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Effects of foliar application of boron and zinc and their combinations on the quality of tomato (*Lycopersicon esculentum* Mill.)

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Abstract:

An experiment was carried out to assess the effect of foliar application of boron, zinc and their combinations on the quality of tomato cv Thilina. This experiment was laid out in a completely randomized design (CRD) replicated eight times. The treatments consisted of T1-H_3BO_3 (150 ppm), T2- H_3BO_3 (250 ppm), T3- H_3BO_3 (350 ppm), T4- $ZnSO_4$ (150 ppm), T5-$ZnSO_4$ (250 ppm), T6-$ZnSO_4$ (350 ppm), T7- H_3BO_3 (150 ppm) + $ZnSO_4$ (150 ppm), T8- H_3BO_3 (250 ppm) + $ZnSO_4$ (250 ppm), T9- H_3BO_3 (350 ppm) + $ZnSO_4$ (350 ppm) and T10- Control.

The results of this study revealed that application of $ZnSO_4$ at the rate of 250 ppm enhanced the yield by two and a half fold than that of control. Application of H_3BO_3 at 250 ppm increased the pulp weight by two and a half fold than control. Combined application of H_3BO_3-350 ppm and $ZnSO_4$-350 ppm increased the acidity and ascorbic acid. Application of H_3BO_3 at the rate of 150 ppm increased the total soluble solids (TSS) whereas H_3BO_3 at 350 ppm increased the p^H of tomato fruits. Among the treatments, the lowest performance was recorded in the control treatment.

The results suggest that under conditions in this experiment, fresh weight of fruits/plant could be increased by two and a half fold *by the foliar application of $ZnSO_4$ at 250 ppm; combined application of H_3BO_3-350 ppm and $ZnSO_4$-350 ppm increased the acidity and ascorbic acid content respectively; H_3BO_3 -150ppm improved the TSS and H_3BO_3 - 350ppm increased the pH of tomato.*

Key words: Boron, zinc, quality, ppm, total soluble solids, ascorbic acids.

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important and widely grown vegetable plants across the world. It is the world's largest vegetable crop after potato in many countries and leading in the list of canned vegetables (Nathan and Quian, 2010). It is also considered as a condiment and find the place in our daily diet. They are rich in minerals, vitamins, essential amino acids, sugars and dietary fibres and contain ample amount of vitamin B and C, iron and phosphorus. In Sri Lanka, it is consumed as a green vegetable or cooked vegetable or as processed products such as canned tomato, sauce, juice, ketchup, stews and soup. There is considerable evidence to show that raw tomato and its products reduced the risk of cancer and cardiovascular diseases (Clinton, 1998 and Giovannucci *et al*., 2002) and this is attributed to the effect of antioxidant properties (Borguini and Torres, 2009). In Sri Lanka, the tomato is cultivated to an extent of 7916 ha with the production of 82,250 Mt/year. The average productivity is 10.39 Mt/ha (Department of census and statistics, 2012). In the Batticaloa district, tomato is grown to an area of about 51 ha with a total production of 315 Mt/ha (Department of census and statistics, 2012/13). However, the adverse environmental conditions such as high temperature that prevail in this area not only reduce the yield but also affect the quality of fruits. Young *et al*. (2003) reported that the tomatoes are susceptible to heat stress damage during the flowering stage owing to the influence of pollen development, anthesis and fertilization. Thus, these effects could be overcome by the application of nutrients.

Yield, fruit quality, fruit size, keeping quality, colour, and taste of tomato can be improved by the application of sufficient and right amount of nutrients (Shukla and Naik, 1993). Further, the tomato is a heavy feeder which requires adequate amounts of nutrients in order to get high yield (Padney and Chandra), and is a vegetable which response well to micronutrients. In addition, the micronutrients act as catalyst and enhance the chemical composition of fruits (Ranganathan and Perumal, 1995) and are also vital for the physiological activities within the plant (Abo-Hamad and El-Feky, 2014). Therefore, the role of these micronutrients are important to boost not only the productivity of the crop but also to improve the quality of fruits. Generally crops are fertilized with macro nutrients such as N, P, K. Normally farmers do not provide these micronutrients to plants, particularly during critical stages of crop growth. Thereby, yield and quality are reduced. One of the easiest ways of improving the quantity and quality of yields is by providing these micronutrients through the foliar application.

