zn_0), Zn @ 4.0 kg ha^{-1} (Zn_4), Zn @ 6.0 kg ha^{-1} (Zn_6) and Zn @ 8.0 kg ha^{-1} (Zn_8); and factor B: control (B_0), B @ 2.0 kg ha^{-1} (B_2) and B @ 3.0 kg ha^{-1} (B_3).

2.4 Experimental Design and Layout

The experiment was laid out in a completely randomized design (CRD) with 4 replications. So, the total numbers of pots were 48 (12×4). The treatments were randomly distributed to the net house of the Department of Agricultural Chemistry of BAU, from November 2017 to March 2018 and the position of the pots were changed time to time to reduce environmental heterogeneity.

2.5 Test Crop and Intercultural Operations

Fifteen (15) days old seedlings of tomato (cv. *Ruma VF*) were collected from the Horticulture Center, Kewatkhali, Mymensingh, Bangladesh and 2 (two) were transplanted in each pot on November 15, 2017. After 7-10 days of transplanting, one seedling was eradicated by keeping a healthy one. Intercultural operations viz. weeding, irrigation, disease and pest management were done manually as and when necessary.

2.6 Dose and Application of Fertilizers

Fertilizers applied in the pot as recommended for high yield goal and medium soil fertility status as described in Fertilizer Recommendation Guide [10]. Fertilizers such as urea, TSP, MoP and gypsum were used as sources of N, P, K and S, respectively @ 90, 30, 50, 10 kg ha^{-1}. Among the fertilizers TSP and gypsum were applied during final pot preparation. Amount of S added from the $ZnSO_4.7H_2O$ was deducted from required amount of gypsum. Urea and MoP were applied at two equal installments, first at 15 days after transplanting (DAT) and second at 35 DAT. No manure was used in the experiment.

2.7 Harvesting of Fruits

Tomato fruits were harvested during early ripening stage when they attained red color. Harvesting was started at 80 days after sowing and it was completed by March, 2018. Hand harvesting was done from each plant and after fruit harvesting, all the samples were tagged and taken to the laboratory.

2.8 Collection of Data

Data were collected on plant height, number of leaves $plant^{-1}$, number of primary branches $plant^{-1}$, number of flower clusters $plant^{-1}$, fruit length and diameter, number of fruits $plant^{-1}$ and fruit yield $plant^{-1}$.

2.9 Analysis of Data

Analysis of variance was done with the help of computer package MSTAT [11]. The data were analyzed statistically by F-test [12]. The mean differences in the treatments were adjudged by the least significant difference (LSD) test.

3. RESULTS AND DISCUSSION

3.1 Effect of Zn on Growth and Yield of Tomato

The plant height of tomato at different days after transplanting (DAT) was not significantly affected by the application of different levels of Zn (Table 1). The longest plant was produced by the application of Zn @ 8.0 kg ha^{-1} at 40, 50, 60, 70 and 80 DAT (57.66, 74.88, 79.66, 88.11 and 92.66 cm, respectively) and the shortest plant was produced from the control treatment at 40 and 50 DAT and application of Zn @ 4.0 kg ha^{-1} at 60, 70 and 80 DAT. But there is a report that described that plant height of tomato was increased by the foliar application of micronutrients [13].

The application of Zn did not significantly affect the number of leaves, branches and flower clusters $plant^{-1}$ at different DATs with few exceptions (at 60 and 80 DAT for leaves; 30 and 75 DATs for branches, and 40 and 80 DATs for flower clusters) (Table 1). The maximum number of leaves $plant^{-1}$ was recorded (9.77, 11.77, 21.11, 24.77 and 57.00 at 30, 40, 60, 70 and 80 DAT, respectively) by the application of Zn @ 6.0 kg ha^{-1} (Table 1). On the other hand, the minimum number of leaves $plant^{-1}$ was recorded from the control treatment at all cases except 80 DAT. The maximum number of branches $plant^{-1}$ (1.11) was obtained by the application of Zn @ 8.0 kg ha^{-1} at 30 DAT and the minimum number of branches $plant^{-1}$ was recorded from the control treatment at 30, 45 and 60 DAT. The branches of

