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Shreya Mondal
Department of Soil Science and Agricultural Chemistry, Palli Siksha Bhavan, Institute of Agriculture, Visva Bharati, Sriniketan, Birbhum, West Bengal, India

GK Ghosh
Department of Soil Science and Agricultural Chemistry, Palli Siksha Bhavan, Institute of Agriculture, Visva Bharati, Sriniketan, Birbhum, West Bengal, India

Corresponding Author:
GK Ghosh
Department of Soil Science and Agricultural Chemistry, Palli Siksha Bhavan, Institute of Agriculture, Visva Bharati, Sriniketan, Birbhum, West Bengal, India

Effect of zinc and boron on growth, yield and quality of Tomato (*Lycopersicon esculentum*) with different application methods in Alfisols of West Bengal

Shreya Mondal and GK Ghosh

Abstract

Tomato (*Lycopersicon esculentum*) is an important vegetable crop from Solanaceae family. It is an important source of Vitamin A, C and minerals like potassium, folate and vitamin E, soluble and insoluble dietary fibers. And major contributors of antioxidants such as carotenoids (Especially, lycopene and β-carotene), phenolics, ascorbic acid. This experiment was laid out in Palli sikhsha bhavana, agriculture farm, Visva Bharati (Sriniketan) in two rabi seasons of 2018-19 and 2019-20 which consisted of 9 treatments of zinc and boron combination with different doses and application method replicated thrice in factorial randomized block design to improve plant growth, yield and quality and also decide the best possible treatment combination. Three treatments of Zinc *viz.* Z_0 (no zinc), Z_f (foliar application @0.5% $ZnSO_4$), Z_s (soil application @6 kg/ha $ZnSO_4$) and three treatments of Boron *viz.* B_0 (no boron), B_f (foliar application @0.25% borax), B_s (soil application @2 kg/ha borax) randomized among themselves. Results reveal that plant height and branch number was not affected with applied treatments but total chlorophyll content of leaves was improvised with boron soil application @2 kg/ha at 30DAT and with boron foliar application @0.25% at 60 DAT. Treatment combination (T_8) of boron in soil @2 kg/ha and zinc as foliar @0.5% was superior for total yield (6.97 ton/ha) of tomato. Combined foliar application of boron @0.25% and zinc @0.5% (T_5) significantly increased number of fruits per plant (5) and fruit yield per plant (543.81 gm). There was no significant effect on fruit length and average fruit yield per plant. Quality attributes *viz.* Vitamin C (902.5 mg/g) and total sugar (2.10) were influenced significantly with zinc soil application @6 kg/ha (T_3) whereas Reducing sugar (2.11) of tomato was influenced by boron soil application @2 kg/ha (T_7). Thus, the results reveal that combined application of boron as foliar @0.25% and zinc soil @6 kg/ha would be the best recommended treatment to impact on plant growth, yield and quality of tomato fruits in red and lateritic soils of Birbhum district.

Keywords: Tomato, zinc, boron, yield, quality, vitamin c, reducing sugar, total sugar, chlorophyll

Introduction

Tomato (*Lycopersicon esculentum*) is an important vegetable crop, which belongs to the family Solanaceae and also used in daily diet due to its good taste It is an important source of Vitamin A, C (Sekhar *et al.*, 2010) [18] and minerals like potassium, folate and vitamin E, soluble and insoluble dietary fibers. Tomatoes are major contributors of antioxidants such as carotenoids (especially, lycopene and β-carotene), phenolics, ascorbic acid (vitamin C) and small amounts of vitamin E in daily diets (Rai *et al.*, 2012) [19]. Inspite of adequate application of NPK fertilizer, normal growth of high yielding varieties could not be obtained due to little or no application of micronutrients. Tomato being a heavy feeder and exhaustive crop removes substantial number of micronutrients from soil. Alfisols which are acidic in soil reaction, light textured, low organic matter and P and are often deficient in S and micronutrients like Zn, B, Mo (Panda *et al.* 1991, Sakal and Singh 1997) [20]. Zinc is an indispensable micronutrient for proper plant growth and development. It plays an important role in different plant metabolic processes such as enzyme activity, development of cell wall, respiration, photosynthesis, chlorophyll formation and other biochemical functions whereas Boron is required for the translocation of sugars, root extension and growth of meristematic tissues, the pyrimidine biosynthetic pathway and the ATPase, it is also involved in translocation of sugars, synthesis of amino acid, protein and carbohydrate metabolism. It plays a vital role in pollen enlargement, fertilization and flowering processes of plants. Chaudhry *et al.* (2007) stated that micronutrients especially zinc (Zn) and boron (B) significantly increased the crop yield over control when applied single or in combination with each other, while Mandal *et al.* (2007) observed significant positive interaction between fertilizer treatments and physiological stages of crop growth. Applications of micro- nutrients i.e.zinc and boron have been reported in increasing growth and fruit yield in tomato (Naga *et al.*, 2013) [10].