Globally, zinc has been identified as the foremost important micronutrient that limits the yield of crops. Zn has a great influence on cell division, nucleic acid metabolism and protein synthesis. It is a cofactor for above 300 enzyme (oxidases and peroxidases) and proteins (Marschner, 2012). A higher number of flowers and fruit set in tomato was due to the effect of various enzymatic activities and formation of indolecetic acid (IAA) by the zinc (Rawaa shakir shnain *et al.*, 2014). Foliar application of $ZnSO_4$ (0.1%) increased the seed yield and quality parameters in chili (Natesh *et al.*, 2005).

Boron is the second most important and essential micronutrient for many plant functions such as; maintaining a balance between sugar and starch, translocation of sugar and carbohydrates, pollen growth and elongation after pollination (Vaughan, 1977 and Blevins and Lukaszewski, 1998) and seed reproduction, normal cell division, nitrogen metabolism and protein formation, and cell wall formation (Ishii and Matsunaga 1996, O'Neill *et al*., 1996 and Kobayashi *et al*., 2004). It also plays a main role in the correct function of cell membranes and the transport of K+ to guard cells to the internal water balance control system (Goldbach *et al*., 2001, Yu *et al*., 2003, and Camacho-Cristóbal and Gonzalez-Fontes 2007). Lack of boron and zinc can affect the yield (Patil *et al*., 2008) and post-harvest storage quality of tomato (Passam *et al*., 2007).

Studies on boron and zinc would help to increase growth, yield and quality of tomato. To date, no systematic studies have been carried out to find out the effect of boron and zinc on the quality of tomato. Therefore, the present study was conducted in order to find out the effect of foliar application of boron and zinc on the quality of tomato in sandy regosols.

Materials and Methods

Pot experiment was conducted at the Crop Farm of the Eastern University of Sri Lanka (Latitude between 7^0 43' and 7^0 431/2' N and the Longitude between 81^0 42' and 81^0 43' E) during the period December 2013 to April 2014. The climatic condition of area is characterized by a mean annual rainfall ranging from 1600 mm to 2100 mm and the average temperature varies from 28^oC to 32^oC. The experimental site falls within the dry zone of Sri Lanka and DL2 agro-ecological zone.

The seedlings were transplanted in polybags at 30 days after planting using sand: red soil: rotted cow dung at the ratio of 1:1:1 (air dried). This experiment was laid out in completely randomized design (CRD) with eight (8) replicates. There were 10 treatments viz. T1-H_3BO_3 (150 ppm), T2-H_3BO_3 (250 ppm), T3-H_3BO_3 (350 ppm), T4- $ZnSO_4$ (150 ppm), T5-$ZnSO_4$ (250 ppm), T6-$ZnSO_4$ (350 ppm), T7-H_3BO_3 (150 ppm) + $ZnSO_4$ (150 ppm), T8-H_3BO_3 (250 ppm) + $ZnSO_4$ (250 ppm), T9-H_3BO_3 (350 ppm) + $ZnSO_4$ (350 ppm) and T10-Control. The cultivar used was Thilina, and the tomato plants were established and maintained in accordance with the Department of Agriculture, Sri Lanka (Department of Agriculture, 1990). The foliar applications were done thrice at 10 days intervals starting from 40 days after transplanting of seedlings. Data were statistically analyzed using SAS 9.1 and mean comparison was performed within treatments using Least Significant Difference at 5% significant level.

