

EFFECTIVENESS OF SOIL AND FOLIAR APPLICATIONS OF ZINC AND BORON ON THE YIELD OF TOMATO

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Abstract

Field experiment was carried out for two consecutive years to study the effectiveness of soil and foliar application of micronutrients on the yield of tomato (*Lycopersicon esculentum* Mill.) at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The micronutrients zinc (Zn) in the form of zinc sulphate ($ZnSO_4 \cdot 7H_2O$) at the rate of 0.05 % and boron (B) in the form of boric acid (H_3BO_3) at the rate of 0.03% were applied as foliar spray at three different stages of plant growth i.e (i) before flower initiation; (ii) after fruit set when it becomes approximately marble sized; and (iii) at 20 days interval of second spray. The tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers. Among various treatments, foliar application of Zn (0.05 %) + B (0.03%) produced maximum fruit yield (85.5 and 81.7 t ha⁻¹ in 2013 and 2014, respectively) while the control no application of Zn (0.0) and B (0.0) produced 66.8 and 60.7 t ha⁻¹ in 2013 and 2014, respectively and it was statistically identical with soil application of B and Zn @ 2 and 6 kg ha⁻¹ (T₅), respectively. The increment of yield was 19.2 to 31.1% and 7.57 to 18.3%, respectively, over control and soil application. The integrated use of foliar application of micronutrients and soil application of macronutrients are recommended to enhance tomato yield.

Keywords: Foliar applications, zinc, boron, tomato and yield.

Introduction

Micronutrient deficiencies are not only hampering crop productivity but also are deteriorating quality. The low micronutrient feed and food stuffs are causing health hazards in human beings and animals. Micronutrient acts as catalyst in the uptake and use of certain macronutrients (Phillips, 2004). Fruit size and quality as well as quality of some crops, are improved with micronutrient (Zn and B) use.

Tomato (*Lycopersicon esculentum* Mill.) is an important vegetable crop, which belongs to the family Solanaceae and also used in daily diet due to its good taste. The yield of tomato has declined due to micronutrient deficiency (Ejaz *et al.*, 2011). Excess use of phosphate fertilizers in soils with micronutrients

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deficiencies is causing imposed deficiency of micronutrients in the plants (Salimpour *et al.*, 2010; Khorgamy and Farnis, 2009; Hopkins and Ellsworth, 2003). With increasing utilization of chemical fertilizer environmental pollution has increased remarkably.

In spite of adequate application of NPK fertilizer, normal growth of high yielding varieties could not be obtained due to little or no application of micronutrients. High fertilizer responsive varieties express their full yield potential when trace elements are applied along with NPK fertilizers (Nataraja *et al.*, 2006). Chaudry *et al.* (2007) stated that micronutrients especially zinc (Zn) and boron (B) significantly increased the crop yield over control when applied single or in combination with each other, while Mandal *et al.* (2007) observed significant positive interaction between fertilizer treatments and physiological stages of crop growth. Considering the aforementioned facts, it is felt necessary to study the factors responsible for fertilizer efficiency improvement.

Keeping in view the key role played by Zn and B nutrition in plant growth, this study is designed to find out the suitable dose and method of Zn and B application for tomato production. The objectives of this research, therefore, were (i) to identify a suitable combination of Zn and B fertilization for tomato production; and (ii) to compare the effects of the methods of micronutrient application foliar vs. soil fertilization on yield of tomato.

Materials and Method

Field research was conducted at micronutrient experimental field of Soil Science Division, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, located at 23°59'26" N and 90°24'52" E. The experiment was laid out in a RCB design with three replications. The unit plot was 3 m × 3 m. Two adjacent unit plots were separated by 75 cm and 1m space was given between the blocks. Land was separated into two parts viz., a. Foliar application and b. Soil application. Part (a) consisted of 12 unit plots and (b) part consisted of 3 unit plots. During final land preparation on November 2013 and 2014, fertilizers were applied to the soil at the rate of N₁₄₀, P₄₅, K₉₀ and S₁₈ kg ha⁻¹ as urea, triple super phosphate, muriate of potash and gypsum, respectively, in both (a) and (b) applications plot. For soil fertilization, at the same time B and Zn were applied at the rates of 2 and 6 kg ha⁻¹ in soil application part (b). BARI Tomato 15 was used in this experiment. Healthy and uniform sized 30 days old seedlings were transplanted at 60 cm × 50 cm spacing and total plant per plot was 30. Inter cultural operations were done as and when needed.

