Research Article

Effect of Calcium, Boron and Zinc Foliar Application on Growth and Fruit Production of Tomato

Bibi Haleema[1*], Abdur Rab[1] and Syed Asghar Hussain[2]

[1]Department of Horticulture, The University of Agriculture Peshawar-3125 Pakistan; [2]Agriculture Research Station (ARS), Baffa, Mansehra-21300 Pakistan.

Abstract | Effect of calcium, boron, and zinc foliar application on growth and fruit production of tomato was investigated during the year 2013 at ARI Tarnab, Peshawar to optimize calcium, boron and zinc concentration for enhancing the growth and fruit related attributes of tomato. The experiment was conducted using Randomized Complete Block (RCB) Design with 3 factors, replicated 3 times. Calcium (0, 0.3, 0.6 and 0.9%), Boron (0, 0.25, 0.5%) and Zinc (0, 0.25, 0.5%) were applied as foliar spray three times. Calcium application at 0.6% increased plant height (88.04 cm), number of primary (2.63) and secondary (7.15) branches, leaves plant^{-1} (182), leaf area (65.52 cm^2), and fruit per plant (66.15). In case of B levels, more plant height (88.14 cm), number of primary (2.61) and secondary (7.44) branches, number of leaves plant^{-1} (177), number fruits plant^{-1} (67.78) were recorded with foliar spray of B at 0.25%, while maximum leaf area was found at 0.5% B. Comparing the means for Zn concentrations, maximum plant height (86.53 cm), number of primary (2.53) and secondary (6.42) branches, leaves plant^{-1} (167), leaf area (63.33 cm^2), and fruit per plant (63.78) were higher with 0.5% foliar Zn application. The interaction between Ca, B and Zn also showed significant results for most of the attributes. Therefore, application of Ca (0.6%), B (0.25%), and Zn (0.5%) as a foliar spray can be used alone or in combination to improve growth and fruit production of tomato.

Received | September 28, 2017; **Accepted** | November 18, 2017; **Published** | December 21, 2017
***Correspondence** | Bibi Haleema, Department of Horticulture, The University of Agriculture Peshawar-3125 Pakistan; **Email:** haleema_12@yahoo.co.in
Citation | Haleema, B., A. Rab, S.A. Hussain. 2018. Effect of calcium, boron and zinc foliar application on growth and fruit production of tomato. *Sarhad Journal of Agriculture,* 34(1): 19-30.
DOI | http://dx.doi.org/10.17582/journal.sja/2018/34.1.19.30
Keywords | Boron levels, Calcium concentration, Fruit production, Growth attributes, Tomato, Zinc concentration

Introduction

Tomato (*Lycopersicom esculentum* Mill.) is a key vegetable crop grown throughout the world (Srividya et al., 2014) and a good source of vitamin A, vitamin C, Ca, Fe, protein, Na, K, Mg (USDA, 2016) antioxidant and carotenoids (Di Masico et al., 1989) that helps in retarding cancer and degenerative diseases (Giovannucci, 1999). Tomato yield in Pakistan is 10.12 t ha^{-1}, which is much less than global yield of 36 t ha^{-1} (MINFA, 2009). Besides, cultivars and cultural practices, many biotic and abiotic factors also limit the yield of tomato crop. (Ali, 2014). Abiotic stresses like changes in environmental conditions and nutrition results in physiological disorders ultimately decrease crop yield (Khavari-Nejad et al., 2009).

Nutrients management is essential to maximize crop yield (Menzel and Simpson, 1987), enhance fruit quality and increase profitability (Ganeshamurthy et al., 2011). Tomato plant requires macro and micro nutrients for growth and development as well as to complete its life cycle (Fageria, 1992; Brady and Weil, 2002). Essential nutrients are needed for optimum plant growth and development (Fageria, 2005; 2007; Fageria and Baligar, 2005). Soil characterized by high pH limits micronutrients availability to the plant (Ibrahim et al., 2008). Thus, application of essential nutrients enhances the uptake and utilization of nutrients (Phillips et al., 2004) and decrease nutrients deficiency related disorders.

The nutrients required in large quantity are supplied through soil application (Fageria et al., 2009) but nutrients needed in lower quantity can be better absorbed through foliar spray (Fageria et al., 2009; Girma et al., 2007). Calcium is an important secondary macro nutrient (Kadir, 2005), which may be deficient in plants either due to low calcium in soil, low calcium availability due to high soil pH, and low mobility in the plants especially to the fruits (Kadir, 2005; Peter, 2005). Therefore, a continuous supply of calcium is required for leaf development, plant canopy, and vigorous root growth (Del-Amor and Marcelis, 2006). Foliar fertilization can supplement soil fertilization to maximize crop yield (Fageria et al., 2009).

Boron is another important micro nutrient required for good quality and high yield of crops (Dale and Krystyna, 1998). It is involved in the synthesis and integrity of cell wall, cell wall lignification, metabolism of RNA, carbohydrate, phenol and Indole Accetic Acid (IAA), respiration and cell membrane integrity (Parr and Loughman, 1983). Boron increases the fruit set percentage by promoting pollen germination and elongation of pollen tube (Abdalla, 2006). Boron content also influences calcium metabolism and its deficiency declines the calcium associated with pectin constituents (Yamaguchi et al., 1986). Boron deficiency results in wilting and leaf drop (Zekri and Obreza, 2003) and adversely affect the quality and yield of many vegetables especially tomato (Imtiaz et al., 2010). Its requirements of plants can be satisfied by both foliar and soil application during growing season, especially during reproductive growth stage (Sajid, 2009).

Zinc (Zn) is another important essential micronutrient which helps in the formation of tryptophan, a precursor of IAA responsible for growth stimulation (Mallick and Muthukrishnan, 1979) and plays a vital role in synthesis of carbonic anhydrase enzyme which helps in transport of CO_2 in photosynthesis (Alloway, 2008). Zinc deficiency causes shorter and thinner internodes, stunted growth, appearance of chlorotic flecks on the older leaves and twisting of leaf borders in upward direction and plant with abnormal features (Passam et al., 2007). The zinc deficiency may be due to soil deficient in Zn, competition with Ca, Mn, Fe, P, to some degree K, and soil properties that influence Zn availability (Srivastava and Singh, 2003). Soil application of Zn is less effective due to roots limitations and low Zn mobility in soil and it is partially immobile in the phloem. By contrast, foliar uptake is rapid, thus, repeated sprays of Zn are needed to overcome the Zn deficiency (Swietlik, 2002).

Keeping in view the importance of Ca, B and Zn in improving tomato growth and yield of tomato, the current study was conducted to evaluate the effect of foliar applied Ca, B and Zn for improved growth of tomato, to enhance the growth of tomato through Ca, B and Zn management and to elucidate the interactive effect of Ca, B, and Zn for the maximum vegetative and reproductive growth of tomato fruit.

Materials and Methods

Effect of calcium, boron, and zinc foliar application on growth and fruit production of tomato was investigated during the year 2013, from January-July at Agricultural Research Institute (ARI), Tarnab Peshawar, Pakistan.

The experiment was conducted in RCB Design with 3 replications. Different concentrations of Calcium (0, 0.3, 0.6 and 0.9%), Boron (0, 0.25 and 0.5%), and Zinc (0, 0.25 and 0.5%) were applied as foliar spray three times during the season. First foliar application was made before start of flowering. 2nd at the time of fruit set and 3rd application was repeated at 15 days after fruit set.