Thus, the key role played by Zn and B nutrition in plant growth, the present study has been designed to find out the suitable dose and method of Zn and B application for tomato growth, production and quality aspect in Alfisols of West Bengal.

Materials and Methods

Field experiment was conducted in Palli-sikhsha bhavana farm, Visva Bharati (Sriniketan) in two rabi season of 2018-19 and 2019-20 which consisted of 9 treatments of zinc and boron combination with different doses and application method replicated thrice in factorial randomized block design. The treatments consisted of T_1: only recommended dose of fertilizer (control); T_2:RDF+ zinc foliar @0.5%; T_3: RDF+ zinc soil application @ 6 kg/ha; T_4: RDF+ boron foliar application @ 0.25%; T_5: RDF + combined application of boron foliar @0.25% and zinc foliar @0.5%; T_6: RDF + combined application of boron foliar @0.25% and zinc soil @6 kg/ha; T_7: RDF + boron soil application @2 kg/ha; T_8: RDF + combined application boron soil application @2kg/ha and zinc foliar @0.5%; T_9: RDF + combined application for boron soil @2 kg/ha + zinc soil @6 kg/ha.

The crop was planted (Spacing of 80 cm x 60 cm), fertilized ($N:P_2O_5: K_2O$::100:50:50) and irrigated as per recommended practices. The crop variety used was Abhilash of seminist. The fertilizer sources for nitrogen, phosphorous and potassium are urea, DAP and muriate of potash and sources for zinc and boron are zinc sulphate heptahydrate and borax. Before fertilizer application random soil samples were collected from experimental site for analysis which revealed the initial soil status of that site (Table1).

Table 1: Initial soil status of experimental site

Particulars	Values obtained	Rating
pH	6.1	Moderately acidic
Electrical conductivity (dS/m) at 25° C	0.09	Normal
Organic carbon (%)	0.29	Low
Available Nitrogen (kg/ha)	171.42	Low
Available Phosphorous (kg/ha)	16.40	Medium
Available Potassium(kg/ha)	183.31	Medium
Available Zn (mg/kg)	0.52	Low
Available B (mg/kg)	0.009	Low

Before transplantation composite soil samples were collected randomly from demarcated experimental site at 0-15cm depth, air dried, powdered and analysed for different soil properties. Soil pH and electrical conductivity were determined as suggested by Jackson (1973). Wet digestion method was employed for soil organic carbon content analysis (Walkley & Black, 1934). Available N content in soil was estimated using Kjeldahl distillation process (Subbiah & Asija, 1956). Bray's No. 1 method was followed for determining available P (Bray & Kurtz, 1945). Ammonium acetate (CH_3 $COONH_4$) was used for extracting available potassium (K) (Jackson, 1973) and readings were taken in flame photometer. 0.005 M DTPA solution (0.005 M Diethylene Triamine Penta Acetic acid + 0.1 M Triethanol amine +0.01 M $CaCl_2$), adjusted to pH 7.3 ± 0.05 was used as the extractant (1:2 soil to extractant ratio) to extract plant available Zn content (Lindsay & Norvell, 1978) with the help of Atomic absorption Spectrophotometer (AAS) and hot water extractable method for boron (Berger & Troug, 1939).

