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Influence of Foliar Application of Boron, Copper and their Combinations on the quality of Tomato (*Lycopersicon esculentum* Mill.)

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Abstract

A pot experiment was carried out to evaluate the influence of foliar application of boron, copper and their combinations on the quality of tomato. The treatments were arranged in a Complete Randomized Design (CRD) with eight (8) replicates. There were ten (10) treatments viz., (T1) H_3BO_3=150 ppm; (T2) H_3BO_3 = 250 ppm; (T3) H_3BO_3 = 350 ppm; (T4) $CuSO_4$ = 150 ppm; (T5) $CuSO_4$ = 250 ppm; (T6) $CuSO_4$ = 350 ppm; (T7) H_3BO_3 (150 ppm) + $CuSO_4$ (150 ppm); (T8) H_3BO_3 (250 ppm) + $CuSO_4$ (250 ppm); (T9) H_3BO_3 (350 ppm) + $CuSO_4$ (350 ppm); (T10) Control (Boron was applied as H_3BO_3 and copper is applied as $CuSO_4$). The results showed that foliar application of boron, copper, and their combinations significantly influenced yield and quality parameters such as acidity, ascorbic acid, TSS and pH. The effect of B is greater than that of Cu. The application of B increased the fresh weight of fruits (H_3BO_3 - 350 ppm), pulp weight (H_3BO_3 - 150 ppm) and TSS (H_3BO_3 - 150 ppm). The combined application of B and Cu improved acidity (H_3BO_3 - 250 ppm + $CuSO_4$ - 250 ppm) and pH (H_3BO_3 -150 ppm + $CuSO_4$ - 150ppm). However, foliar application of Cu alone significantly enhanced ascorbic acid ($CuSO_4$ - 350 ppm) and TSS ($CuSO_4$ - 250 ppm). It is apparent that B concentration at different levels had significant positive effect on most of the quality parameters tested.

Keywords: Boron, Copper, Quality, PPM, Total soluble solids, Ascorbic acids.

Introduction

Tomato is one of the nourishing vegetables cultivated all over the world. It endows with several uses to human. *The fruits* are having a wide array of valuable nutrients viz. vitamin B (biotin, B6, folate and niacin); C (22%); K (6%) and molybdenum. It is a good source of macro (phosphorus, potassium) and micronutrients (copper, manganese), dietary fiber (4%), vitamin A and E.

The fruits can be consumed in many ways i.e. as raw or cooked vegetable or processed into various products such as canned tomato, sauce, juice, ketchup, puree, stews and soup. Tomatoes have an outstanding antioxidant property[1]. Health benefits of tomatoes are; it lowers the danger of cancer (especially prostate cancer), cardiovascular diseases[2,3] and total cholesterol, LDL cholesterol, and triglycerides. The significance of tomato as a beneficial crop is very apparent. The potential for production of tomato is high. However, farmers do not cultivate on a large scale due to high flower dropping by heat stress. The main cause for heat stress is high temperature and the effect on fruit is the reduction in quantity and quality of fruits. Heat stress injury is very common in tomato in high temperature areas and the injury occurs during the flowering stage that affects the development of pollen, pollination and fertilization[4]. Therefore, rapid way of getting high quantity and quality of yield is through the application of nutrients. Macro and micronutrients are necessary for proper plant growth and development in tomato[5]. Application of these micronutrients results in better crop growth and yield[6]. Boron shows a dynamic role as a stabilizer of the cell wall pectic network[7]. It encourages the firmness and rigidity of the structure of cell wall. Hence, it retains the structure and strongness of the cell in plants[8]. It also enhances sugar and hydrocarbons passage through phloem[9]. Fruit set, fruit development, colour, total soluble solids, firmness and shelf life were close to optimum when the tomato was supplied with a balanced nutrient solution at the rate of 0.16 mg B L^{-1}. Soil application of boron @ 20 kg borax/ha had a positive effect on the number of fruits/plant, the weight of fruits and seed yield compared to 10 kg borax/ha in tomato[10].

Shoulder check crack is caused by boron deficiency and the incidence can be reduced by the application of boron[11]. In addition, the firmness of tomato fruits is reduced by the application of boron and the problem becomes severe during storage period[12].

