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Research Article

EFFECT OF BORON AND CALCIUM ON GROWTH, YIELD AND QUALITY OF TOMATO (*Solanum lycopersicum* L.) Cv. ABHILASH

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Abstract: The present investigation was carried out at Agricultural Research Farm, Department of Horticulture, Suresh Gyan Vihar University, Jagatpura, Jaipur, Rajasthan to study the effect of Boron and Calcium on plant growth, yield and quality attributes on tomato under semi-arid condition during kharif season of the year 2022-23. The experiment was laid out in Factorial Randomized Block Design with three replications which comprises of sixteen treatment combinations included four different levels of Boron (0, 0.1, 0.2 and 0.3%) and four levels of Calcium (0, 0.2, 0.4 and 0.6%). The interaction effect of Boron @ 0.2 % + Calcium @ 0.6 % significantly influenced majority of vegetative characters, yield attributes and biochemical parameters. The highest plant height (47.67 cm) and (135.55 cm) at 30 DAT and 60 DAT, respectively, (43.33) leaves per plant, (9.33) primary branches plant^{-1}, (126.40 g) heaviest fruit weight, maximum (5.26 kg) plant^{-1} and (65.59 t ha^{-1}) yield and highest (3.44) B:C ratio was recorded at Boron @ 0.2 % + Calcium @ 0.6 %. The maximum (5.56%) TSS, (24.90 mg/100g) ascorbic acid, (17.18 days) shelf-life and minimum (0.26%) acidity also observed in same treatment combination in biochemical parameters. It is, therefore, concluded from the present study that the foliar application of Boron @ 0.2 % + Calcium @ 0.6 % at 30 days after transplanting were found to be best and showed a significant effect on vegetative growth, yield and quality of tomato cv. 'Abhilasha'.

Keywords: *Boron, Calcium, Tomato, Interaction, Growth, Yield, Quality, Biochemical*

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Introduction

Tomato (*Solanum lycopersicum* L.) belongs to family solanaceae having chromosome number 2n=24 and is a self-pollinated crop. Tomato is one of most popular and nutritious fruit vegetables, widely grown around the world. According to available information of numerous wild and cultivated relatives, it originated in Peru of South America, Ecuador and Bolivia and its production spread throughout the world and it is grown in the open fields, greenhouses and net houses [1].

The major tomato growing countries are China, India, USA, Turkey, Egypt, and Italy. Total area under tomato crop in India is assessed to be 0.778 million ha with the production of 21.18 million tonnes and productivity of 27.22 tonnes/ha [2]. The highest productivity is obtained in the United States of America. In India, the Leading producing states are Andhra Pradesh, Karnataka, Maharashtra, Uttar Pradesh, Orissa, Assam, Madhya Pradesh, and Bihar.

Tomato is one of the most popular and widely grown vegetable crops, ranking second in importance next to potato in many countries [3]. The application of less-than-optimal fertilizer dose, it decreases the yield and quality of tomato fruit [4]. The yield and fruit quality depends on the cultivar and the climatic conditions in which it is grown [5], as well as an optimum supply of fertilizers [6]. Generally, a balanced supply of nutrients is essential for optimum yield and fruit quality [7]. Calcium is an important secondary nutrient that plays a key role in the structure of cell walls and cell membranes, fruit growth, and development, as well as general fruit quality [8]. It enhances resistance to bacterial and viral diseases [9]. The calcium taken up from the soil is translocated to the leaves but very little goes from the leaves to the fruit. The plants require proper amount of calcium for vigorous growth of leaf and root as well as canopy development [10]. Boron is also an important role in tomato quality but it is easily leached out from the soil and its deficiency can occur in tomatoes grown under heavy rainfall conditions and can cause fruit cracking [11]. Boron deficiency appears as thickened, wilted, or curled leaves and the cracking and rotting of fruit, tubers, or roots. Adequate boron levels help to maintain leaf potassium levels in tomato during fruit development [12]. Foliar application of boron is preferred over soil application because of the very narrow range from deficient to toxic levels [13]. Tariq and Mote (2007) [14] reported that the benefits of Ca and B application depend on a balance between Ca and B levels in the plant. The low Ca and high B content may be detrimental to plant growth and yield. The current study was therefore initiated to investigate the influence of foliar application of calcium and boron either alone or in combination on the growth, quality, and yield of tomato. Boron and Calcium are important plant nutrient that may overcome the fruit cracking and blossom end rot melody and improve the socio-economic status of farmers. Its production should be planned according to the need of the market. So, small, or marginal farmers can earn a good profit per unit area.