Different growth parameters that were observed are plant height, number of branches and chlorophyll content in leaves and were collected at 30 days interval till harvest from five randomly tagged plants. Chl. *a*, chl. *b* and total chorophyll were analysed as per standard procedure given by Hiscox & Israelstam (1979). Data regarding yield and its attributes like total yield (ton/ha), fruit length (mm), fruit width (mm), number of fruits per plant, fruit yield per plant (gm) and average fruit weight per plant (gm) were collected after harvesting. Quality parameters like vitamin C, reducing sugar and total sugar were estimated from broccoli head as per standard procedure.

Statistical analysis was carried out following the method of analysis of variance (ANOVA). For comparisons between treatment means, standard error of the mean difference (Sd) and least significant difference (LSD) at $\alpha = 0.05$ level of significance were calculated (Gomez and Gomez, 1984) in Microsoft office Excel 2007.

Result and Discussion

Growth parameters

The results in table 2 indicate the data obtained for plant height and number of branches as influenced by soil and foliar application of zinc and boron on tomato plants at 30 DAT and 60 DAT. Plant height is seen to have increased with gradual time but results show no significant impact on it. Highest plant height was recorded for combined application of boron in soil @2 kg/ha and zinc as foliar @0.5% with a value of 53.89 cm and 103.89 cm for 30DAT and 60DAT respectively over control plots (T_1) which recorded lowest value. Even in number of branches application of zinc and boron had no significant effect. Highest value was recorded for combined application of boron in soil @2 kg/ha and zinc as foliar @0.5% (T_8) and lowest value was recorded for control plots with no boron and zinc application (T_1). For both 30DAT and 60DAT. Ali *et al.* (2015) [1] reported that combined foliar application of zinc and boron was more effective than the individual application of zinc or boron on growth parameters.

Chlorophyll is an important photosynthetic pigment which largely determines photosynthetic capacity for plant growth. Chlorophyll A (Chl *a*) and Chlorophyll B (Chl *b*) are important for primary reaction. They absorb sunlight at different wavelengths which directly influence the photosynthetic capacity of the plant (Croft *et al.*, 2017). The data regarding chlorophyll content of leaves as influenced by zinc and boron application for the years 2018-19, 2019-20 and pooled analysis for both years at various growth is shown in table 3. Data reveals that the application of boron and zinc had no significant effect on chlorophyll a and chlorophyll b at 30 DAT and 60 DAT. But the highest value was recorded for soil application of Boron @2 kg/ha for both chla and chl b at 30 DAT i.e. 2.25 mg/g and 1.34 mg/g respectively and in 60 DAT, highest value for chl a was zinc foliar application @0.5% and for chl b it is boron foliar application @0.25% with a value of 1.61 mg/g and 0.9 mg/g. Total chlorophyll content in leaves had significant affect with zinc and boron application. Highest value at 30 DAT was recorded for boron soil application @2 kg/ha and at 60 DAT foliar application of boron @0.25% with a value of 3.94 mg/g and 2.68 mg/g.

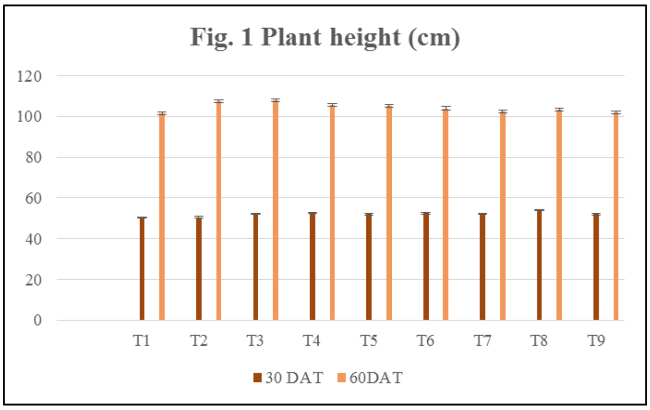
Yield and its attributes

Results in table 3 indicate yield and its attributes as influenced by application of zinc and boron with different application method on tomato. Total yield of tomato fruits was significantly influenced by combined application of boron soil @2kg/ha and zinc as foliar @0.5% which recorded highest value of 6.97 ton/ha which was at par with results of Barche *et al.* (2011) followed by T_6 (5.7 ton/ha). Lowest value was recorded for control plots (T_1).