The sources of Ca, B, and Zn were $CaCl_2.2H_2O$, boric acid, and zinc sulphate, respectively. AnalaR Grade chemicals were used to prepare the nutrient solution. The percent calcium was calculated in molecular formula of the respective source and then found the quantity of calcium, boron and zinc source used for the mentioned percent solutions. Hand sprayer was used to spray the nutrients uniformly on each plant. Tween-Twenty, a surfactant, was added to the solution at the rate of 0.5 cc / 100 ml of water for better retention of the chemicals. The plants of control group were sprayed with plain water. All foliar applications were made early in morning for better absorption and long lasting effect.

The seeds of tomato cultivar Riogrande were obtained from National Agriculture Research Council (NARC) Islamabad and nursery was raised at ARI Tarnab during third week of January. Seedlings were hardened-off and transplanted in the first week of March on one side of raised bed keeping row-to-row distance 70 cm and plant to plant distance 30 cm. Plot size was 6.1 m^2.

Experimental area was thoroughly prepared and all routine cultural practices like weeding and hoeing during crop growth and development were kept constant and uniform. The nursery plants were sown on raised bed with 3 m length and 1 m width.

Physico-chemical analysis of the soil of the experimental site

The soil of the experimental site was slightly alkaline in reaction with pH of 8.13, electrical conductivity of 0.475 dSm^{-1}, deficient in some nutrients like P, Zn, B and Ca (4.06, 1.38, <0.5 mg $kg^{-1}$and 7.4%, respectively). The potassium content was adequate in the experimental site i.e. 337.2 mg kg^{-1}.

Data were recorded on vegetative and reproductive parameters as per following procedure:

Plant height (cm): The plant height of five plants, taken at random was measured from soil level to the tip of the longest stem. The mean plant height was recorded after final harvest.

Number of primary branches plant^{-1}: The number of primary branches of five randomly taken plants was counted and average to represent the corresponding treatments.

Number of secondary branches plant^{-1}: The secondary branches developed on primary branches of each 5 randomly taken plants were counted and averaged to represent the corresponding treatments.

Number of leaves plant^{-1}: The parameter was recorded by counting leaves of five plants at random and then averaged.

Leaf area (cm^2): The leaf area of 5 randomly selected plants was recorded by taking five leaves for each plant in each experimental unit. The leaf area was estimated with a leaf area machine (C1-2O2-Area Meter USA) calculated in cm^2.

Number of fruit plant^{-1}: The number of fruits plant^{-1} was counted from tagged plant at each picking till final harvest from last week of May to July. The number of fruits at each harvest was added and average was calculated for each treatment.

Statistical analysis

The data were analyzed statistically using procedure appropriate for Randomized Complete Block Design (RCBD) with three factors using statistical software Statistix 8 (Statistix® 8 Analytical Software, 2003). Means were compared using LSD when F test was found significant (Jan et al., 2009).

Results and Discussion

Plant height (cm)

The foliar application of Ca, B, and Zn significantly affected plant height of tomato. The interactions of Ca x B and B x Zn were also significant, but the interactions of Ca x Zn and Ca x B x Zn had no significant effect on plant height of tomato (Table 1). An increase from 78.82 cm to 88.14 cm in plant height of tomato was recorded with increasing the Ca concentration of foliar spray from control to 0.6% but 0.9% Ca spray significantly decreased plant height to 83.37 cm (Table 1). The plant height of tomato also increased from 77.22 cm to 88.14 cm with increasing B from 0 to 0.25%, but adding more B up to 0.5% decreased the plant height (84.78 cm) of tomato (Table 1). Moreover, the plant height increased consistently with increasing concentration of Zn as foliar spray. The Plant height was 80.61 and 83.61 cm with 0 and 0.25% Zn application that significantly increased to 86.53 cm with increasing the Zn concentration to 0.5% (Table 1). Regarding the interaction of Ca and B, the minimum plant height (75.33 cm) was recorded with 0.3% Ca + 0% B while plant treated with 0.6% Ca +0.25% B had the maximum plant height (95.33 cm) (Figure 1). The interaction of Ca and Zn was also found significant. The minimum plant height (72.00 cm) was recorded in control plants that increased to 91.00 cm in plants treated with 0.25% B + 0.25% Zn (Figure 2).

Number of primary branches per plant

Foliar application of Ca, B and Zn significantly affected primary branches plant^{-1}. The interactions of

Table 1: *Effect of calcium, boron, and zinc foliar application on plant height, number of primary branches and number of secondary branches of tomato.*

Calcium Levels (%)	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}
0	78.82 c	1.85 c	4.74 c
0.3	83.29 b	1.93 c	5.30 c
0.6	88.04 a	2.63 a	7.15 a
0.9	83.37 b	2.26 b	5.96 b
LSD at α 0.05	3.23	0.29	0.56
Boron (%)			
0	77.22 c	1.83 b	4.47 c
0.25	88.14 a	2.61 a	7.44 a
0.5	84.78 b	2.06 b	5.44 b
LSD at α 0.05	2.80	0.25	0.49
Zinc (%)			
0	80.61 c	1.92 b	5.08 c
0.25	83.61 b	2.06 b	5.86 b
0.5	86.53 a	2.53 a	6.42 a
LSD at α 0.05	2.80	0.25	0.49
Interactions			
Ca x B	Fig 1	Fig 3	Fig 5
Level of Significance	**	**	**
Ca x Zn	---	---	---
Level of Significance	NS	NS	NS
B x Zn	Fig 2	Fig 4	Fig 6
Level of Significance	**	**	**
Ca x B x Zn	---	---	---
Level of Significance	NS	NS	NS

Means followed by similar letter(s) in column do not differ significantly from one another. **NS:** *Non-significant;* ***, **:** *Significant at 5 and 1% level of probability, respectively.*

Ca x B and B x Zn had a significant effect on the primary branches plant^{-1}, but the interactions of Ca x Zn and Ca x B x Zn was found non-significant (Table 1). The highest primary branches per plant (2.63) was recorded in tomato plants with foliar application of Ca at 0.6%, while the lowest primary branches per plant (1.83) was recorded in control treatment. (Table 1). Similarly, the foliar application of B increased the primary branches per plant up to 2.61 with increase in B levels up to 0.25%. However, more increase in B to 0.5% declined the primary branches to 2.06 (Table 1).

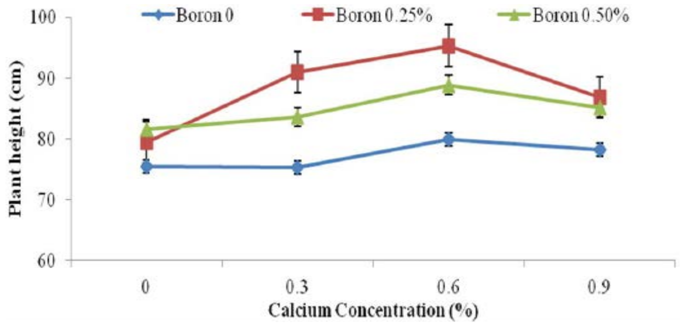

Figure 1: *The interaction of Ca and B application on plant height of tomato. The vertical bars represent standard error.*