Copper nutrient plays a pivotal role in the growth and development of plants and a necessary redox element taking part in a wide variety of processes, comprising of respiration and photosynthesis or the detoxification of superoxide radicals[13]. Nevertheless, additional copper can persuade modifications in photosynthetic and respiratory processes, activities of enzyme and DNA, and integrity of membranes[14-17]. Copper is also essential for the development of resistance to diseases in plants[18]. These two micronutrients have effects on the productivity of the crops and the human beings. Information on the effect of boron and copper on the quality of tomato fruit is limited under Sri Lanka conditions. Therefore, the present study was carried out to evaluate the influence of foliar application of boron and copper and their combinations on the quality of tomato.

Materials and Methods

A pot experiment was carried out at the Crop Farm of the Eastern University, Sri Lanka, located between 7^0 43' and 7^0 431/2' N latitude and the Longitude between 81^0 42' and 81^0 43' E, from December 2013 to April 2014. The climatic condition of the area is characterized by a mean annual rainfall ranging from 1600 mm to 2100 mm and the average temperature varies from 28°C to 32°C. This study comprises of three levels of boron and copper with the control, arranged in Complete 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) $CuSO_4$ = 150 ppm; (T5) $CuSO_4$ = 250 ppm; (T6) $CuSO_4$ = 350 ppm; (T7) H_3BO_3 (150 ppm) + $CuSO_4$ (150 ppm); (T8) H_3BO_3 (250 ppm) + $CuSO_4$ (250 ppm); (T9) H_3BO_3 (350 ppm) + $CuSO_4$ (350 ppm); (T10) Control (Boron was applied as H_3BO_3 and copper applied as $CuSO_4$). The variety used was Thilina. The foliar applications were done three times at 10 days intervals beginning from 40 days after transplanting of the seedling. The seedlings were raised as per the recommendation of the Department of Agriculture. The seedlings were raised in the nursery and transplanted in polybags at 30 days after planting (DAP). Potting media was sand: red soil: rotted cow dung at the ratio of 1:1:1. Recorded data were statistically analyzed using SAS 9.1 and means were compared using Least Significant Difference test at 5% significant level.

Results and Discussion

Fresh weight of fruits/plant: The highest fresh weight of fruits/plant (362.10 g) was obtained with 350 ppm of H_3BO_3, but this was on par with H_3BO_3 at 150 ppm (312.30 g) and 250 ppm (327.60 g) and $CuSO_4$ at 150 (169.40 g) ppm and 250 ppm (192.40 g) (Table-1). This was followed by the foliar application of CuSO4 at 350 ppm. As a result, boron at 350 ppm, 250 ppm and 150 ppm contributed to yield benefit over control by 7.6, 6.9 and 6.5 times, respectively. The yield benefit of boron at 350 ppm over CuSO4 350 ppm was 3.4 times. From this, it is clear that 350 ppm of foliar application of H_3BO_3 is sufficient for exploiting high yield in tomato.

This might be due to the fact that boron took part in the division and expansion of cells, and enhanced the volume of intercellular space in mesocarpic cells, and quicker translocation of metabolites from the source to sink (fruits)[19]. Significant improvement in weight of fruits by the borax application has been also reported by Dutta P. et al.[20] in litchi and Dutta P.[21] in mango cv. Himsagar. It is also documented that boron has positive effects on improving the rates of carbohydrate and RNA[22]. Therefore, the improvement in yield might be due to the increase in carbohydrate that in turn increased the weight of the fruits.

Table - 1
Effect of foliar application of B and Cu on fresh weight of fruits/plant

Treatments	Fresh weight of fruits (g)
H_3BO_3 (150 ppm) (T1)	312.30^{ab}
H_3BO_3 (250 ppm) (T2)	327.60^{ab}
H_3BO_3 (350 ppm) (T3)	362.10^{a}
$CuSO_4$ (150 ppm) (T4)	169.40^{abc}
$CuSO_4$ (250 ppm) (T5)	192.40^{abc}
$CuSO_4$ (350 ppm) (T6)	108.10^{bc}
H_3BO_3 (150 ppm)+$CuSO_4$ (150 ppm) (T7)	211.90^{abc}
H_3BO_3 (250 ppm)+$CuSO_4$ (250 ppm) (T8)	210.00^{abc}
H_3BO_3 (350 ppm)+$CuSO_4$ (350 ppm) (T9)	120.60^{bc}
Control (T0)	47.70^{c}
F test	**

P<0.05; ns-not significant, **Means followed by the same letter in each column are not significantly different to Least significant different at 5% level*