Table 2: Growth parameters as influenced by Zinc and boron with different application methods at 30 DAT and 60 DAT

Treatments		PLANT HEIGHT (cm)						Number of branches					
		30 DAT			60 DAT			30 DAT			60 DAT		
		2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T_1		45.1	55.6	50.33	101.74	101.35	101.55	9	10	10	32	34	33
T_2		55.8	45.2	50.52	107.31	107.42	107.37	9	9	9	42	42	42
T_3		52.2	52.1	52.17	107.64	107.95	107.80	9	10	9	38	37	38
T_4		52.7	52.7	52.70	105.09	106.13	105.61	10	11	10	39	39	39
T_5		52.0	52.1	52.03	105.29	105.18	105.23	10	10	10	42	41	42
T_6		52.3	52.7	52.50	104.29	103.68	103.98	9	9	9	46	47	46
T_7		52.3	52.0	52.14	102.73	102.16	102.44	10	10	10	36	36	36
T_8		54.2	53.6	53.89	103.79	102.98	103.38	11	11	11	45	44	44
T_9		52.0	52.0	51.99	102.61	101.53	102.07	10	10	10	40	40	40
Mean		52.07	51.99	52.03	104.50	104.27	104.38	9.59	9.96	9.78	39.92	39.82	39.87
SEM	B	1.72	0.63	0.832	2.24	0.98	1.27	0.33	0.22	0.17	2.42	0.51	1.08
	Zn	1.72	0.63	0.832	2.24	0.98	1.27	0.33	0.22	0.17	2.42	0.51	1.08
	B X Zn	2.98	1.10	1.441	3.89	1.70	2.19	0.58	0.38	0.30	4.19	0.89	1.88
CD (0.05)	B	*	*	*	*	*	*	1.00	*	0.51	*	*	*
	Zn	*	1.90	*	*	*	*	*	*	*	*	*	*
	B X Zn	*	3.29	*	*	*	*	*	*	*	*	*	*
CV (%)		9.92	3.66	4.80	6.44	2.82	3.64	10.46	6.65	5.25	18.18	3.86	8.15

Treatments: T_1: only recommended dose of fertilizer (control); T_2:RDF+ zinc foliar @0.5%; T_3: RDF+ zinc soil application @ 6 kg/ha; T_4: RDF+ boron foliar application @ 0.25%; T_5: RDF + combined application of boron foliar @0.25% and zinc foliar @0.5%; T_6: RDF + combined application of boron foliar @0.25% and zinc soil @6 kg/ha; T_7: RDF + boron soil application @2 kg/ha; T_8: RDF + combined application boron soil application @2 kg/ha and zinc foliar @0.5%; T_9: RDF + combined application for boron soil @2 kg/ha + zinc soil @6kg/ha. Recommended dose of fertilizer: N:P_2O_5: K_2O::100:50:50 (kg/ha) were applied through urea, DAP and muriate of potash.