Foliar application

To study the effect of Zn and B as foliar spray on growth and yield of tomato, two micronutrients Zn and B at a single rate alone and at different combinations

in the form of zinc sulphate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$) containing 23 % Zn at the rate of 0.05 % and boric acid (H_3BO_3) having 18 % boron at the rate of 0.03 % were applied as foliar spray at three different stages of plant growth (i) before flower initiation; (ii) after fruit set when it becomes approximately marble sized; and (iii) at 20 days interval of second spray. The treatment combinations of foliar spray of Zn and B were T_1 : Zn (0.0 %) + B (0.0%) as control; T_2 : Zn (0.05 %) + B (0.0%); T_3 : Zn (0.0 %) + B (0.03%); and T_4 : Zn (0.05 %) + B (0.03%). Soil fertilization treated as T_5 : Zn (6) and B (2) kg ha^{-1} was applied basal as stated above.

The solution of all treatments were prepared and contained urea at the rate of 0.08 % to activate mineral absorption and surf (detergent) used as wetting agent at the rate of 0.01 % for reducing contact angle between the liquid and leaf surface (Sajid *et al.*, 2010). The volume of water 1.0 liter plant^{-1} was estimated (3 split at three different stages of plant growth viz., 300 ml + 300 ml + 400 ml of solution, approximate) to wet completely the tomato plant. The spray solution was prepared separately on the basis of 2.17 mg and 1.67 mg of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ and H_3BO_3 in 1.0 liter of water, respectively. Urea at the rate of 1.74 mg and surf 0.1 mg liter^{-1} as a wetting agent were applied along with each treatment. The foliar spray contained Zn (0.05%) and B (0.03%), amended with surfactant to curtail water desertion during the spray process, to ensure the nutrients adhered to the leaf surface, and to maximize uptake by foliage. Data were collected on fruit diameter, fruit height, individual fruit weight and fruit yield of tomato and recorded data were analyzed statistically and means were compared by Tukey's multiple comparisons test using Excel Statistics version 4.0 (Esumi Co. Ltd., Tokyo, Japan).

To compare different treatments combination with control/soil application treatment the following equation was applied (Rhaman *et al.*, 2011).

$$\begin{aligned} \text{MBCR (Over control)} &= \frac{\text{Gross return (T}_1\text{)} - \text{Gross return (T}_0\text{)}}{\text{VC (T}_1\text{)} - \text{VC (T}_0\text{)}} \\ &= \frac{\text{Added benefit (over control)}}{\text{Added cost (over control)}} \end{aligned}$$

Where, $T_1 = T_1, T_2, T_4, T_5$ treatments; $T_0 =$ Control treatment; VC = Variable cost; and Gross return = Yield \times price.

Methods of chemical analysis of soil

Initial soil samples collected from 0-15 cm depth prior to fertilizer application, were analyzed for all important soil parameters using standard procedures (Table 1). Soil pH was measured by a combined glass calomel electrode. Organic carbon was determined by the wet oxidation method. Total N was determined by a modified Kjeldahl method. Calcium (Ca), magnesium (Mg) and K were

determined by NH_4OAc extractable method, copper (Cu), iron (Fe) and zinc (Zn) were determined by DTPA extraction followed by AAS reading. Boron (B) was determined by CaCl_2 extraction method. Available P was determined by the Bray and Kurtz method while S was determined using the turbidimetric method with BaCl_2 .

Results and discussion

Experimental field soil was neutral in reaction pH (7.08), low in organic matter (1.09%), total nitrogen content (0.06%) and exchangeable potassium (0.08 meq 100g), however quite high in available phosphorus ($15.1 \mu\text{g g}^{-1}$). The status of B ($0.13 \mu\text{g g}^{-1}$) was below the critical level and Zn ($2.60 \mu\text{g g}^{-1}$) was higher than the critical level (Table 1). In general terrace soil (Chiata Series) of Joydebpur is acidic in nature. But the soil of experimental field does not belong to terrace soil. Soil development in this experimental field has been made with river-bed soil from the nearby areas.