Table 1. Effect of different doses of Zn on different growth attributes of tomato

Treatments	Plant height (cm)						Number of leaves plant^{-1}						Number of branches plant^{-1}			
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	30 DAT	45 DAT	60 DAT	75 DAT
Zn_0	35.55	52.55	68.22	76.44	83.77	90.66	8.55	10.66	13.33	17.11b	24.22	52.00ab	0.33b	4.22	5.33	7.77a
Zn_4	36.88	57.11	70.22	74.88	81.77	88.22	9.77	11.22	15.22	20.22a	24.66	45.33b	1.00ab	4.44	5.44	6.88ab
Zn_6	34.00	54.66	71.11	76.44	83.88	89.33	9.77	11.77	14.88	21.11a	24.77	57.00a	0.88ab	4.33	5.77	7.00ab
Zn_8	36.00	57.66	74.88	79.66	88.11	92.66	9.44	11.44	15.44	19.89ab	24.66	47.88ab	1.11a	4.44	5.33	6.22b
$LSD_{(0.05)}$	-	-	-	-	-	-	-	-	-	2.78	-	9.64	0.69	-	-	1.24
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	**	**	NS	NS	**
CV%	15.41	16.41	13.27	12.05	11.35	10.97	13.93	12.63	15.73	14.56	18.12	19.52	85.49	28.97	21.91	18.29

*NS = not significant; ** means significant at 1% level of probability*

Table 2. Effect of different doses of Zn on different yield attributes and yield of tomato

Treatments	Number of flower cluster plant^{-1}						Fruit length (cm)	Fruit diameter (cm)	Number of fruits plant^{-1}	Fruit yield plant^{-1} (g)
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT				
Zn_0	1.11	2.66b	6.88	8.33	13.66	11.33b	3.64b	4.59b	15.66	546b
Zn_4	1.44	3.55ab	7.33	9.11	12.55	18.22a	3.90a	5.07a	19.00	722a
Zn_6	0.88	3.33ab	5.66	8.44	13.55	17.11a	3.88a	4.93ab	18.66	641ab
Zn_8	1.11	4.66a	7.33	9.11	11.77	15.11a	3.68b	4.89ab	17.50	604ab
$LSD_{(0.05)}$	-	1.83	-	-	-	3.43	0.15	0.39	-	166.75
Level of significance	NS	**	NS	NS	NS	**	**	**	NS	**
CV%	86.35	52.71	44.65	38.46	31.66	22.74	4.25	8.24	22.68	0.65

*NS = not significant; ** means significant at 1% level of probability* tomato plant were increased by the application of Zn [14].

The maximum number of flower clusters plant^{-1} were recorded at 30, 50, 60 and 80 DATs by the application of Zn @ 4.0 kg ha^{-1} (Table 2). On the other hand, the minimum number of flower clusters plant^{-1} was recorded from the control treatment at 40, 60 and 80 DATs. Fruit length of tomato was highly influenced by the application of Zn. The highest fruit length of tomato was recorded from the application of Zn @ 4.0 kg ha^{-1} and the lowest fruit length was obtained from the control treatment (Table 2). Fruit diameter of tomato varied significantly due to the application of different levels of Zn. The highest diameter of fruit was obtained from the application of Zn @ 4.0 kg ha^{-1}, which was statistically at par with the use of Zn @ 6.0 and 8.0 kg ha^{-1}. The lowest diameter of fruit was recorded from the control treatment. But number of fruits plant^{-1} was not affected significantly by the application of different levels of Zn (Table 2). The maximum number of fruits was obtained from the application of Zn @ 4.0 kg ha^{-1} while the minimum number of fruits was obtained from the control treatment. Zinc increases the number of fruits plant^{-1} by increasing IAA synthesis as well as carbohydrates translocation [15-16]. However, the fruit yield of tomato was significantly affected by the application of different doses of Zn. The average yield of tomato varied from 546-722 g plant^{-1} due to application of different doses of Zn. The highest fruit yield was recorded from the application of Zn @ 4.0 kg ha^{-1} treatment which was statistically similar to Zn @ 6.0 and 8.0 kg ha^{-1} treatments whereas the lowest yield was obtained from the control treatment (Table 2).