Materials and Methods

The present investigation was carried out at Agricultural Research Farm, Department of Horticulture, Suresh Gyan Vihar University, Jagatpura, Jaipur, Rajasthan during kharif season of the year 2022-23. The field experiment was laid out in Factorial Randomized Block Design (RBD) with 16 treatments and three replications. The treatments were randomized at the time of transplanting of seedlings. The size of the net plot was 1.8 m x 3.0 m. The tomato cv. 'Abhilasha' was chosen for the experiment and seeds were collected from Jaipur city. The seedlings were raised in shade net house in the month of June and 5 weeks old seedlings were transplanted at 60 cm x 45 cm spacing's on 30th July, 2022. The soil of the experimental field was sandy loam in texture and had pH 8.2 and EC 0.48 dSm-1, organic carbon (0.45 %).

Table-1 Effect of Calcium and Boron on vegetative growth parameters of tomato cv. 'Abhilasha'

	Plant height (cm)			No. of leaves /plant	No of branches / plant	No. of days to first flowering	No. flower clusters/plant	No. of flowers/cluster
	30 DAT	45 DAT	60 DAT					
Control (Water spray)	22.73	38.53	93.54	21.73	5.94	37.27	4.17	4.07
Boron								
Boron @ 0.1 %	24.53	40.80	99.50	22.53	6.44	34.50	4.45	4.32
Boron @ 0.2 %	25.67	43.27	102.61	22.87	6.84	33.84	4.62	4.49
Boron @ 0.3 %	26.60	45.93	105.52	23.93	6.73	32.61	4.83	4.69
SEm±	0.98	1.32	1.70	0.91	0.08	1.01	0.19	0.18
C.D. (p=0.05)	2.83	3.84	4.93	NS	0.24	NS	NS	NS
Calcium								
Calcium @ 0.2 %	27.40	47.00	99.82	24.07	6.91	33.47	5.07	4.94
Calcium @ 0.4 %	28.73	46.73	104.52	25.40	7.08	31.50	5.31	5.18
Calcium @ 0.6 %	29.47	58.07	106.45	26.80	7.44	30.71	5.48	5.31
SEm±	0.98	1.32	1.70	0.91	0.08	1.01	0.19	0.18
C.D. (p=0.05)	2.83	3.84	4.93	2.65	0.24	2.93	0.56	0.52
Interaction between Calcium x Boron								
Boron @ 0.1 % + Calcium @ 0.2 %	31.40	61.40	109.45	28.73	7.66	30.41	5.71	5.56
Boron @ 0.1 % + Calcium @ 0.4 %	32.60	63.20	112.42	30.27	7.95	29.38	5.87	5.74
Boron @ 0.1 % + Calcium @ 0.6 %	34.67	66.07	114.48	31.67	7.69	27.50	6.41	6.25
Boron @ 0.2 % + Calcium @ 0.2 %	36.47	68.47	123.69	33.53	8.10	25.72	6.57	6.47
Boron @ 0.2 % + Calcium @ 0.4 %	43.60	72.33	127.44	39.60	8.40	25.48	7.86	7.76
Boron @ 0.2 % + Calcium @ 0.6 %	47.67	68.60	135.55	43.33	9.33	24.48	8.49	8.39
Boron @ 0.3 % + Calcium @ 0.2 %	40.27	71.20	111.33	36.27	8.12	27.72	7.36	7.26
Boron @ 0.3 % + Calcium @ 0.4 %	39.53	72.47	123.23	35.53	8.39	29.07	7.26	7.12
Boron @ 0.3 % + Calcium @ 0.6 %	37.40	65.73	119.49	33.07	7.91	30.37	6.84	6.74
SEm±	1.95	2.65	3.40	1.83	0.17	2.02	0.38	0.36
C.D. (p=0.05)	5.66	NS	9.86	5.30	0.49	NS	1.12	1.03