Table 1. Initial properties of the soil samples of experimental field

Soil Properties	pH	OM %	Ca	Mg	K	Total N %	P	S	B	Cu	Fe	Zn
			meq 100g ⁻¹				$\mu\text{g g}^{-1}$					
Result [§]	7.08	1.09	6.88	2.26	0.08	0.06	15.1	3.33	0.13	2.01	11.2	2.60
Critical level	-	-	2.0	0.5	0.12	-	10	10	0.2	0.2	4.0	0.6

The tomato yield and its contributing yield traits were significantly affected by foliar fertilizer treatments as against soil application of B and Zn fertilizers, as depicted by the significance of F-values from the analysis of variance (Tables 2 and 3). A significant variation was observed for tomato yield when the plants treated with foliar application of Zn and B alone or either in combinations. Maximum yield (85.5 and 81.7 t ha⁻¹ in 2013 and 2014, respectively) was produced, when plants were treated with 0.05% of Zn in combination with 0.03% of B, followed by plants sprayed with 0.05% of Zn alone (84.3.1 and 76.8 t ha⁻¹ in 2013 and 2014, respectively). Minimum fruit yield (66.8 and 60.7 t ha⁻¹ in 2013 and 2014, respectively) was produced by untreated plants - control. Comparatively lower yield was recorded in plants which sprayed with 0.03% of B alone than that of plants sprayed with 0.05% Zn. Soil of this experiment is neutral and content of Zn was $2.6 \mu\text{g g}^{-1}$, which was higher than the critical limit. But due to neutrality Zn is unavailable to uptake by plant. For that reason, only B application did not help maximize the yield of tomato. Mousavi (2011) reported that soils with high pH, in this type of soils solubility of micronutrients except B is less and cause decline uptake of these elements by plant. On the other hand, higher yield in treatment sprayed with 0.05% Zn alone, perhaps these increases in fruit yields were due to the significant increase in leaf Zn concentration which in turn induced more

flowering and minimized the fruit drop in tomato plant (Garcia *et al.* 1984). Higher yield in foliar application of Zn without B application might be due to foliar application of zinc increased B uptake by plants in the soils with sufficient stores (Rengel *et al.*, 1998). The supply of B needed for reproductive growth in many crops is more needed than that needed for vegetative growth (Mengel and Kirkby, 1982; Marschner, 1986; Hanson, 1991).

Table 2. Agronomic traits of tomato as affected by foliar and soil application of Zn and B during 2013

Treatment	Agronomic traits			Fruit yield	
	Fruit diameter (cm)	Fruit height (cm)	Individual fruit wt. (g)	Yield (kg plot ⁻¹)*	Yield (t ha ⁻¹)
1. Zn (0.0) + B (0.0) – control	4.18±0.26c	5.07±0.32c	55.8±10.2c	60.1±8.72c	66.8±9.68c
2. Zn (0.05 %) + B (0.0%) foliar application	4.59±0.19ab	5.32±0.26b	65.6±5.09ab	75.9±10.7a	84.3±11.9a
3. Zn (0.0 %) + B (0.03%) foliar application	4.44±0.45ab	5.29±0.28bc	60.9±8.62bc	72.1±10.1ab	80.1±11.3ab
4. Zn (0.05 %) + B (0.03%) foliar application	4.68±0.19a	5.41±0.18a	68.5±6.26a	77.0±11.5a	85.5±12.8a
5. Zn (6) + B (2) soil application (kg ha ⁻¹)	4.37±0.22b	5.18±0.61bc	59.3±6.03bc	67.4±7.07bc	74.9±7.9bc
CV (%)	4.96	7.06	12.1	14.7	-

Mean values in the same column followed by the same letters are not significantly different ($P < 0.05$). * Plot size: 9 m².