3.2 Effect of B on Growth and Yield of Tomato

Effect of different doses of B has significant impact on plant height of tomato (Table 3). Application of B @ 3.0 kg ha^{-1} produced the longest plant at 60, 70 and 80 DATs, although at the initial stage of plant growth, the tallest plant was recorded from the application of B @ 2.0 kg ha^{-1}. However, the shortest plant at all DATs was obtained from the control treatment. Boron in the form of boric acid (H_3BO_3) @300 ppm increased the plant height of tomato [17].

Effect of different doses of B on the number of leaves, branches and flower clusters plant^{-1} of tomato was statistically significant at most of the observations with a few exceptions (Table 3). The highest number of leaves plant^{-1} was recorded from the control treatment at 80 DAT, whereas application of B @ 3.0 kg ha^{-1} produced the highest number of leaves plant^{-1} at 40 and 50 DATs. However, the lowest number of leaves plant^{-1} at the later stage of growth was obtained from the application of B @ 2.0 kg ha^{-1} and at the earlier stage of growth it was obtained from the control treatment. The number of leaves increased by the application of 2.0 kg B ha^{-1} [18]. The highest number of branches plant^{-1} was recorded from the treatment B @ 2.0 kg ha^{-1} at 30 DAT. But at the maturity, the highest number of branches plant^{-1} was obtained from the control treatment, which was statistically similar with B @ 2.0 kg ha^{-1} treatment. The number of branches plant^{-1} increased by the application of boron [19].

The highest number of flower clusters plant^{-1} was recorded from the application of B @ 2.0 kg ha^{-1} and the lowest number was produced from the control treatment at all DATs (Table 4). Application of B @ 2.0 ppm increased the number of leaves and number of flowers, and increase in these two factors might have caused to increase the number of fruits in tomato [20]. The application of different levels of B expressively affected the fruit length, diameter, number of fruits and yield of tomato (Table 4). The highest fruit length and diameter were obtained from the application of B @ 2.0 kg ha^{-1} and the lowest fruit length and diameter were obtained from the control treatment. The mean number of fruits plant^{-1} of tomato ranged from 15.66-23.33. The maximum number of fruits was recorded from the application of B @ 3.0 kg ha^{-1} and the minimum number of fruits was obtained from the control treatment. Boron regulates the metabolism of carbohydrates and increase carbohydrate supply for formation of flowers and fruit set in tomato as well as decrease flower abscission. The application of different doses of B markedly affected the fruit yield of tomato [21-23]. The highest fruit yield of tomato was recorded from the application of B @ 3.0 kg ha^{-1}, which was statistically similar to the treatment B @ 2.0 kg ha^{-1} and the lowest fruit yield was recorded from the control treatment (Table 4).

3.3 Interaction Effect of Zn and B on Growth and Yield of Tomato

The interaction effects of different doses of Zn and B on plant height of tomato at different DATs are presented in Table 5. There were no significant variations among the treatments at

Table 3. Effect of different doses of B on different growth attributes of tomato

Treatments	Plant height (cm)						Number of leaves plant^{-1}						Number of branches plant^{-1}			
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	30 DAT	45 DAT	60 DAT	75 DAT
B_0	19.75b	35.75b	52.75b	59.83b	72.83b	83.83b	8.25b	10.16b	14.50	22.00a	27.58a	60.08a	0.17b	4.08	5.83	7.66a
B_2	44.00a	66.50a	81.83a	84.83a	88.75a	92.00ab	10.41a	11.75a	14.66	18.58b	23.00b	41.66b	1.42a	4.83	5.25	6.75ab
B_3	43.08a	64.25a	78.75a	85.91a	91.58a	94.83a	9.50a	11.91a	15.00	18.16b	23.16b	49.91b	0.92a	4.16	5.33	6.50b
$LSD_{(0.05)}$	4.64	7.70	7.99	7.83	8.11	8.37	1.10	1.20	-	2.41	3.77	8.35	0.60	-	-	1.07
Level of significance	**	**	**	**	**	**	**	**	NS	**	**	**	**	NS	NS	**
CV%	15.41	16.41	13.27	12.05	11.35	10.97	13.93	12.63	15.73	14.56	18.12	19.52	85.49	28.97	21.91	18.29