Table-2 Effect of Calcium and Boron on yield and fruit quality parameters of tomato cv. 'Abhilasha'

	No. fruits /plant	Fruit diameter (cm)	Fruit weight (g)	Yield/plant (kg)	Yield (t/ha)	B:C ratio
Control (Water)	37.53	2.97	46.48	1.94	24.18	1.28
Boron						
Boron @ 0.1 %	41.33	3.81	58.44	2.44	30.40	1.60
Boron @ 0.2 %	47.27	3.97	68.08	2.84	35.38	1.86
Boron @ 0.3 %	46.47	3.85	65.33	2.73	33.99	1.78
SEm±	1.10	0.10	1.97	0.09	1.10	
C.D. (p=0.05)	3.20	NS	5.72	0.26	3.20	
Calcium						
Calcium @ 0.2 %	51.53	3.92	69.77	2.91	36.30	1.91
Calcium @ 0.4 %	54.73	3.96	73.88	3.08	38.43	2.02
Calcium @ 0.6 %	63.73	4.13	82.34	3.44	42.84	2.25
SEm±	1.10	0.10	1.97	0.09	1.10	
C.D. (p=0.05)	3.20	0.29	5.72	0.26	3.20	
Interaction between Calcium x Boron						
Boron @ 0.1 % + Calcium @ 0.2 %	65.33	4.17	87.54	3.66	45.54	2.40
Boron @ 0.1 % + Calcium @ 0.4 %	69.27	4.56	94.65	3.95	46.04	2.42
Boron @ 0.1 % + Calcium @ 0.6 %	69.47	4.31	88.49	3.69	49.24	2.59
Boron @ 0.2 % + Calcium @ 0.2 %	71.87	4.24	98.25	4.10	51.11	2.69
Boron @ 0.2 % + Calcium @ 0.4 %	72.93	4.74	105.47	4.40	54.87	2.88
Boron @ 0.2 % + Calcium @ 0.6 %	74.87	5.16	126.40	5.26	65.59	3.44
Boron @ 0.3 % + Calcium @ 0.2 %	70.07	4.34	98.63	4.12	54.73	2.87
Boron @ 0.3 % + Calcium @ 0.4 %	73.73	4.55	105.21	4.39	51.31	2.69
Boron @ 0.3 % + Calcium @ 0.6 %	68.87	4.24	93.63	3.91	48.71	2.55
SEm±	2.20	2.20	3.94	0.18	2.21	
C.D. (p=0.05)	6.40	0.57	11.44	0.51	6.40	

A basal dose of well rotten FYM @ 5 kg/m² was uniformly mixed in the soil 15 days before transplanting. Half dose of nitrogen (10 g/ m²), full dose of phosphorus (20 g/m²) and potassium (10 g/ m²) was supplied through urea, single super phosphate and muriate of potash, respectively as basal application at transplanting time. Remaining half dose of nitrogen (10 g/m²) was applied at 30 DAT. The tomato plants were foliar sprayed with Calcium Nitrate ($Ca(NO_3)_2 . 4 H_2O$) and Boric Acid (H_3BO_3) as a source of calcium and boron at 30 days after transplanting as per recommended in respective treatments. Different intercultural practices like gap filling, irrigating, staking, weeding etc. were performed as per crop requirement. The five plants of each plot were randomly selected and tagged. The data were recorded for various growth, yield and quality parameters in tomato during the course of investigation subjected to statistical analysis by using factorial RBD for analysis of variance (ANOVA) as suggested online opstat software by Sheoran *et al.* (1998) [15].