Results and Discussion

Fresh weight of fruits/ plant

The effect of foliar application on fresh weight of fruits is given in Table 1. It ranged from 126 g in the control to 321 g in H_3BO_3 at 150 ppm. At harvest, fresh weight of fruits/plant was significantly higher ($p<0.01$) when $ZnSO_4$ was applied at the rate of 250 ppm followed by 150 ppm of H_3BO_3, 250 ppm of H_3BO_3, 350 ppm of $ZnSO_4$ and combined application of 350 ppm (H_3BO_3 + $ZnSO_4$), and lowest fresh weight of fruits/ plant was recorded in control treatment (Table 1). This might be due to the fact that boron and zinc involved in the division and expansion of cells, and improved the volume of intercellular space in mesocarpic cells in addition to quicker translocation of metabolites into the sink (fruits) (Brahmachari *et al*., 2001) and effect of zinc, which is necessary for the carbonic enzyme that is present in all photosynthetic tissues, and needed for chlorophyll biosynthesis, thus increased the translocation of photosynthetic assimilates in fruits (Ali *et al.,* 2008). Mahnaz Abdollahi *et al.* (2010) reported that higher fresh weight of fruits/plant was recorded in strawberry at the foliar application of 100 ppm of $ZnSO_4$, which is two and a half times lesser than the level used in this study. Similar finding was documented in chilli at the rate of 5000 ppm of $ZnSO_4$ by Muhammad Waseem Kalroo *et al.*

(2013), which is twenty times (20) higher than the concentration used in this study.

Table 1: Effect of foliar application of B and Zn on fresh weight of fruits/plant

Treatments	**Fresh weight of fruits**
T1- H_3BO_3 (150 ppm)	320.52 ^{b}
T2- H_3BO_3 (250 ppm)	311.00 ^{b}
T3- H_3BO_3 (350 ppm)	420.67 ^{ab}
T4- $ZnSO_4$ (150 ppm)	289.06 ^{bc}
T5- $ZnSO_4$ (250 ppm)	599.17 ^{a}
T6- $ZnSO_4$ (350 ppm)	332.96 ^{b}
T7- H_3BO_3 (150 ppm)+$ZnSO_4$(150 ppm)	422.11 ^{ab}
T8- H_3BO_3 (250 ppm)+$ZnSO_4$(250 ppm)	295.87 ^{bc}
T9- H_3BO_3 (350 ppm)+$ZnSO_4$(350 ppm)	347.39 ^{b}
T0- Control	126.08 ^{c}
F test	0.0014
LSD	183.47

**Means followed by the same letter in each column are not significantly different to Least significant different at 5% level*

Fruit quality parameters

Pulp weight/ fruit

In canning industry, pulp weight is considered as a key quality parameter. At harvest, pulp weight/fruit was highest ($p< 0.01$) in the application of H_3BO_3 at the rate of 250 ppm, the lowest pulp weight/fruit was noticed with $ZnSO_4$ at 150 ppm and control (Table 2). This may be due to the accumulation of photosynthates in the sink (Salam *et al.*, 2011) and improvement in size and number of cells by B nutrient (Khayyat *et al.*, 2007). Application of H_3BO_3 at the rate of 1500 ppm in date palm resulted in greater pulp weight (Khayyat *et al.*, 2007), which was six (6) times greater than the rate used in this experiment.

Seed weight/ fruit

Boron had a significant ($p<0.01$) influence on seed weight/ fruit. The maximum seed weight/fruit was recorded ($p<0.01$) in the foliar application of H_3BO_3 at 250 ppm, followed by the $ZnSO_4$ application at 150 ppm, 250 ppm and 350 ppm. The minimum seeds weight/fruit were recorded with control (Table 2)**.** This may be attributed to the effect of boron on pollen germination and the development of the pollen tube, and greater production of fertilized ovules resulted in higher seeds per fruit (Nymora *et al.*, 2000**,** Sotomayor *et al.*, 2010 and Rawaa Shakir Shnain *et al.*, 2014). Naga Sivaiah *et al.* (2013) reported that the application of B at 100 ppm increased the seed yield in tomato which was two and a half times lesser than the rate of B used in this experiment.