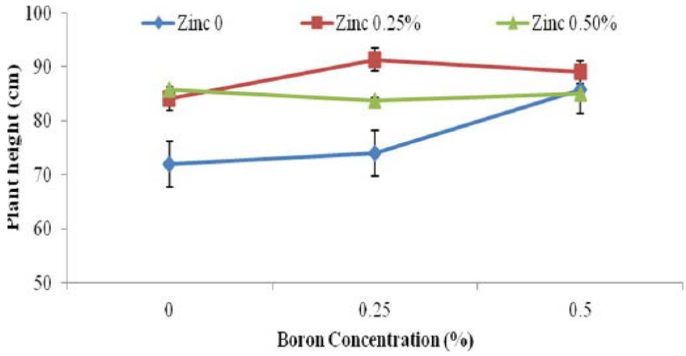

Figure 2: *The interaction of B and Zn application on plant height of tomato. The vertical bars respresent standar error.*

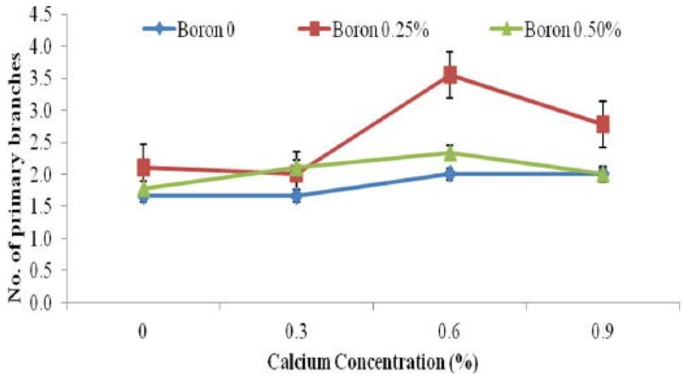

Figure 3: *The interaction of Ca and B application on the number of primary branches of tomato. The vertical bars represent standard error.*

The primary branches of tomato constantly increased with increasing concentration of Zn. while the primary branches was not significant between 0 and 0.25% Zn concentrations (1.92 and 2.06, respectively), it increased significantly with further increase in Zn concentration up to 0.5% (2.53) (Table 1). The interaction between Ca and B indicated that the maximum branches plant^{-1} (3.55) was recorded with 0.6% Ca + 0.25% B application as compared to 1.67 branches plant^{-1} in control treatment (Figure 3). The interaction between B and Zn showed that primary branches of tomato were higher (3.58) at 0.5% B + 0.25% Zn while lower number of primary branches (1.83) was recorded in control treatment (Figure 4).

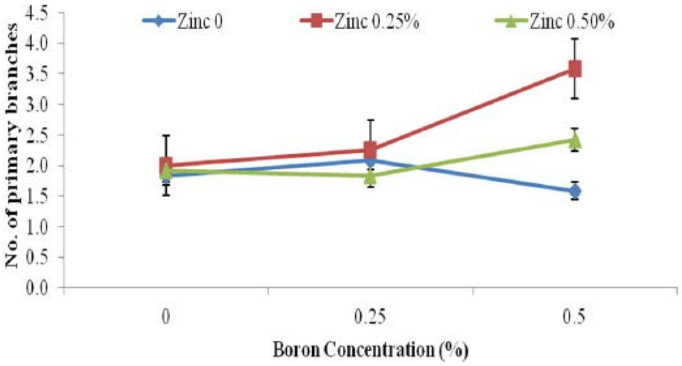

Figure 4: *The interaction of B and Zn application on the number of primary branches of tomato. The vertical bars represent standard error.*

Secondary branches per plant

Foliar application of Ca, B and Zn and interactive effect of CaxB and BxZn had a significant influence on secondary branches per plant of tomato, whereas the rest of the interactions were found non-significant (Table 1). The secondary branches per plant increased from 4.74 to 7.15 with the application of Ca from 0 to 0.6%, respectively. While incremental increase of Ca up to 0.9% reduced the secondary branches (5.96) (Table 1). Likewise, the secondary branches increased from 4.47 to 7.44 with increased B from 0 to 0.25%. However, more application of B to 0.5% decreased the secondary branches (5.44) (Table 1). The secondary branches linearly increased with increasing Zn concentration. The highest secondary branches 6.42 were recorded with Zn at 0.5%, followed by (5.86) secondary branches plant^{-1} at 0.25% Zn. The minimum secondary branches (5.08) were recorded in untreated plants (Table 1). The interaction of Ca and B indicated that combined application of Ca and B had even greater influence as compared to alone application of each of it. Plants treated with 0.6% Ca + 0.25% B increased the secondary branches to 10.00 as compared to 4.11 in control plants (Figure 5). The interaction between B and Zn indicated that application of 0.25% B + 0.5% Zn resulted in the maximum number of secondary branches (8.67), while plants sprayed with 0.5% B + 0% Zn had the minimum (3.83) number of secondary branches plant^{-1} (Figure 6).

Number of leaves per plant

The foliar application of Ca, B, and Zn significantly affected the number of leaves plant^{-1}. The Ca x B, Ca x Zn and B x Zn interactions were also significant, but Ca x B x Zn interaction was not significant (Table 2). Increasing Ca from 0 to 0.6% significantly increased the leaves plant^{-1} increased from 103 to 182, respectively but declined to 148 with additional Ca application up to 0.9% (Table 2). Foliar application of B from 0 to 0.25% significantly increased the leaves from 112 to 177. However, high B concentration (0.5%) decreased the leaves plant^{-1} to 132 (Table 2). Increasing Zn concentration increased the number of leaves, which was the highest (167) with the application of 0.5% Zn, followed by 148 leaves plant^{-1} recorded with 0.25% Zn application. Whereas the least leaves number per plant (106) were noted in control (Table 2). The interaction between Ca and B indicated that leaves plant^{-1} increased tomato leaves to the maximum (240) at 0.25% B + 0.6% Ca, while the control plants had the minimum leaves plant^{-1} (69.78) (Figure 7).

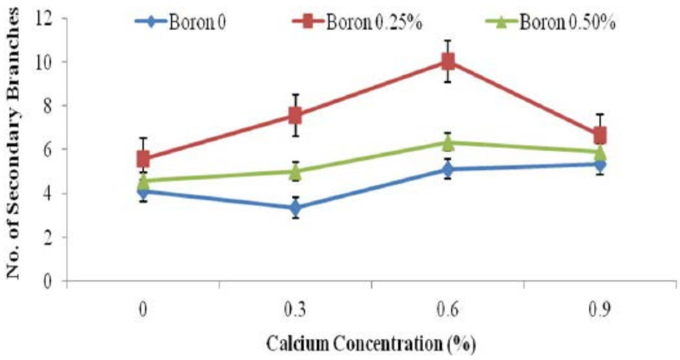

Figure 5: *The interaction of Ca and B application on the number of secondary branches of tomato. The vertical bars represent standard error.*

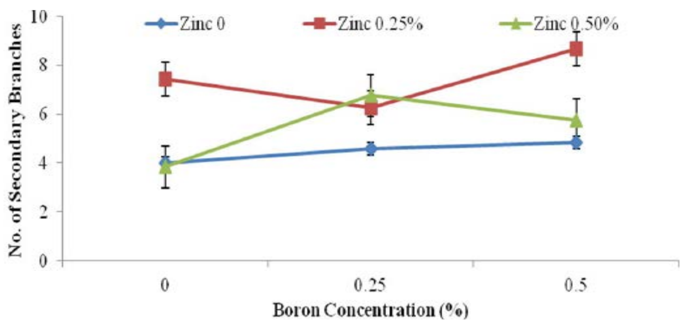

Figure 6: *The interaction of B and Zn application on the number of secondary branches of tomato. The vertical bars represent standard error.*

The interaction between Ca and Zn revealed that the highest leaves (236) were counted in plants sprayed with combination of 0.25% Zn + 0.6% Ca. The minimum leaf number (78) was recorded in control plants (Figure 8). The interaction between B and Zn resulted in increased leaves plant^{-1}. The maximum leaves plant^{-1} (213.58) was found in plants treated with 0.25% B + 0.5% Zn, while the minimum number of leaves plant^{-1} (98.83) was in plants sprayed with 0.5%

B and no Zn (Figure 9).