*NS = not significant; ** means significant at 1% level of probability*

Table 4. Effect of different doses of B on different yield attributes and yield of tomato

Treatments	Number of flower cluster plant^{-1}						Fruit length (cm)	Fruit diameter (cm)	Number of fruits plant^{-1}	Fruit yield plant^{-1} (g)
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT				
B_0	0.25b	1.75b	4.91b	7.33	11.41	13.50b	3.64b	4.59b	15.66b	546b
B_2	1.75a	4.83a	8.25a	9.83	14.33	18.75a	4.27a	5.29a	20.33ab	810a
B_3	1.41a	4.08a	7.25ab	9.08	12.91	14.08b	4.18a	5.23a	23.33a	921a
$LSD_{(0.05)}$	0.83	1.58	2.57	-	-	2.97	0.13	0.34	3.69	144.41
Level of significance	**	**	**	NS	NS	**	**	**	**	**
CV%	86.35	52.71	44.65	38.46	31.66	22.74	4.25	8.24	22.68	0.65

*NS = not significant; ** means significant at 1% level of probability*

Table 5. Interaction effect of different levels of Zn and B on different growth attributes of tomato at different Days after Transplanting (DAT)

Treatment interactions	Plant height (cm)						Number of leaves plant^{-1}						Number of branches plant^{-1}			
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	30 DAT	45 DAT	60 DAT	75 DAT
$Zn_0 \times B_0$	17.66	33.66	49.00	57.33	67.33	80.67	6.33	9.00	12.33	17.33	24.66	59.66	0.00	3.00	4.00c	7.00
$Zn_4 \times B_0$	41.66	59.00	78.00	80.66	87.33	91.00	10.00	11.33	12.66	16.33	25.00	49.33	0.33	5.33	6.33ab	9.00
$Zn_6 \times B_0$	47.33	65.00	77.66	91.33	96.66	100.33	9.33	11.66	15.00	17.66	23.00	47.00	0.66	4.33	5.66abc	7.33
$Zn_8 \times B_0$	21.66	39.33	54.33	60.00	69.00	83.33	8.33	10.33	16.00	23.00	29.33	51.66	0.33	4.33	6.00abc	7.66
$Zn_0 \times B_2$	45.00	69.00	85.00	88.33	93.00	93.33	10.66	11.33	14.66	21.00	24.66	36.00	2.00	5.00	5.66abc	6.66
$Zn_4 \times B_2$	21.66	38.33	56.33	63.00	77.66	86.33	8.66	10.00	14.00	25.33	29.66	62.66	0.00	4.66	7.00a	8.00
$Zn_6 \times B_2$	38.33	62.66	85.66	92.00	97.66	101.33	9.66	12.66	14.33	19.33	22.00	53.66	0.66	4.00	6.00abc	7.33
$Zn_8 \times B_2$	47.33	75.00	93.00	96.00	98.33	103.33	10.00	11.66	15.00	18.33	20.00	26.66	1.33	4.66	4.66bc	5.66
$Zn_0 \times B_3$	44.00	64.66	71.33	76.33	83.33	88.00	10.33	12.00	15.66	16.66	20.33	48.33	0.66	4.00	4.66bc	6.33
$Zn_4 \times B_3$	42.00	63.00	71.33	74.33	76.33	80.33	11.00	12.66	16.33	18.66	22.33	54.66	2.00	4.33	4.33bc	5.66
$Zn_6 \times B_3$	18.00	31.66	51.33	59.00	77.33	85.00	9.66	11.33	15.66	22.33	26.66	66.33	0.33	4.33	6.33ab	8.00
$Zn_8 \times B_3$	42.66	64.66	80.33	84.00	88.66	89.67	8.66	11.33	15.00	19.00	27.33	50.66	1.66	4.33	5.00abc	5.00
$LSD_{(0.05)}$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.02	-
Level of significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
CV%	15.41	16.41	13.27	12.05	11.35	10.97	13.93	12.63	15.73	14.56	18.12	19.52	85.49	28.97	21.91	18.29