Acidity of fruits

There were significant variations ($p<0.0001$) in acidity of fruits between treatments. In most of the treatments, application of H_3BO_3 and $ZnSO_4$ increased the acidity (Table 3). Higher acidity of fruits was recorded at the concentration of combined application of H_3BO_3-350 ppm + $ZnSO_4$-350 ppm followed by, combined application of H_3BO_3-250 ppm and $ZnSO_4$-250 ppm. Lower acidity of fruits was recorded in control treatment (Table 3). Combined application of 6000 ppm $ZnSO_4$+5000 ppm H_3BO_3 increased the acidity of guava fruit due to higher synthesis of nucleic acids because

Table 2: Effect of foliar application of B and Zn on pulp weight and seed weight (g)

Treatment	Pulp weight/ fruit (g)	Seed weight/ fruit (g)
T1- B (150 ppm)	73.67 ^{ab}	1.99 ^{ab}
T2- B (250 ppm)	82.72 ^{a}	2.32 ^{a}
T3- B (350 ppm)	73.74 ^{ab}	1.81 ^{ab}
T4- Zn (150 ppm)	61.92 ^{c}	1.33 ^{b}
T5- Zn (250 ppm)	73.24 ^{ab}	1.44 ^{b}
T6- Zn (350 ppm)	71.92 ^{abc}	1.27 ^{b}
T7- B(150 ppm)+Zn(150 ppm)	71.58 ^{bc}	1.65 ^{ab}

T8- B(250 ppm)+Zn(250 ppm)	67.22 bc	1.45 b
T9- B(350 ppm)+Zn(350 ppm)	74.76 ab	1.84 ab
T0- Control	61.94 c	0.43 c
F test	0.0131	0.0025
LSD	10.85	0.79

**Means followed by the same letter in each column are not significantly different to Least significant different at 5% level*

of maximum availability of plant metabolism (Nitin Trivedi *et al.*, 2012). However, in this experiment, maximum acidity of fruits was obtained from the combined application of 350 ppm (H_3BO_3 + $ZnSO_4$) in tomato plant, which was 17 times lesser than the rate used by Nitin Trivedi *et al.* (2012).

Ascorbic acid content of fruits

Foliar application of B and Zn had a significant effect ($p<0.0001$) on ascorbic acid content (Table 3). Maximum ascorbic acid content of fruits was obtained in plants receiving 350 ppm of (H_3BO_3 + $ZnSO_4$), followed by 250 ppm of (H_3BO_3 + $ZnSO_4$), minimum ascorbic acid content of fruits was recorded in control (Table 3). Combined application of 6000 ppm $ZnSO_4$ + 5000 ppm H_3BO_3 increased the ascorbic acid of guava fruit may be due to higher synthesis of nucleic acid as a consequence of maximum availability of plant metabolism (Nitin Trivedi *et al.*, 2012). The highest ascorbic acid content of tomato was obtained with the application of B 1250 ppm + Zn 1250 ppm (Rawaa Shakir Shnain *et al.*, 2014). However, in this experiment, combined application of H_3BO_3 + $ZnSO_4$ (350 ppm) increased the ascorbic acid content which was three and a half times lesser than that used by Rawaa Shakir Shnain *et al.* (2014).

Total Soluble Solid (TSS) content of fruits

There were remarkable differences ($p<0.0001$) observed in TSS between different application of B and Zn treatments. It ranged from 3.5 - 6 ^{0}brix. TSS content was highest at H_3BO_3 -150 ppm followed H_3BO_3 -250 ppm and $ZnSO_4$ - 250 ppm (Table 3).

Lowest TSS of fruits was recorded in 150 ppm of $ZnSO_4$, 350 ppm of $ZnSO_4$, 350 ppm of H_3BO_3+$ZnSO_4$ and control (Table 3). It was reported that activity of hydrolyzing enzyme was increased by the application of boron and zinc and resulted in increased breakdown of polysaccharides into simple sugars (Brahmachari and Rani, 2004). Higher TSS might be contributed to the efficient translocation of photosynthates to the fruit by the regulation of boron (Nitin Trivedi *et al*., 2012). Boron (H_3BO_3) is considered as a nutrient that increases the phloem carbohydrate movement, which may increase fruit soluble solid content (Marschner, 1995). This finding was in agreement with the studies done by Singh *et al*. (2004) who reported that the pre-harvest application of boron and zinc increased total soluble solids in guava fruits. Arvind Bhatt *et al*. (2012) recorded that foliar application of B at the rate of 50000 ppm increased the TSS content in mango. However, the concentration used in this experiment was much lesser (333 times) than that used by Arvind Bhatt *et al*. (2012).