Table 2: *Effect of calcium, boron, and zinc foliar application on No. of leaves plant^{-1}, leaf area (cm^2) and number of fruit plant^{-1} of tomato.*

Calcium Levels (%)	No. of Leaves plant^{-1}	leaf area (cm^2)	Number of fruit plant^{-1}
0	103 d	46.33 c	50.11 d
0.3	126 c	58.85 b	55.96 c
0.6	182 a	65.52 a	66.15 a
0.9	148 b	54.37 b	60.89 b
LSD at α 0.05	20.67	5.57	2.61
Boron (%)			
0	112 c	49.03 c	46.67 c
0.25	177 a	57.44 b	67.78 a
0.5	132 b	62.33 a	60.39 b
LSD at α 0.05	17.85	4.82	2.26
Zinc (%)			
0	106 c	48.48 c	54.22 c
0.25	148 b	57.06 b	56.83 b
0.5	167 a	63.33 a	63.78 a
LSD at α 0.05	17.85	4.82	2.26
Interactions			
Ca x B	Fig 7	Fig 10	Fig 12
Level of Significance	**	*	**
Ca x Zn	Fig 8	---	---
Level of Significance	*	NS	NS
B x Zn	Fig 9	Fig 11	Fig 13
Level of Significance	**	**	**
Ca x B x Zn	---	---	---
Level of Significance	NS	NS	NS

Means followed by similar letter(s) in column do not differ significantly from one another. **NS:** *Non-significant;* ***, **:** *Significant at 5 and 1% level of probability, respectively.*

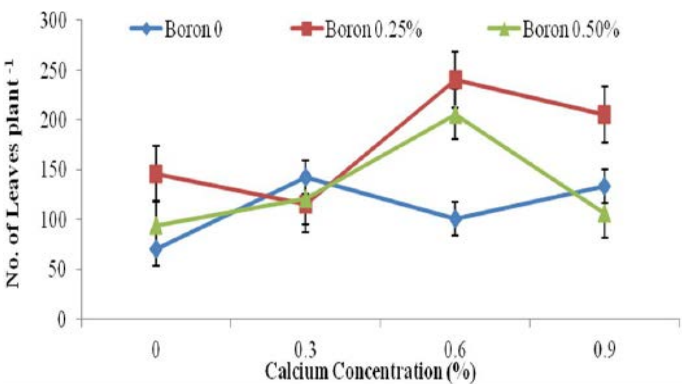

Figure 7: *The interaction of Ca and B application on the number of leaves plant^{-1} of tomato. The vertical bars represent standard error.*

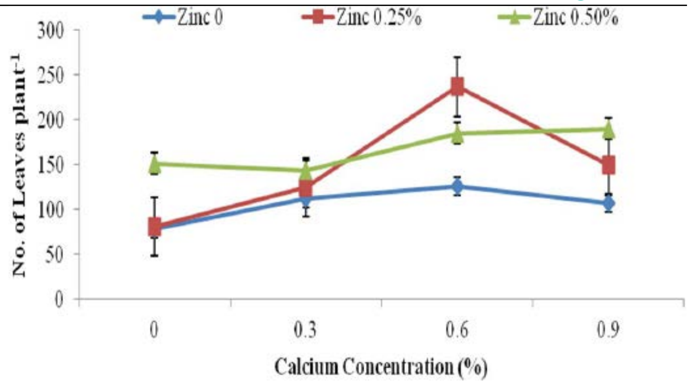

Figure 8: *The interaction of Ca and Zn application on the number of leaves plant^{-1} of tomato. The vertical error bars represent standard error.*

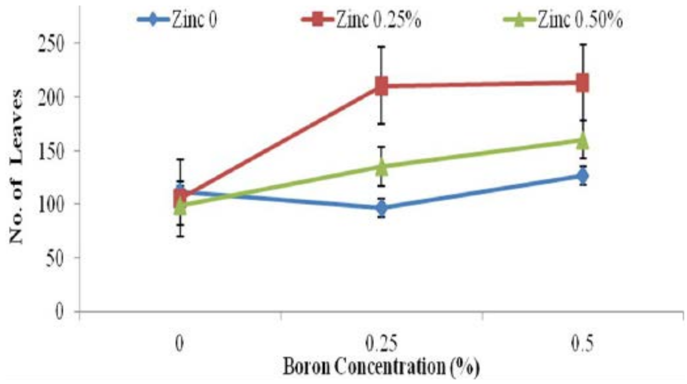

Figure 9: *The interaction of B and Zn application on the number of leaves plant^{-1} of tomato. The vertical bars represent standard error.*

Leaf area (cm^2)

Foliar application of Ca, B, and Zn significantly affected leaf area of tomato. The Ca x B and B x Zn interactions were also significant, while Ca x Zn and Ca x B x Zn interactions effect was not significant on leaf area (Table 2). The leaf area increased from 46.33 to 65.52 cm^2 when Ca concentration of the foliar spray was increased from 0 to 0.6%. However, further increment in the concentration of Ca to 0.9% decreased the leaf area (54.37 cm^2), which was statistically at par with leaf area recorded at 0.3% Ca application (58.85 cm^2) (Table 2). The average leaf area increased with increase in B concentration from 0 to 0.5%. The leaf area was recorded maximum 62.33 cm^2 in plants sprayed with 0.5% B solution was followed by 57.44 cm^2 leaf area with 0.25% B application. The least leaf area 49.03 cm^2 was recorded in control plants (Table 2). Similarly, leaf area of tomato increased with increasing Zn concentration. The leaf area was the highest (63.33 cm^2) at 0.5% Zn followed by leaf area of 57.06 cm^2 at 0.25% Zn concentration. Leaf area was the least (48.48 cm^2) in control plants (Table 2). The interaction between Ca and B indicated that the leaf area of tomato was the highest at 0.5% concentration of B with increasing concentration of Ca till

0.6%. The plants treated with 0.6% Ca + 0.5% B had the maximum leaf area (79.22 cm^2) in contrast to the leaf area (38.22 cm^2) of control plants (Figure 10). The interaction between B and Zn illustrated that the leaf area of tomato continuously enhanced with increase in concentration of B at all levels of Zn. The leaf area increased from the minimum of 45.92 cm^2 in control plants to the maximum of 78.83 cm^2 in plants sprayed with 0.5% of B + 0.5% Zn (Figure 11).