Results and Discussion

Vegetative growth and yield parameters:

Plant height (cm)

The highest plant height (105.52 cm) and (106.45 cm) was recorded at boron @0.3 and calcium @0.6%, respectively at 60 DAT whereas, the lowest plant height (93.54 cm) was recorded in control (water spray). The interaction effect of calcium and boron showed significant effect on plant height at all periodic growth stages 30, 45 and 60 DAT. The highest plant height (47.67 cm) and (135.55 cm) was observed at 30 and 60 DAT, respectively in plant sprayed with boron @ 0.2% + calcium @0.6% and the lowest plant height (22.73 cm) and (93.54 cm) at 30 and 60 DAT, respectively was recorded in plant sprayed with water in control treatment. Boron plays an important role in activation of cell division and cell elongation. Similarly, calcium is also important for proper cell division, cell elongation, and cell wall development.

Table-3 Effect of Calcium and Boron on biochemical parameters of tomato cv. 'Abhilasha'

	TSS (%)	Acidity (%)	Vitamin –C (mg/100g)	Shelf-life (days)
Control (Water spray)	2.05	0.56	19.41	8.87
Boron				
Boron @ 0.1 %	2.58	0.47	21.78	11.24
Boron @ 0.2 %	3.00	0.46	25.35	13.96
Boron @ 0.3 %	2.88	0.44	24.35	11.52
SEm±	0.09	0.01	0.45	0.47
C.D. (p=0.05)	0.27	0.03	1.31	NS
Calcium				
Calcium @ 0.2 %	3.08	0.43	14.94	13.34
Calcium @ 0.4 %	3.26	0.42	15.82	13.79
Calcium @ 0.6 %	3.63	0.41	17.63	14.59
SEm±	0.09	0.01	0.45	0.47
C.D. (p=0.05)	0.27	0.03	1.31	1.36
Interaction between Calcium x Boron				
Boron @ 0.1 % + Calcium @ 0.2 %	3.86	0.39	18.74	13.06
Boron @ 0.1 % + Calcium @ 0.4 %	4.18	0.39	20.27	15.51
Boron @ 0.1 % + Calcium @ 0.6 %	3.90	0.41	18.95	15.09
Boron @ 0.2 % + Calcium @ 0.2 %	4.33	0.30	19.42	14.73
Boron @ 0.2 % + Calcium @ 0.4 %	4.65	0.29	20.83	15.69
Boron @ 0.2 % + Calcium @ 0.6 %	5.56	0.26	24.90	17.18
Boron @ 0.3 % + Calcium @ 0.2 %	4.35	0.36	19.49	13.29
Boron @ 0.3 % + Calcium @ 0.4 %	4.64	0.31	20.78	15.60
Boron @ 0.3 % + Calcium @ 0.6 %	4.13	0.33	18.50	14.86
SEm±	0.19	0.02	0.90	0.94
C.D. (p=0.05)	0.55	0.06	2.62	2.72

Therefore, boron, and calcium enhance the number of metabolites necessary for building plant organs, consequently the vegetative growth of plants increased [16]. These findings are in close conformity with the findings of Hussain *et al.* (2001) [17] and Wójcik and Lewandowski (2016) [18].

Average number of leaves plant -1

It is evident from the data presented in [Table 1] that the significant difference was observed among all treatments at 60 DAT. The maximum (43.33) leaves plant-1 were observed in plant sprayed with boron @ 0.2% + calcium @0.6% and the lowest (21.73) leaves plant-1 in control, which was reduced significantly. The calcium @0.6% also favoured for production of more number of leaves plant-1 but boron showed non-significant effect. This might be due to enhancing of metabolites necessary for building plant organs by calcium and boron. Similar results were also reported by Sivaiah *et al.* (2013) [19] and Sathya *et al.* (2013).