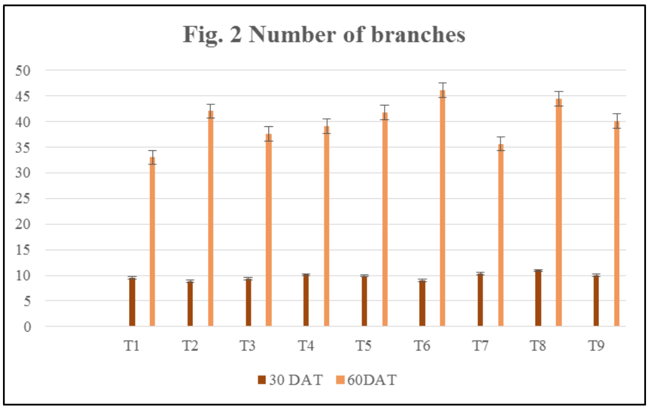
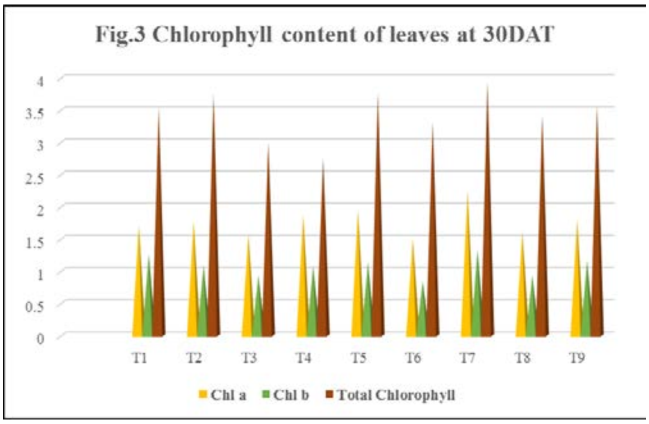


Fig 1, 2: Illustrates different growth parameters as influenced by Zinc and Boron with different application methods (On the basis of pooled data).



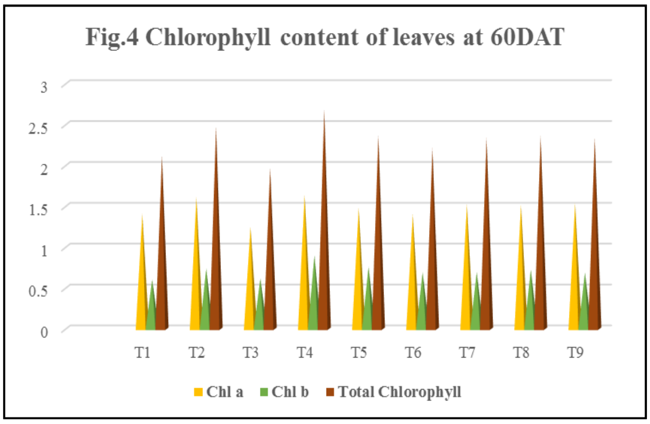


Fig. 3 & Fig. 4: illustrates chlorophyll content of leaves at different growth stages as influenced by Zinc and Boron with different application methods (on the basis of pooled data)

Table 3: Chlorophyll content of leaves as influenced by Zinc and boron with different application methods at 30DAT and 60 DAT