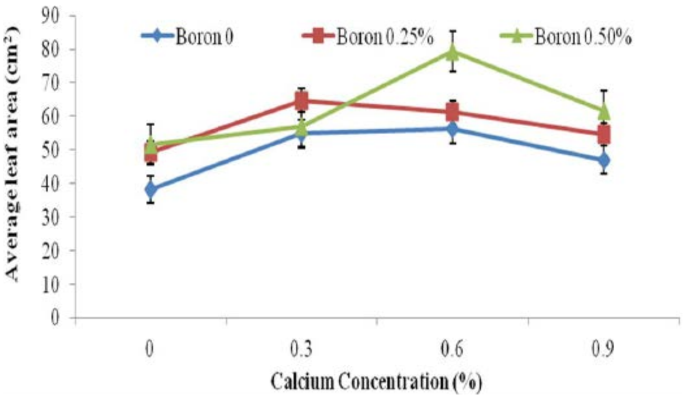

Figure 10: *The interaction of Ca and B application on the leaf area of tomato. The vertical bars represent standard error.*

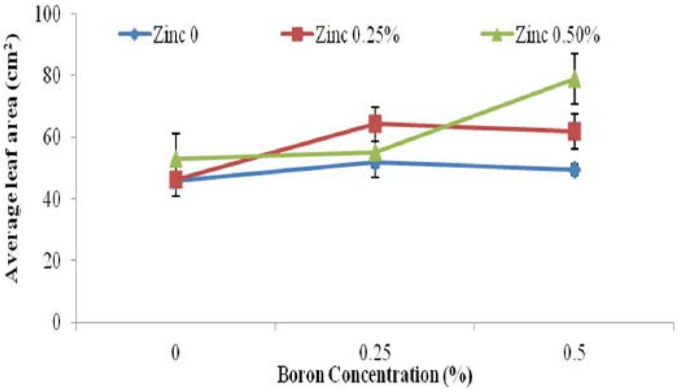

Figure 11: *The interaction of B and Zn application on the leaf area of tomato. The vertical bars represent standard error. Vertical bars represent standard error.*

Number of fruits plant^{-1}

Foliar application of Ca, B, and Zn significantly influenced fruits plant^{-1}. The CaxB and BxZn interactions were significant while Ca x Zn and Ca x B x Zn interactions were not significant for fruits plant^{-1} (Table 2). Fruits plant^{-1} increased from 50.11 to 66.15 when Ca concentration as foliar spray was increased from 0 to 0.6%. However, additional enhancement in concentration of Ca to 0.9% decreased fruits plant^{-1} (60.89) (Table 2). Likewise, fruits plant^{-1} increased from 46.67 to 67.78 with increment in concentration of B as foliar spray from 0 to 0.25%. However, promotion in concentration of B to 0.5% declined fruits plant^{-1} (60.39) (Table 2). The fruits plant^{-1} of tomato continuously increased with increasing concentration of Zn. The fruits plant^{-1} in control plants (0% Zn) was 54.22 that increased to 63.78 when Zn concentration increased to 0.5% followed by 56.83 fruits plant^{-1} with 0.25% Zn application (Table 2). The interaction between Ca and B indicated that fruits plant^{-1} improved with increasing concentration of Ca from 0 to 0.6% at 0.25% of B. However, increasing Ca concentration to 0.9% did not increase fruit number plant^{-1}. The increase in number of fruit plant^{-1} of tomato was higher (78.00) in plants treated with 0.25% B + 0.6% Ca as compared to fruits plant^{-1} (39.67) in control (Figure 12). The interaction between B and Zn revealed that fruits plant^{-1} were increased from (38.33) in control to (70.83) in plants treated with 0.5% B + 0.5% Zn (Figure 13).

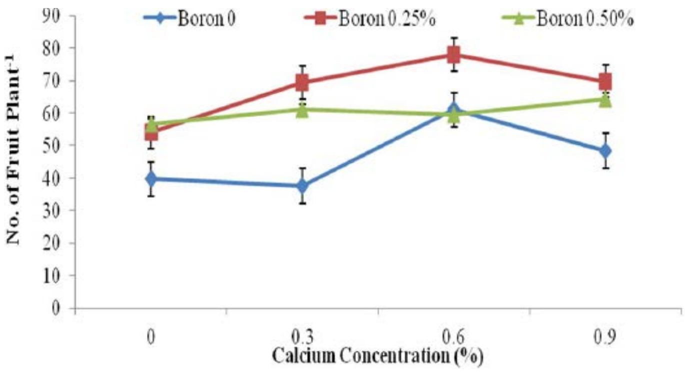

Figure 12: *The interaction of Ca and B application on the number of fruits plant^{-1} of tomato. The vertical bars represent standard error.*

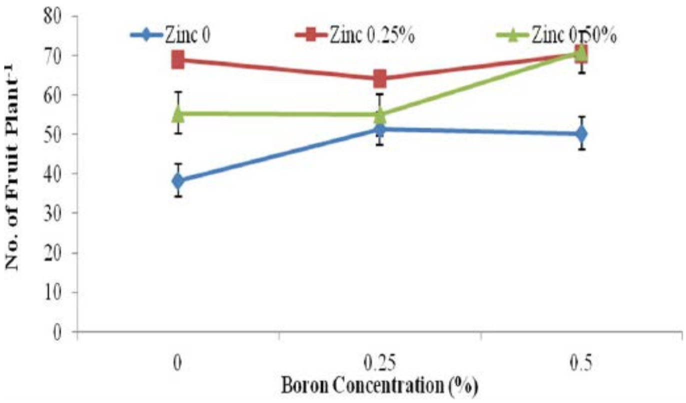

Figure 13: *The interaction of B and Zn application on the number of fruits plant^{-1} of tomato. The vertical bars represent standard error.*

The plant height, primary and secondary branches, leaves per plant and average leaf area increased by 12, 42, 51, 77 and 41%, respectively over control treatment when calcium levels were increased from 0 to 0.6% but further increase in Ca (0.9%) reduced these parameters. Likewise, plant height, primary and secondly branches and leaf number per plant significantly increased by 14, 42, 66 and 58, respectively with increased B concentration up to 0.25% whereas further addition of B in foliar spray up to 0.5% decreased these parameters. However, the leaf area increased by 27% at 0.5% level of B. Plant height, primary and secondary branches, leaves plant^{-1} and leaf area increased by 7, 32, 26, 58 and 31% than control with increasing Zn concentration from 0 to 0.5%. However, the Ca x B and B x Zn interactive effect was found more effective in increasing the growth parameters as compared to the sole application of each nutrient.

The increment in the study attributes by application is due to the fact that calcium is an essential constituent of plant cell wall and plays a significant function in cell division and enlargement (Rashid, 2000; Ilyas et al., 2014). The Ca is directly involved in improving photosynthesis which results in high leaf number (Hussain et al., 2003). The Ca alone improved leaf area by activating enzymes, photosynthesis and carbohydrates metabolism (Bergmann, 1992; Hussain et al., 2003). Therefore, it is likely to observe taller plants, more branches per plant and more leaf area with foliar application of Ca. Increasing Ca^{+2} concentration enhanced plant length, leaf area and fruits number (Hao and Papadopoulos, 2003; Rubio et al., 2009; Shafeek et al., 2013). The present results are in close conformity with Ayyub et al. (2012) who reported that tomato plant height, generally, respond positively to foliar application of Ca and increases vegetative or shoot growth of tomato plant. Likewise, the boron is also linked with the development of plant cell wall and differentiation of cells and results in improved shoot growth (Basavarajeshwari et al., 2008) and thus increased plant height, branches per plant and leaves per plant (Ilyas et al., 2014; Oyinlola, 2004), which greatly confirmed the present results. It was also observed that further increase in B concentration decrease the plant height, branches, leaves per plant and average leaf area. Plant demand for Boron as micronutrient varies broadly. The ranges of deficiency and excess causing toxicity are also slim. Boron management is tricky as its optimum plant's application range is restricted and optimal B doses can differ from soil to soil (Gupta, 1993; Marschner, 1995). There is very a slim array in decisive tissue concentrations between boron excess and deficiency for different plant species (Blamey et al., 1997). The toxicity of B exerts different effects on vascular plants such as in decreased photosynthetic rates, decline in the cell division, and decreased suberin and lignin levels (Nable et al., 1997; Reid, 2007). Plant exposed to high B concentration, may have reduced vegetative growth like height, leaves, branches and reproductive growth like flowers and fruits (Nable et al., 1997; Bagheri et al., 1992).