Number of primary branches

The maximum (6.84) and (7.44) branches were produced per plant at boron @0.2 and calcium @0.6%, respectively at 60 DAT whereas, the minimum (5.94) branches per plant was recorded in control (water spray). The interaction effect of calcium and boron showed significant effect on number of branches per plant. The maximum (9.33) branches was recorded at 60 DAT in plant sprayed with boron @ 0.2% + calcium @0.6% whereas, minimum (5.94) branches was recorded in control. The increased plant height with foliar application of calcium and boron may be produced more branches due to more available space and more photosynthate. These results are found in agreement with the findings of Mishra *et al.* (2012) [20], Patil *et al.* (2009) and Sathya *et al.* (2013).

Number of flower clusters and flowers

The maximum (5.31) flower clusters per plant and (5.18) flowers per cluster were recorded in calcium @0.4% which is at par with calcium @0.6% and boron showed non-significant effect on both parameters. The interaction effect of calcium and boron showed significant effect on number of branches per plant. The maximum (8.49) flower clusters per plant and (8.39) flowers per cluster in plants sprayed with boron @ 0.2% + calcium @0.6% whereas, minimum (4.17) flower clusters per plant and (4.07) flowers per cluster in plants was recorded in control. Application of micronutrients might be attributed to enhance the photosynthesis activity and increased production and accumulation of carbohydrates. Micronutrients may have favorable effect on vegetative growth and retention of flowers. Singh and Tiwari (2013) [21]; Mishra *et al.* (2012) and Sathya *et al.* (2013) also reported the similar results.

Average number of fruits plant-1

In [Table-2] showed that the maximum (47.27) fruits per plant were observed in boron @ 0.2% and (63.73) fruits per plant in calcium @ 0.6% treatment whereas, minimum (37.53) fruits per plant were recorded in water sprayed plants. The interaction effect between calcium and boron significantly influenced number of fruits per plant and the maximum (74.87) fruits per plant in boron @ 0.2% + calcium @ 0.6% and it is at par with all interaction treatments except boron @ 0.1% + calcium @ 0.2 % (65.33) fruits per plant while, the minimum (37.53) fruits per were observed in control plants sprayed with water. It may also be stated that the sufficient application and the efficient absorption of foliar sprayed calcium and boron were promote the production of more photosynthesis required for good number of tomato fruits.

Fruit diameter (cm)

Calcium significantly increased the fruit diameter but in different concentrations of boron showed the non-significant difference on fruit diameter. The maximum (4.13 cm) fruit diameter was recorded in calcium @ 0.6% treatment which is significantly higher over other treatments. The maximum (5.16 cm) fruit diameter was observed in boron @ 0.2% + calcium @ 0.6% which is at par with (4.74 cm) in boron @ 0.2% + calcium @ 0.4%. The interaction effect of both treatments showed the significant difference over other treatments. It might be due to calcium and boron promote the photosynthesis rate and cell divisions that increase the fruit diameter (Singh and Tiwari, 2013; Mishra et al., (2012) and Sathya *et al.* (2013).

Fruit weight (g)

The heaviest (68.08 g) fruit were recorded in boron @ 0.2 % treatment. Calcium treatment produced heavier fruits than boron treatments and (82.34 g) fruit weight was recorded in calcium @ 0.6 % treatment. The interaction effect between calcium and boron significantly influenced fruit weight and the highest (126.40 g) fruit weight was recorded in boron @ 0.2% + calcium @ 0.6% and it produced significantly heavier fruits than other treatments while, the lightest (46.48 g) fruit weight were recorded in control [Table-2]. It may also be stated that the application of optimum dose of calcium and boron were promote the production of more photosynthesis required for good fruit weight and its components.

These results are in close conformity with the findings of Singh and Tiwari (2013) and Wójcik and Lewandowski (2016).