Plants sprayed with Zn in combination with B or alone Zn showed maximum response in fruit diameter, fruit height and individual fruit weight compared with control and soil application of both elements. Gitte *et al.* (2005) observed that the combined application of Zn and B exhibited yield increases over unfertilized controls. The data given in Table 2 indicated that micronutrient and their foliar doses had significant effect on fruit yield of tomato. Among various treatments, foliar application of Zn (0.05 %) + B (0.03%) (T₄) produced maximum grain yield (81.3 t ha⁻¹) while the control (T₁) no use of Zn (0.0) and B (0.0) produced 63.6 t ha⁻¹. And T₄ was statistically differed with soil application of B and Zn @ 2 and 6 kg ha⁻¹ (T₅), respectively. The foliar application of Zn in combination with B and Zn alone was more effective than the soil application of both fertilizers. When compared the fruit yield from control or soil application plot with foliar applications the increment of yield were 19.2 to 31.1% and 7.57 to 18.3%, respectively, over

control and soil application (Table 4). The maximum marginal benefit-cost ratio (MBCR) of 211 was obtained by application of Zn in combination with B followed by Zn alone (181) which are almost on par at each other compared to control which recorded minimum gross returns of Tk. 957000 ha⁻¹.

Table 3. Agronomic traits of tomato as affected by foliar and soil application of Zn and B during 2014

Treatment	Agronomic traits			Fruit yield	
	Fruit diameter (cm)	Fruit height (cm)	Individual fruit wt. (g)	Yield* (kg plot ⁻¹)	Yield (t ha ⁻¹)
1. Zn (0.0) + B (0.0) – control	3.72±0.14b	4.26±0.32b	49.3±3.46b	54.6 ±2.12b	60.7±2.35b
2. Zn (0.05 %) + B (0.0%) foliar application	4.55±0.54a	5.09±0.41a	63.1±5.99a	69.1±6.64ab	76.8±7.38ab
3. Zn (0.0 %) + B (0.03%) foliar application	4.37±0.24ab	4.91±0.27ab	54.9±5.14b	64.7±2.52ab	71.9±2.80ab
4. Zn (0.05 %) + B (0.03%) foliar application	4.63±0.31a	5.17±0.34a	67.2±4.44a	73.5±8.68a	81.7±9.65a
5. Zn (6) + B (2) soil application (kg ha ⁻¹)	4.25±0.41ab	4.79±0.49ab	51.0±6.10b	59.8±4.89ab	66.4±5.44ab
CV (%)	6.64	5.90	5.86	9.42	-

Mean values in the column followed by the same letters are not significantly different ($P < 0.05$). * Plot size: 9 m²

Table 4. Yield comparison between foliar and soil application of Zn and B and their economics of two years average

Treatment	Fruit yield (t ha ⁻¹)	Yield increased (%)		Variable cost [§] (Tk ha ⁻¹)	Gross return (Tk ha ⁻¹)	MBCR	
		Over control	Over soil application			over control	over soil application
1. Zn (0.0) + B (0.0) – control	63.8	-	-10.8	14595	957000	-	(16.0)
2. Zn (0.05 %) + B (0.0%) foliar application	80.6	26.4	14.0	15988	1209000	181	-29.2
3. Zn (0.0 %) + B (0.03%) foliar application	76.0	19.2	7.57	15991	1140000	131	-15.7
4. Zn (0.05 %) + B (0.03%) foliar application	83.6	31.1	18.3	16004	1254000	211	-38.2
5. Zn (6) + B (2) soil application (kg ha ⁻¹)	70.7	10.8	-	21070	1060500	(16.0)	-

[§] Variable cost considering only fertilizer and wage rate

Input prices (Tk kg⁻¹): Urea: 16; TSP: 25; MoP: 15; Gypsum: 15; Zincsulphate: 140; Boric acid: 240.

Wage rate: 230 Tk

Out put price (Tk kg⁻¹): Tomato: 15

Conclusion

Foliar applications of micronutrients are more suitable than the soil application, due to the rapid overcoming on deficient, easy to use, reducing the toxicity caused by accumulation and preventing of elements stabilization in the soil. The integrated use of foliar application of micronutrients and soil application of macronutrients is recommended to enhance tomato yield. This paper also suggests that foliar application of micronutrients; particularly of Zn and B is an effective technology for increasing the yield of tomato.

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