Increase in plant height, branches and leaves per plant with foliar application of Zn may be due to Zn role in tryptophan formation, required for auxin synthesis and plant growth (Mallick and Muthukrishnan, 1979). Besides, the increase in the biosynthesis of auxin, Zn also promotes nutrient uptake (Cakmak, 1999) that ultimately increase vegetative growth and so as the leaf number as well. Zinc may also enhance translocation of metabolites as well as cell elongation and thus, increase the leaf area (Hatwar et al., 2003). Since both Ca and B are required for plant growth (Bose and Tripathi, 1996) and B also enhances the metabolism of Ca particularly in the cell wall (Blevins and Lukaszewki, 1998), thus Ca + B combination was proved more effective in producing taller plants, more branches per plant and high leaf number which were in accordance with the results of Asad et al. (2003), Dole and Wilkins (2005), Rab and Haq (2012). Similarly, the combination of Zn and B was more effective in promoting plant height, branches plant^{-1} and leaves plant^{-1} probably by increasing photosynthetic and metabolic activity, cell division and cell elongation (Hatwar et al., 2003) Likewise, the combined application of Zn + B was found significantly more effective in increasing number of branches as compared to alone application of each nutrient (Zn and B) (Denre et al., 2014; Harris and Mathuma, 2015) due to enhanced photosynthesis (Rawat and Mathpal, 1984). The Zn + B combination also have significant function in formation of plant meristem (Shnain et al., 2014), so resulted in higher number of branches (Harris and Mathuma, 2015). The Zn + B combined application increased the leaf number per plant of tomato (Ayyub et al., 2012; Singh and Tiwari, 2013). Shnain et al. (2014) recorded an increase in vegetative attributes of tomato with 1.25 g L^{-1} B and 1.25 g L^{-1} Zn both alone and in combination.

Fruits per plant increased by 32% when Ca concentration increased from 0 to 0.6% over control. Likewise, fruit per plant increased significantly by 45% when boron was increased from control to 0.25%. Fruits plant^{-1} consistently increased by 18% when Zn concentration was increased from 0 to 0.5%. The interactions of Ca x B and B x Zn were more effective in increasing the fruit plant^{-1} than alone application of Ca, B and Zn.

The increase in the number of fruit of tomato with

Ca application might be due the higher uptake of phosphorus that resulted in more flower cluster (Dey, 2000; Ilyas et al., 2014) and enhanced fruits plant^{-1} in tomato plant (Ilyas et al., 2014). Moreover, calcium may also inhibit flower abscission and, thus, results in increased fruits plant^{-1} (Smit and Combrink, 2005).

The foliar application of B enhances sugars levels of the stigma and helps in fruit set by promoting the pollen tube growth along with pollen germination (Singh et al., 2003). Boron regulates the metabolism of carbohydrates (Haque et al., 2011) and increase carbohydrate supply for formation of flowers and fruit set in tomato (Smit and Combrinke, 2005; Desouky et al., 2009) as well as decrease flower abscission (Smit and Combrink, 2005). Thus, boron application increased fruits plant^{-1}.

The zinc increase the number of fruits plant^{-1} by increasing IAA synthesis (Shnain et al., 2014) as well as carbohydrates translocation (Singh and Tawari, 2013). The foliar application of Zn also increases the photosynthates translocation to the fruit, and decrease in flowers and fruits abscission (Graham et al., 2000; Ruby et al., 2001; Ali et al., 2008). Thus, Zn foliar application may results in more fruits plant^{-1}. Thus, the combination of Ca+ and B was more effective in increasing fruits plant^{-1}. Similarly, B and Zn promote the translocation of carbohydrate from site of formation to sinks that resulted in increased fruits plant^{-1} (Singh and Tiwari, 2013).

Conclusions and Reccomendations

Sole application of calcium, boron and zinc and interactive effect of Ca × B and Ca × Zn had a significant effect on the growth as well as on the fruit production of tomato. Therefore, tomato plants could be sprayed with 0.6% Calcium, 0.25% Boron and 0.5% Zn alone and in combination for improving the vegetative and reproductive attributes. However, 0.5% boron enhanced the leaf area of tomato.

Author's Contributions

Bibi Haleema: is the principal author and this manuscript is part of her Ph.D work.
Abdur Rab: was the main supervisor.
Syed Asghar Hussain: was the co-supervisor of the principal author and helped to make available the resources for completion of research and also helped in reviewing the manuscript.

Acknowledgments

The authors highly appreciate the financial support of Higher Education Commission for the successful completion of this research project.

References

Abdalla, M.M. and N.H. El-Khoshiban. 2007. The influence of water stress on growth, relative water content, photosynthetic pigments, some metabolic and hormonal contents of two *Triticium aestivum* cultivars. J. App. Sci. Res. 3(12): 2062-2074.

Alloway, B.J. 2008. Fundamental aspects of zinc in soils and plants. Zinc in Soils and crop nutrition. 2nd Edi, Published by IZA and IFA, Brussels, Belgium and Paris, France, Pp: 30-52.

Ali, S., K.A. Riaz, G. Mairaj, M. Arif, M. Fida and S. Bibi. 2008. Assessment of different crop nutrient management practices for yield improvement. Aust. J. Crop Sci. 2(3): 150- 157.

MINFAL. 2009. Agricultural Statistics of Pakistan. Government of Pakistan. Ministry of Food, Agriculture and Livestock. Islamabad.

Asad, A., E.P.C. Blamey and D.G. Edward. 2003. Effects of boron foliar applications on vegetative and reproductive growth of sunflower. Ann. Bot. 92: 565–570. https://doi.org/10.1093/aob/mcg179

Ayyub, C.M., M.A. Pervez, M.R. Shaheen, M.I. Ashraf, M.W. Haider, S. Hussain and N. Mahmood. 2012. Assessment of various growth and yield attributes of tomato in response to pre-harvest applications of calcium chloride. Pak. J. Life Soc. Sci. 10(2): 102-105.

Bagheri, A.J.G. Paull, A.J. Rathjen, S.M. Ali and D.B. Moody. 1992. Genetic variation in the response of Pea (*Pisum Sativum L.*) to high soil concentrations of boron. Plant Soil. 146(1-2): 261-269. https://doi.org/10.1007/BF00012020

Basavarajeshwari, C.P., R.M. Hosamani, P.S. Ajjappalavara, B.H. Naik, R.P. Smitha and K.C. Ukkund. 2008. Effect of foliar application of micronutrients on growth and yield components of tomato (*Lycopersicon esculentum*). Karnataka J. Agric. Sci. 21(3): 428-430.

Bergmann, W. 1992. Nutritional disorders of plants. Development, visual and analytical diagnosis.