Yield Parameters

[Table-2] revealed that the boron @ 0.2% produced the highest (2.84 kg) plant-1 and (35.38 tonnes ha^{-1}) tomato yield and calcium @ 0.6 % produced the highest (3.44 kg) plant-1 and (42.84 tonnes ha^{-1}) tomatoes. Boron @ 0.2% and calcium @ 0.6% produced significantly higher yield over other treatments whereas, control (water spray) produced the lowest yield (1.94 kg) plant-1 and (24.18 tonnes ha^{-1}). The highest (5.26 kg) yield plant-1 and (65.59 tonnes ha^{-1}) yield was recorded in boron @ 0.2% + calcium @ 0.6%. It was observed that interaction effects between calcium and boron had significant difference on fruit yield ha^{-1} which was much higher in comparison to control (1.94 kg) plant-1 and (24.18 tonnes ha^{-1}). Micronutrients application may be attributed to enhanced photosynthesis activity and increased production and accumulation of carbohydrates and favorable effect on fruits, which increased number of fruits per plant besides increasing the size. These results in agreement with the findings of Singh and Tiwari (2013), Mishra *et al.* (2012), Patil *et al.* (2009), Sivaiah *et al.* (2013) and Sathya *et al.* (2013). The highest benefit: cost ratio (3.44) was recorded in boron @ 0.2% + calcium @ 0.6% whereas, the lowest benefit: cost ratio (1.28) was recorded under control (water spray). It was observed that the interaction effects between calcium and boron had higher benefit: cost ratio as compare to boron and calcium alone. The calculated B: C ratio (3.44) is gives valuable information to farmers or growers in semi-arid climatic conditions to improve socio-economic status and livelihood of growers.

Biochemical Parameters

It apparent from the data presented in [Table-3] the highest TSS (5.56%) was observed in boron @ 0.2% + calcium @ 0.6% whereas lowest TSS (2.05%) was recorded in control. The lowest (0.26%) acidity was recorded in boron @ 0.2% + calcium @ 0.6% and highest (0.56%) acidity was recorded in control. It indicates that the TSS and acidity had reversible relationship means when TSS increases then acidity decreases. The date in [Table-3] revealed that the interaction effect between boron and calcium had significant effect on both parameters over control. Boron and calcium enhance the number of metabolic activities that make biochemical changes. The (25.35 mg/100g) and (17.63 mg/100g) Vitamin - C was observed in boron @ 0.2 % and calcium @ 0.6%, respectively. The highest (24.90 mg/100g) Vitamin - C was also recorded in boron @ 0.2% + calcium @ 0.6% whereas lowest (19.41 mg/100g) Vitamin - C was recorded in control. It was observed that different concentrations of boron, calcium and combination of both nutrients had significant. The ascorbic acid content consistently increased with increasing calcium concentration, as it reduces loss of ascorbic acid in the storage due to oxidative regulation processes in the cytosol, where calcium delays rapid oxidation of ascorbic acid [22].

Average shelf-life of tomato (days)

The maximum (17.18 days) shelf-life of tomato fruits were recorded in boron @ 0.2% + calcium @ 0.6% and minimum (8.87 days) shelf-life was recorded in control (water sprayed plants). No significant effect was observed in different concentrations of boron but calcium nutrient increased the tomato shelf-life. The interaction of boron and calcium had significant effect over control. However, some other treatments in interaction of boron and calcium were observed at par. It indicates that foliar sprayed nutrients increased the shelf-life of tomato. The significant increase in shelf-life of tomato fruits may be due to the effect of calcium and boron that helped in improving the shelf-life. The calcium accelerates most of the physiological attributes, which results in increased cell division and cell elongation. The cell enlargement occurs as a result of plasticity of cell wall.

Application of research: Tomato has blossom end rot and fruit cracking problem and generated information is useful for farmers for improvement of their socio-economic status.

Research Category: Horticulture

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Cultivar / Variety / Breed name: Tomato (*Solanum lycopersicum* L.) Cv. Abhilash

Conflict of Interest: None declared

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