Treatments		30 DAT									60 DAT								
		Chl *a*			Chl *b*			Tot Chl			Chl *a*			Chl *b*			Tot Chl		
		2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T_1		1.41	2.02	1.72	0.88	1.66	1.27	2.42	3.90	3.55	1.30	1.52	1.41	0.54	0.67	0.61	1.93	2.30	2.12
T_2		1.75	1.79	1.77	1.11	1.08	1.09	3.02	3.03	3.75	1.79	1.44	1.61	0.61	0.87	0.74	2.52	2.44	2.48
T_3		1.60	1.56	1.58	0.94	0.93	0.94	2.68	2.63	3.00	1.40	1.10	1.25	0.42	0.82	0.62	1.90	2.03	1.97
T_4		2.24	1.51	1.88	1.39	0.77	1.08	3.84	2.41	2.75	1.88	1.41	1.64	0.71	1.10	0.90	2.72	2.65	2.68
T_5		1.88	2.03	1.96	1.16	1.13	1.15	3.20	3.34	3.77	1.64	1.32	1.48	0.52	1.00	0.76	2.27	2.46	2.36
T_6		1.47	1.55	1.51	0.90	0.80	0.85	2.50	2.48	3.32	1.57	1.24	1.41	0.56	0.82	0.69	2.24	2.18	2.21
T_7		2.16	2.33	2.25	1.37	1.31	1.34	3.74	3.84	3.94	1.60	1.45	1.53	0.56	0.83	0.70	2.27	2.41	2.34
T_8		1.61	1.62	1.62	0.96	0.91	0.94	2.72	2.68	3.43	1.67	1.36	1.51	0.66	0.80	0.73	2.45	2.27	2.36
T_9		1.82	1.80	1.81	1.14	1.20	1.17	3.13	3.17	3.57	1.74	1.33	1.54	0.65	0.73	0.69	2.51	2.17	2.34
Mean		1.77	1.80	1.79	1.10	1.09	1.09	3.03	3.05	3.45	1.62	1.35	1.49	0.58	0.85	0.71	2.31	2.32	2.32
SEM	B	0.164	0.04	0.09	0.082	0.04	0.05	0.166	0.03	0.03	0.073	0.06	0.04	0.038	0.06	0.04	0.108	0.07	0.07
	Zn	0.164	0.04	0.09	0.082	0.04	0.05	0.166	0.03	0.03	0.073	0.06	0.04	0.038	0.06	0.04	0.108	0.07	0.07
	B X Zn	0.283	0.07	0.15	0.142	0.07	0.08	0.288	0.05	0.05	0.127	0.10	0.07	0.066	0.11	0.07	0.187	0.12	0.12
CD (0.05)	B	*	0.12	*	*	0.12	0.14	*	0.09	*	*	*	*	*	*	*	*	*	*
	Zn	*	0.12	*	*	0.12	*	*	0.09	*	*	0.17	*	*	*	*	*	0.20	*
	B X Zn	*	0.20	*	*	0.21	*	0.862	0.16	*	*	*	*	*	*	*	*	*	*
CV (%)		27.71	6.53	14.77	22.52	10.88	12.85	16.45	3.08	2.53	13.56	12.88	8.08	19.56	22.62	17.22	14.01	8.75	9.03

Treatments: T_1: only recommended dose of fertilizer (control); T_2:RDF+ zinc foliar @0.5%; T_3: RDF+ zinc soil application @ 6 kg/ha; T_4: RDF+ boron foliar application @ 0.25%; T_5: RDF + combined application of boron foliar @0.25% and zinc foliar @0.5%; T_6: RDF + combined application of boron foliar @0.25% and zinc soil @6 kg/ha; T_7: RDF + boron soil application @2 kg/ha; T_8: RDF + combined application boron soil application @2 kg/ha and zinc foliar @0.5%; T_9: RDF + combined application for boron soil @2 kg/ha + zinc soil @6kg/ha. Recommended dose of fertilizer: N: P_2O_5: K_2O::100:50:50 (kg/ha) were applied through urea, DAP and muriate of potash.

Fruit length of tomato was not significantly affected by zinc and boron application despite the fact that combined application of boron and zinc produced better outcome than single application which might have affected total yield. The mean fruit length ranged between 45.78 mm to 49.89 mm where treatment T_9 (Boron@2 kg/ha and zinc @6 kg/ha in soil) recorded highest value over control plots. Fruit width significantly increased with zinc and boron application over control plots. Treatment T_4 (boron as foliar @0.25%) was superior among all other treatments with a value of 60.90 mm. The results were similar with Abdur *et al.* (2011) and Saravaiya *et al.* (2014) [15] where they have agreed for foliar application of boron enhances fruit diameter which contributes to total yield of tomato fruit. Moreover, Sajid *et al.* (2013) has confirmed in his study that foliar application is an appropriate way to feed the tomato crop to enhance the growth, flowering and marketable yield. Number of fruits and fruit yield per plant increased significantly with zinc and boron in different application methods over control plots. Highest number of fruits was recorded for combined foliar application of zinc @0.5% and boron @0.25% (T_5) followed by T_2, T_6 and T_9. Dasari *et al* (2022) in their study reported similar results where number of fruits was influenced by combined application of zinc and boron because boron helps in pollen germination and zinc helps in synthesis of plant hormones IAA which contributes in yield and other attributes. Highest fruit yield per plant was recorded for combined foliar application of zinc @0.5% and boron @0.25% (T_5) with a value of 543.81g followed by T_6 (boron foliar @0.25% and zinc in soil @6 kg/ha). Boron deficiency in tomatoes can lead to stunted growth and reduced fruit development. Rahman *et. al* (2023) [11] focused on the impact of foliar boron spray on summer tomato growth and yield which resulted in the highest fruit weight, fruit quantity, and overall yield. Average fruit weight per plant had no significant effect with zinc and boron application but combined soil application of zinc @6 kg/ha and boron 2 kg/ha (T_9) among the treatments applied.