Gustav Fisher Verlag, Jena Germany.
Blamey, F.P.C., R.K. Zollinger and A.A. Schneiter. 1997. Sunflower production and culture. In Schneiter AA (Ed) Sunflower technology and production. Am. Soc. Agron. Pp 595-670.
Blevins, D.G. and K.M. Lukaszewski. 1998. Boron in plant structure and function. Ann. Rev. Plant Physiol. Mol. Biol. 49: 481–500. https://doi.org/10.1146/annurev.arplant.49.1.481
Bose, U.S. and S.K. Tripathi. 1996. Effect of micro nutrients on growth, yield and quality of tomato Cv. Pusa Ruby in M.P. Crop Res. Hissar. 12 (1): 61-64.
Brady, N.C. and R.R. Weil. 2002. The Nature and Properties of Soils. 13th Ed. Upper Saddle River, NJ: Prentice Hall.
Cakmak, I., M. Kalayci, H. Ekiz, H.J. Braun, Y. Kilinc and A. Yilmaz. 1999. Zn deficiency as a practical problem in plant and human nutrition in Turkey: A NATO-Science for stability project. Field Crop Res. 60: 175–188. https://doi.org/10.1016/S0378-4290(98)00139-7
Dale, G.B. and M.L. Krystyna. 1998. Boron in plant structure and function. Annu. Rev. Plant Physiol. Plant Mol. Biol. 49: 481-500. https://doi.org/10.1146/annurev.arplant.49.1.481
Del-Amor, F.M. and L.F.M Marcelis. 2006. Differential effect of transpiration and Ca supply on growth and Ca concentration of tomato plants. Sci. Hort. 111:17-23. https://doi.org/10.1016/j.scienta.2006.07.032
Denre, M., P.K. Bandopadhyay, A. Chakravarty, S. Pal and A. Bhattacharya. 2014. Effect of foliar application of humic acid, zinc and boron on biochemical changes related to productivity of pungent pepper (*Capsicum annuum* L.). Afr. J. Plant Sci. 8(6): 320-335. https://doi.org/10.5897/AJPS2014.1155
Desouky, I.M., L.F. Haggog, M.M.M. Abd-El-Migeed, Y.F.M. Kishk and E.S. El-Hadi. 2009. Effect of boron and calcium nutrients sprays on fruit set, oil content and oil quality of some olive cultivars. World J. Agric. Sci. 5: 180–185.
Dey, S.C. 2000. Tomato Crop. In: Vegetable Growing. Pub. Co., Agrobios. New Delhi, India. pp. 59-61.
Di-Masico, P., S. Kaiser and H. Sies. 1989. Lycopene as the most efficient biological carotenoid singlet oxygen quencher. Arch. Biochem. Biophys. 274: 532-8. https://doi.org/10.1016/0003-9861(89)90467-0
Dole, J.M. and H.F. Wilkins. 2005. Floriculture: Principles and Species.2nd ed. Prentice Hall, New Jersey.
Fageria, N.K., M.P.B. Filho, A. Moreira and C.M. Guimaraes. 2009. Foliar fertilization of crop plants. J. Plant Nutr. 32: 1044–1064. https://doi.org/10.1080/01904160902872826
Fageria, N.K. 1992. Maximizing crop yields. New York: Marcel Dekker.
Fageria, N.K. 2005. Soil fertility and plant nutrition research under controlled conditions: Basic principles and methodology. J. Plant Nutr. 28: 1–25. https://doi.org/10.1080/01904160500311037
Fageria, N.K. 2007. Soil fertility and plant nutrition research under field conditions: Basic principles and methodology. J. Plant Nutr. 30: 203–223. https://doi.org/10.1080/01904160601117887
Fageria, N.K. and V.C. Baligar. 2005. Enhancing nitrogen use efficiency in crop plants. Adv. Agron. 88: 97–185. https://doi.org/10.1016/S0065-2113(05)88004-6
Ganeshamurthy, A.N., G.C. Satisha and P. Prakash. 2011. Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes. Karnataka J. Agric. Sci. 24: 29-38.
Giovannucci, E. 1999. Tomatoes, tomatoes-based products, lycopene and cancer: Review of epidemiologic literature. J. Natl. Cancer Inst. 91: 317-331. https://doi.org/10.1093/jnci/91.15.1331A
Girma, K., K.L. Martin, K.W. Freeman, J. Mosali, R.K. Teal, W.R. Raun, S.M. Moges and D.B. Arnall. 2007. Determination of optimum rate and growth for foliar applied phosphorus in corn. Comm. Soil Sci. Plant Anal. 38: 1137–1154. https://doi.org/10.1080/00103620701328016
Graham, R.D., R.M. Welch and H.E. Bouis. 2000. Addressing micronutrient nutrition through enhancing the nutritional quality of staple foods. Adv. Agron. 70: 77-161. https://doi.org/10.1016/S0065-2113(01)70004-1
Gul, R. 2011. Characterization and inheritance studies of desirable attributes in tomato. M.Sc (Hons) Thesis. Department of Plant Breeding and Genetics. The University of Agriculture Peshawar.
Gupta, U.C. 1993. Factors affecting boron uptake by plants. In: Gupta UC, editor. Boron and Its Role in Crop Production. Boca Raton, FL, USA: CRC Press. pp. 87–104
Hao, X. and A.P. Papadopoulos. 2003. Effects of calcium and magnesium on growth, fruit yield

and quality in a fall greenhouse tomato crop grown on rockwool. Can. J. Plant Sci. 83: 903–912. https://doi.org/10.4141/P02-140

Haque, M.E., A.K Paul and J.R. Sarker. 2011. Effect of nitrogen and boron on the growth and yield of tomato (*Lycopersicon esculentum* M.). Int. J. Bio-Res. Stress. Manag. 2: 277–282.

Harris, K.D. and V. Mathuma. 2015. Effect of foliar application of boron and zinc on growth and yield of tomato (*Lycopersicon esculentum* Mill.). Asian J. Pharm. Sci. Technol. 5(2): 74-78.

Hatwar, G.P., S.V. Gondane, S.M. Urkude and O.V. Gahukar. 2003. Effect of micronutrients on growth and yield of chilli. J. Soil Crop. 13:1239-1254.

Hussain, P.R., R.S. Meena, M.A. Dar and A.M. Wani. 2012. Effect of post-harvest calcium chloride dip treatment and gamma irradiation on storage quality and shelf-life extension of Red delicious apple. J. Food Sci. Technol. 49: 415-426. https://doi.org/10.1007/s13197-011-0289-0

Hussain, N., A. Ali, G. Sarwar, F. Mujeeb and M. Tahir. 2003. Mechanism of salt tolerance in rice. Pedosphere. 13: 233-238.

Ibrahim, F.E. 2005. Effect of postharvest treatments on storage ability and keeping quality of Amaar apricot fruits. Ann. Agric. Sci. Moshtohors. 43: 849-867.

Ibrahim, M, A. Hassan, M. Iqbal, E.E. Valeem. 2008. Response of wheat growth and yield to various levels of compost and organic manure. Pak. J. Bot. 40:2135–2141

Ilyas, M., G. Ayub, Z. Hussain, M. Ahmad, B. Bibi, A. Rashid and Luqman. 2014. Response of tomato to different levels of calcium and magnesium concentration. World Appl. Sci. J. 31 (9): 1560-1564.

Imtiaz, M., A. Rashid, P. Khan, M.Y. Memon and M. Aslam. 2010. The role of micronutrients in crop production and human health. Pak. J. Bot. 42(4): 2565-2578.