Fruit quality: Pulp weight/fruit: Significantly (P<0.01) higher pulp weight was recorded when plants were sprayed with micronutrient boron H_3BO_3 at 150 ppm (29.72 mg/100 g pulp), followed by the plants sprayed with micronutrients each at 250 ppm of H_3BO_3 and 250 ppm $CuSO_4$ (19.75 mg/100 g pulp) (Table-2). However, the pulp weighs in H_3BO_3 at 250 and 350 ppm, $CuSO_4$ -150 and 350 ppm, H_3BO_3 + $CuSO_4$ -350 ppm and control were the same (Table-2). The lowest pulp weight was observed when plants were sprayed with 250 ppm $CuSO_4$ (12.03 mg/100 g pulp).

These results indicated that H_3BO_3 at a low level (150 ppm) and combined application of H_3BO_3 250 ppm and $CuSO_4$ 250 ppm resulted in higher pulp weight. Pulp weight is an important factor for the canning industry. An increment in pulp weight was totally due to the application of boron. This could be due to the addition of photosynthates in the sink[23] and enlargement in size and the number of cells produced by B micronutrient[24]. A higher value of pulp weight was reported when date palm was sprayed with H_3BO_3 at the rate of 1500 ppm[24] which was ten (10) times superior to the rate used in this experiment.

Table - 2
Effect of foliar application of B and Cu on pulp weight and seed weight

Treatments	Pulp weight (mg/100 g pulp)	Seed weight (g)
H_3BO_3 (150 ppm) (T1)	29.72^{a}	1.56
H_3BO_3 (250 ppm) (T2)	19.60^{bc}	2.93
H_3BO_3 (350 ppm) T3	16.23^{bcd}	2.9
Cu SO4 (150 ppm) (T4)	16.83^{bcd}	2.97
Cu SO4 (250 ppm) (T5)	12.03^{d}	2.99
Cu SO4 (350 ppm) (T6)	18.45^{bc}	3.02
H_3BO_3 (150 ppm)+ CuSO4 (150 ppm) (T7)	14.50^{cd}	2.35
H_3BO_3 (250 ppm)+ CuSO4(250 ppm) (T8)	19.75^{b}	2.36
H_3BO_3 (350 ppm)+ CuSO4 (350 ppm) (T9)	16.55^{bcd}	1.95
Control T0	17.00^{bcd}	2.69
F test	**	ns

P<0.05; ns-not significant, **Means followed by the same letter in each column are not significantly different to Least significant different at 5% level*

Seed weight: Foliar application of nutrients (B and Cu) had no remarkable effects on seed weight/fruit (Table-2). However, foliar spraying of B at 100 ppm[25] and H_3BO_3 at 250 ppm[26] increased the seed yield in tomato. This showed that the involvement of boron in germination of pollens and further growth of the pollen tube were greater, and higher production of fertilized ovules caused in higher seeds per fruit[27-29].

Acidity/fruit: Acidity was significantly (P<0.0001) improved by combined application of the micronutrients H_3BO_3 (250 ppm) + $CuSO_4$ (250 ppm), followed by the treatments when $CuSO_4$ was applied at 150 ppm and 350 ppm (Table-3). Conversely, acidity was same in $CuSO_4$ - 250 ppm, H_3BO_3 + $CuSO_4$ - 150 and 350 ppm. Low acidity was observed when plants were sprayed with H_3BO_3 at 150 ppm and when plants were not sprayed with any micronutrients (control) (Table-3). However, low acidity was recorded in fruits with the foliar application of H_3BO_3 at 350 ppm (Table-3).

Ascorbic acid content of fruits: Maximum ascorbic acid content (1100 mg/100g pulp) was recorded in $CuSO_4$ (350 ppm) which was statistically on par with H_3BO_3 (150 ppm), $CuSO_4$ (250 ppm), H_3BO_3 (150 ppm) +$CuSO_4$ (150 ppm) and H_3BO_3 (350 ppm) + $CuSO_4$ (350 ppm) whereas minimum ascorbic acid was observed (525 mg/100g pulp) in control. This might be due to the effect of Cu and B. The application of boron elevated the level of ascorbic acid content and this led to the higher content of ascorbic acid as synthesized from sugar. These results are in conformity with those of Kar P.L. et al.[30] in pine-apple.