*NS = not significant; * means significant at 5% level of probability*

Table 6. Interaction effect of different levels of Zn and B on yield and different yield attributes of tomato

Treatment interactions	Number of flower cluster plant^{-1}						Fruit length (cm)	Fruit diameter (cm)	Number of fruits plant^{-1}	Fruit yield plant^{-1} (g)
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT				
$Zn_0 \times B_0$	0.33	2.33	5.66	6.33	14.66	8.66de	3.35d	4.86	15.66	547j
$Zn_4 \times B_0$	1.33	3.66	7.33	8.33	12.66	18.66abc	4.27a	5.30	23.33	921b
$Zn_6 \times B_0$	1.66	4.00	7.66	10.33	13.66	14.66bc	4.08a	5.06	19.00	810e
$Zn_8 \times B_0$	0.33	2.00	5.66	8.33	14.66	14.00bcd	3.42d	4.91	18.33	623h
$Zn_0 \times B_2$	2.00	4.33	10.66	12.00	13.33	16.33bc	3.59cd	4.33	15.33	642g
$Zn_4 \times B_2$	1.33	3.66	7.66	11.00	15.00	23.33a	4.18a	5.42	22.00	1057a
$Zn_6 \times B_2$	0.33	2.00	5.33	7.33	13.66	18.00abc	3.77bc	5.18	21.00	814e
$Zn_8 \times B_2$	1.33	6.33	7.00	8.00	7.66	15.66bc	3.75c	4.39	15.33	721f
$Zn_0 \times B_3$	2.00	4.33	5.66	7.00	9.66	15.00bc	3.36d	4.52	17.00	605i
$Zn_4 \times B_3$	2.33	5.00	8.00	11.00	12.00	18.00abc	4.03ab	5.05	23.33	906c
$Zn_6 \times B_3$	0.33	1.66	4.66	7.66	13.00	19.66ab	3.80bc	4.76	22.00	834d
$Zn_8 \times B_3$	1.66	6.00	10.33	11.66	14.66	13.33cd	3.70c	4.73	18.66	827d
$LSD_{(0.05)}$	-	-	-	-	-	5.94	0.27	-	-	8.56
Level of significance	NS	NS	NS	NS	NS	**	**	NS	NS	**
CV%	86.35	52.71	44.65	38.46	31.66	22.74	4.25	8.24	22.68	0.65

*NS = not significant; ** means significant at 1% level of probability*

different observations except number of branches plant^{-1} at 60 DAT. The tallest plant was recorded from combined application of Zn @ 8.0 kg ha^{-1} and B @ 2.0 kg ha^{-1} at all observation dates followed by the application of Zn @ 6.0 kg ha^{-1} and B @ 2.0 kg ha^{-1} at 50, 60, 70 and 80 DATs. On the other hand, control treated plants produced the shortest plant at 50, 60, 70 and 80 DATs. Zinc helps in auxin synthesis and in association with boron helps cell wall development and cell differentiation of plants [19].

The interaction effects of different doses of Zn and B on number of leaves and branches plant^{-1} of tomato were also insignificant at different DATs (Table 5). The highest number of leaves plant^{-1} was recorded from the combined application of Zn @ 6.0 kg ha^{-1} and B @ 3.0 kg ha^{-1} at 80 DAT. On the other hand, the combined application of Zn @ 8.0 kg ha^{-1} and B @ 2.0 kg ha^{-1} produced a minimum number of leaves plant^{-1} at 70 and 80 DATs, while at the earlier stage of growth it was obtained from the control treatment. It is reported that the number of leaves increased due to combined foliar application of Zn and B [16]. The highest number of branches plant^{-1} was recorded from the application of Zn @ 4.0 kg ha^{-1} without B at 75 DAT followed by the combined application of Zn @ 4.0 kg ha^{-1} and B @ 2.0 kg ha^{-1} and combined application of Zn @ 6.0 kg ha^{-1} and B @ 3.0 kg ha^{-1}. On the other hand, control treatment produced the minimum number of branches plant^{-1} at 30, 45 and 60 DATs but at 75 DAT the lowest number of branches plant^{-1} was obtained from the application of Zn @ 8.0 kg ha^{-1} and B @ 3.0 kg ha^{-1}. Micronutrients mixture with Zn, Fe and B increased the number of branches plant^{-1} [24].