Jan, M.T., P. Shah, P.A. Hollington, M.J. Khan and Q. Sohail. 2009. Agriculture Research: Design and Analysis, A Monograph. The University of Agriculture, Peshawar.

Kadir, S.A. 2004. Fruit quality at harvest of "Jonathan" apple treated with foliar applied calcium chloride. J. Plant Nutr. 27: 1991-2006. https://doi.org/10.1081/PLN-200030102

Kadir, S.A. 2005. Influence of pre harvest calcium application on storage quality of Jonathan apple in Kansas. Kansas Acad. Sci. 118: 129-36. https://doi.org/10.1660/0022-8443(2005)108[0129:IOPCAO]2.0.CO;2

Khavari-Nejad, R.A., F. Najafi and C. Tofigi, 2009. Diverse responses of tomato to N and P deficiency. Int. J. Agric. Biol. 11: 209–213.

Mallick, M.F.R. and Muthukrishnan, C.R. 1980. Effect of micro nutrients on tomato (*Lycopersicon esculentum* Mill.), Effect on flowering, fruit-set and yield. South Indian Hort. 28 (1): 14-20.

Marschner, H. 1995. Mineral nutrition of higher plants. 2nd Ed. Academic Press, San Diego. Pp. 379-396.

Menzel, C.M. and D.R. Simpson. 1987. Lychee nutrition: A review. Sci. Hort. 31: 195-224. https://doi.org/10.1016/0304-4238(87)90046-X

Nable, R.O., G.S. Banuelos and J.G. Paull. 1997. Boron toxicity. Plant Soil. 193: 181-198. https://doi.org/10.1023/A:1004272227886

Oyinlola, E.Y. 2004. Response of irrigated tomatoes (*Lycopersicon lycopersicum* Karst) to boron fertilizer: Growth and nutrient concentration. Nigeria. J. Soil Res. (2004) 5: 62-69.

Parr, A.J. and B.C. Loughman. 1983. Boron and membrane function in plants. In: Metals and Micronutrients: Uptake and Utilization by Plants, D.A. Robb and W.S. Pierpoint (Eds.). Academic Press, New York. pp. 87-107. https://doi.org/10.1016/B978-0-12-589580-4.500122

Passam, C.H., C. Ioannis, Karapanos, J. Penelope, Bebeli and D. Savvas. 2007. A review of recent research on tomato nutrition, breeding and post-harvest technology with reference to fruit quality. Eur. J. Plant Sci. Biotecnol. 1(1): 1-21.

Peter, K.H. 2005. Calcium: A central regulator of plant growth and development. The Plant Cell, 17:2142-2155. https://doi.org/10.1105/tpc.105.032508

Phillips, A.L., C. Barry and J. Giovannoni. 2004. Signal transduction systems regulating fruit ripening. Trends Plant Sci. 9: 331–338. https://doi.org/10.1016/j.tplants.2004.05.004

Rab, A. and I. Haq. 2012 Foliar application of calcium chloride and borax influences plant growth, yield, and quality of tomato (*Lycopersicon esculentum* Mill.) fruit. Tur. J. Agric. Fores. 36: 695-701.

Rashid, M. 2000. Secondary and micronutrients. In: Soil Science. National Book Foundation, Islamabad. pp. 342-343.

Rawat, P.S. and K.N. Mathpal. 1984. Effect of micronutrients on yield and sugar metabolism of some of the vegetables under Kumaon hill conditions. Sci. Cult. 50:243-244.

Reid, R. 2007. Update on boron toxicity and tolerance in plants. In: Xu F, Goldbach HE, Brown PH, Bell RW, Fujiwara T, Hunt CD, Goldberg S, Shi L, eds. Advances in Plant and Animal Boron Nutrition. Springer, Dordrecht, The Netherlands. pp. 83-90. https://doi.org/10.1007/978-1-4020-5382-5_7

Rubio, J.S., F. Garcia-Sanchez and R.F. Martinez. 2009. Yield, blossom-end rot incidence, and fruit quality in pepper plants under moderate salinity are affected by K+ and Ca^{2+} fertilization. Sci. Hort. 119: 79–87. https://doi.org/10.1016/j.scienta.2008.07.009

Ruby, R., V.S. Brahmachari and R. Rani. 2001. Effect of foliar application of calcium, zinc and boron on cracking and physicochemical composition of litchi. Orissa J. Hort. 29:50-54.

Sajid, M. 2009. Effect of micronutrients (Zn and B) as foliar spray on growth and yield of sweet orange (C*itrus sinensis* L.) cv. Blood red. Ph.D Dissertation. Department of Horticulture, The University of Agriculture Peshawar.

Shafeek, M.R., Y.I. Helmy, W.A. El-Tohamy and H.M. El-Abagy. 2013. Changes in growth, yield and fruit quality of cucumber (*Cucumis sativus* L.) in response to foliar application of calcium and potassium nitrate under plastic house conditions. Res. J. Agric. Biol. Sci. 9: 114–118.

Shnain, R.S., V.M. Prasad and S. Saravanan. 2014. Effect of zinc and boron on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill) cv. Heem Sohna, under protected cultivation. Eur. Acad. Res. (3): 4572-4597.

Singh, H.M. and J.K. Tiwari. 2013. Impact of micronutrient spray on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill). Hort. Flora. Res. Spectrum. 2(1): 87-89.

Singh, M., V.K. Batra, A.K. Bhatia, V. Singh and S.K. Arora. 2003. Response of foliar application of micronutrients on tomato variety Hisar Arun. Veg. Sci. 30 (2): 182-184.

Smit, J.N. and N.J.J. Combrink. 2005. Pollination and yield of winter-grown greenhouse tomatoes as affected by boron nutrition, cluster vibration and relative humidity. South Afr. J. Plant Soil. 22: 110–115. https://doi.org/10.1080/02571862.2005.10634691

Srivastava, A.K. and S. Singh. 2003. Soil-plant nutrient limits in relation to optimum fruit yield of sweet orange (*Citrus sinensis* Osbeck) cultivar Mosambi. Indian. J. Agric. Sci. 73(4): 209-211.

Srividya, S., S.S. Reddy, V. Sudhavani and R. Reddy .2014. Effect of post-harvest chemicals on fruit physiology and shelf Life of tomato under ambient conditions. Int. J. Agric. Food Sci. Technol. 5(2): 99-104.

Statistix_8 Analytical Software. 2003. Statistix_ 8 User's Manual. Tallahassee, Florida: Analytical Software. ISBN 1-881789-06-3.

Swietlik, D. 2002. Zinc nutrition of fruit trees by foliar sprays. Acta Hort. 93(594): 123-129. https://doi.org/10.17660/ActaHortic.2002.594.11

USDA National Nutrient Database for Standard Reference Release 28 (2016). Basic Report 11529, Tomatoes, red, ripe, raw, year round average Report Date: January 03, 2016. Nutrient values and weights are for edible portion. Software v.2.3.2. The National Agricultural Library.

Yamaguchi, T., T. Hara and Y. Sonoda. 1986. Distribution of calcium and boron in the pectin fraction of tomato leaf cell wall. Plant Cell Physiol. 27:729-732.

Yaseen, M. and M. Ahmad. 2010. Nutrition management in Citrus: Effect of multi nutrients foliar feeding on the yield of kinnow at different locations. Pak. J. Bot. 42: 1863-1870.

Zekri, M. and T.A. Obereza. 2003. Micronutrient deficiencies in citrus: Iron, zinc and manganese. Institute of Food and agricultural Services, University of Florida, USA.