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

Treatments	Acidity	Ascorbic acid (mg/100g)	TSS (^{0}H)	pH
H_3BO_3 (150 ppm) (T1)	0.50^{cd}	105.00^{ab}	6.00^{a}	4.42^{cde}
H_3BO_3 (250 ppm) (T2)	0.73^{b}	65.00^{c}	5.15^{abc}	4.18^{e}
H_3BO_3 (350 ppm) (T3)	0.43^{d}	55.00^{c}	5.50^{ab}	4.63^{abc}
CuSO4 (150 ppm) (T4)	0.69^{b}	95.00^{b}	4.60^{bc}	4.23^{e}
Cu SO4 (250 ppm) (T5)	0.63^{bc}	105.00^{ab}	5.75^{a}	4.32^{de}
Cu SO4 (350 ppm) (T6)	0.70^{b}	110.00^{a}	5.75^{a}	4.44^{bcde}
H_3BO_3(150 ppm) +CuSO4(150ppm) (T7)	0.63^{bc}	100.00^{ab}	4.75^{bc}	4.74^{a}
H_3BO_3 (250 ppm) +CuSO4(250ppm) (T8)	0.95^{a}	95.00^{b}	4.50^{c}	4.71^{ab}
H_3BO_3 (350 ppm)+CuSO4(350 ppm) (T9)	0.62^{bc}	100.00^{ab}	4.50^{c}	4.32^{de}
Control (T0)	0.48^{cd}	52.50^{c}	3.50^{d}	4.52^{abcd}
F test	***	***	***	**

P<0.05; ns-not significant, **Means followed by the same letter in each column are not significantly different to Least significant different at 5% level*

Total Soluble Solid (TSS) content of fruits: Variation in total soluble solid was significant. The TSS content of fruits ranged from 3.5 - 6^0brix. TTS was increased significantly when micronutrients were applied separately at a lower level in H_3BO_3 at 150 ppm and higher level in $CuSO_4$ at 250 ppm and 350 ppm (Table-3), followed by $CuSO_4$ at 150 ppm and H_3BO_3 + $CuSO_4$ - 159 ppm. Lowest TSS was observed in the control (T0). This is in agreement with the studies of Harris K.D. et al.[26] who reported that boron (150 ppm and 250 ppm) increased the TSS. Boron encourages quick mobilization of water and sugar in the fruit and this resulted in higher TSS in tomato. Similar results have also been reported by Dutta P.[21] in mango. It is obvious that foliar application of boron increased the activity of the hydrolyzing enzyme[31] and that in turn increased the simple sugars from starch[32]. Higher TSS might be contributed to the efficient translocation of photosynthates to the fruits by the control of boron[33]. Boron (H_3BO_3) is a nutrient that improves the vascular movement of carbohydrate, which may enhance the fruit soluble solid content[34]. This finding was in agreement with the studies of Singh Ramendra et.al.[35] who reported that the pre-harvest spraying of boron and zinc increased TSS in guava fruits.

pH content of fruits: Boron and Copper had a significant influence (P<0.0001) on the pH content of fruits. The pH was maximum by the foliar application of H_3BO_3 (150 ppm) +$CuSO_4$ (150 ppm) and the minimum pH was achieved in plants sprayed with $CuSO_4$ (150 ppm) and H_3BO_3 (250 ppm) (Table 3). It is apparent that B and Cu combination increased the pH while the plants sprayed with these nutrients separately, had reduced the pH of the tomato fruits.

Application of B at 200 ppm increased the pH content of grapevine[36]. Nonetheless, in this study, application of B @150 ppm produced minimum pH content of fruits in the tomato plant, which was close to the level tested by Rahim Nikkhah et.al.[36].

Conclusion

Foliar application of boron, copper, and their combinations significantly influenced yield and quality parameters such as acidity, ascorbic acid, TSS and pH. The effect of B is greater than that of Cu. The application of B increased the fresh weight of fruits (H_3BO_3-350ppm), pulp weight (H_3BO_3-150ppm) and TSS (H_3BO_3-150ppm). The combined application of B and Cu improved acidity (H_3BO_3-250 ppm + $CuSO_4$-250 ppm) and pH (H_3BO_3-150ppm + $CuSO_4$-150ppm). However, foliar application of Cu alone significantly enhanced ascorbic acid ($CuSO_4$-350ppm) and TSS ($CuSO_4$-250ppm). It is apparent that B concentration at different levels had significant positive effect on most of the quality parameters tested.

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