There were no significant variations among the Zn and B interactions on the number of flower clusters plant^{-1} of tomato at different observations except at 80 DAT and the results are presented in Table 6. The highest number of flower clusters plant^{-1} was recorded from the combined application of Zn @ 4.0 kg ha^{-1} and B @ 2.0 kg ha^{-1} followed by the combined application of Zn @ 6.0 kg ha^{-1} and B @ 3.0 kg ha^{-1} at 80 DAT. On the other hand, control treatment produced the minimum number of flower clusters plant^{-1} followed by Zn @ 8.0 kg ha^{-1} and B @ 3.0 kg ha^{-1}. It is also evident from Table 6 that numbers of flower clusters plant^{-1} of tomato were lower at 80 DAT than 70 DAT in some treatments, due to some flower clusters dropped out.

Interaction effect of Zn and B on the fruit length of tomato was also statistically significant. The average fruit length of tomato varied from 3.35 to 4.27 cm (Table 6). The highest fruit length was obtained from the application of Zn @ 4.0 kg ha^{-1}

without B which was statistically at par with the combined application of Zn @ 4.0 kg ha^{-1} and B @ 2.0 kg ha^{-1}, and application of Zn @ 6.0 kg ha^{-1} without B. On the other hand, the lowest fruit length was obtained from the control treatment. The length of fruit was significantly increased by the application of Zn and B by improving cell size or cell number [25-26].

Number of fruits $plant^{-1}$ and fruit diameter of tomato did not vary significantly by the combined application of different levels of Zn and B (Table 6). The average number of fruits $plant^{-1}$ of tomato ranged between 15.33 to 23.33 due to interaction of different levels of Zn and B. The maximum number of fruits $plant^{-1}$ was obtained from combined application of Zn @ 4.0 kg ha^{-1} without B and combined application of Zn @ 4.0 kg ha^{-1} and B @ 3.0 kg ha^{-1} treatments while the minimum number of fruits $plant^{-1}$ was obtained from the combined application of Zn @ 8.0 kg ha^{-1} and B @ 2.0 kg ha^{-1}. The combined application of Zn and B increased the number of fruits $plant^{-1}$ in tomato [27]. The average diameter of the fruit ranged from 4.33 to 5.42 cm. The highest fruit diameter of tomato was obtained from combined application of Zn @ 4.0 kg ha^{-1} and B @ 2.0 kg ha^{-1}. The lowest fruit diameter was obtained from combined application of B @ 2.0 kg ha^{-1} without Zn (Table 6). But the interaction effect of different levels of Zn and B on fruit yield of tomato was statistically significant (Table 6). The average fruit yield of tomato ranged from 547-1057 g $plant^{-1}$ due to interaction of different levels of Zn and B. The highest fruit yield of tomato was obtained from combined application of Zn @ 4.0 kg ha^{-1} and B @ 2.0 kg ha^{-1}. On the other hand, the lowest fruit yield was obtained from control treatment.

4. CONCLUSION

Application of micronutrients particularly Zn and B play an important role to boost up tomato production in micronutrient deficient areas of Bangladesh. It can be summarized from the present study that combined application of Zn and B, @ 4.0 and 2.0 kg ha^{-1}, respectively has a significant positive effect on growth and yield of tomato fruits. However, there were some inconsistencies in results, particularly for the application of different levels of Zn, which might be due to its content in soils, environmental factors and different management practices. Furthermore, Zn and B fertilizers recommendation in future should be site, location and variety specific.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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