pH content of fruits

Boron had a marked an influence ($p<0.0001$) on pH content of fruits. pH was maximized by application of H_3BO_3 at the rate of 350 ppm (Table 3). Low pH content of fruits was recorded in 150 ppm of H_3BO_3, 250 ppm of H_3BO_3, 150 ppm of $ZnSO_4$, combined application of H_3BO_3 + $ZnSO_4$ at 150 ppm and H_3BO_3 + $ZnSO_4$ at 250 ppm (Table 2). Rahim Nikkhah *et al*. (2013) documented that application of B at 200 ppm increased the pH content of grapevine. However, in this experiment maximum pH content of fruits was obtained from the application of B (350 ppm) in tomato plant, which was close to the level tested by Rahim Nikkhah *et al*. (2013).

Table: 3 Effect of foliar application of B and Zn on acidity, ascorbic acid content, TSS and pH of fruits

Treatments	**Acidity**	**Ascorbic acid content** (mg/100 g)	**TSS (^{0}B)**	**P^H**
T1- B (150 ppm)	0.50^{ef}	28.29^{de}	6.00^{a}	4.30^{d}
T2- B (250 ppm)	0.73^{de}	28.81^{bcd}	5.15^{bc}	4.22^{d}
T3- B (350 ppm)	0.43^{f}	28.65^{cde}	5.50^{ab}	4.91^{a}
T4- Zn (150 ppm)	1.02^{ab}	29.23^{bcd}	3.25^{d}	4.32^{d}
T5- Zn (250 ppm)	0.97^{abc}	29.23^{bcd}	4.80^{bc}	4.48^{c}
T6- Zn (350 ppm)	0.77^{cd}	29.99^{bc}	3.75^{d}	4.59^{bc}
T7- B(150 ppm)+ Zn(150 ppm)	0.43^{f}	28.88^{bcd}	4.65^{c}	4.27^{d}
T8- B(250 ppm)+ Zn(250 ppm)	0.84^{bcd}	30.36^{b}	5.25^{abc}	4.33^{d}
T9- B(350 ppm)+ Zn(350 ppm)	1.08^{a}	32.98^{a}	3.75^{d}	4.62^{b}
T0- Control	0.48^{f}	27.19^{e}	3.50^{d}	4.51^{bc}
F test	0.0001	0.0001	0.0001	0.0001
LSD	0.23	1.59	0.82	0.14

**Means followed by the same letter in each column are not significantly different to Least significant different at 5% level*

Conclusion

It is evident from the study that the application of H_3BO_3 and $ZnSO_4$ had a significant impact on the quality of fruits. Application of $ZnSO_4$ at the rate of 250 ppm boosted the fresh weight of fruits/plant by two and a half fold than that of control. Application of H_3BO_3 at 250 ppm improved the pulp weight by two and a half fold than control. Combined application of H_3BO_3-350 ppm and $ZnSO_4$-350 ppm increased the acidity and ascorbic acid. Application of H_3BO_3 at the rate of 150 ppm improved the total soluble solids (TSS) whereas H_3BO_3 at 350 ppm improved the p^H of tomato fruits. Among the treatments, the lowest performance was recorded in the control treatment.

The results suggest that under conditions in this experiment marketable fresh weight of fruits/plant could be increased by two and a half fold by the foliar application of $ZnSO_4$ at 250 ppm; combined application of H_3BO_3-350 ppm and

$ZnSO_4$-350 ppm increased the acidity and ascorbic acid content respectively; H_3BO_3 -150ppm improved the TSS and H_3BO_3 -350ppm increased the pH of tomato.

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