Quality parameters

Data in table 4 represents quality attributes *viz.* Vitamin C, Total sugar and Reducing sugar as influenced by zinc and boron application with different methods on tomato. Vitamin C and Total sugar in tomato (Fresh weight) was significantly influenced by zinc-boron application and highest value was recorded for zinc foliar application @6 kg/ha (T_3) for both Vitamin C (902.5 mg/g) and Total sugar (2.10) Since, zinc is involved in physiological processes, enzyme activation, translocation of sugar and protein (Yang *et al*, 2020) [17]. Zinc is important in the oxidation and reduction processes, which are important in the sugar metabolism (Rath *et al*, 1980) [13]. Raj *et al.* (2012) [12] observed similar results where foliar application of micronutrient improved ascorbic acid content in tomato fruits. Reducing sugar was promoted significantly with soil application of boron @2kg/ha recording highest value of 2.11. Gauch and Dugger (1953) [4] provided evidences which were indicative of participation of boron in sugar translocation in higher plants. They have reported that boron, by virtue of its ability to make complex with sugars facilitated the transport of sugars in plants. Salam *et al.* (2010) [14] and Meena *et. al* (2015) [8] both reported that application of zinc and boron, alone or in combination will be more effective in improvising the quality aspects of tomato.

Table 4: Yield and its attributes as influenced by Zinc and boron with different application methods

Treatments	Yield (ton/ha)			Fruit length			Fruit width			no. of fruits per plant			Fruit yield per plant			Average fruit wt. per plant		
	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T_1	3.60	3.02	3.31	49.28	42.28	45.78	53.99	49.99	51.99	2	2	2	219.59	202.59	211.09	91.49	78.49	84.99
T_2	5.92	5.34	5.63	50.65	43.65	47.15	60.88	56.88	58.88	4	5	4	397.11	380.11	388.61	111.40	98.40	104.90
T_3	4.80	4.22	4.51	52.75	45.75	49.25	61.64	57.64	59.64	3	3	3	352.77	335.77	344.27	116.29	103.29	109.79
T_4	5.38	4.80	5.09	51.78	44.78	48.28	62.90	58.90	60.90	2	2	2	260.00	243.00	251.50	121.37	108.37	114.87
T_5	4.59	4.01	4.30	52.28	45.28	48.78	60.83	56.83	58.83	5	6	5	552.31	535.31	543.81	115.12	102.12	108.62
T_6	5.99	5.41	5.70	50.29	43.29	46.79	58.93	54.93	56.93	4	3	4	422.17	405.17	413.67	105.51	92.51	99.01
T_7	4.20	3.62	3.91	50.56	43.56	47.06	57.38	53.38	55.38	3	3	3	297.61	280.61	289.11	99.19	86.19	92.69
T_8	7.26	6.68	6.97	50.73	43.73	47.23	56.19	52.19	54.19	3	4	3	338.09	321.09	329.59	95.07	82.07	88.57
T_9	4.72	4.14	4.43	53.39	46.39	49.89	62.30	58.30	60.30	4	5	4	359.09	342.09	350.59	122.24	109.24	115.74
Mean	5.16	4.58	4.87	51.30	44.30	47.80	59.45	55.45	57.45	3.21	3.69	3.45	355.41	338.41	346.91	108.63	95.63	102.13
SEM B	0.380	0.267	0.24	0.753	0.753	0.75	1.095	1.095	1.09	0.233	0.235	0.15	26.219	26.501	42.55	4.433	4.902	4.64
SEM Zn	0.380	0.267	0.24	0.753	0.753	0.75	1.095	1.095	1.09	0.233	0.235	0.15	26.219	26.501	42.55	4.433	4.902	4.64
SEM B X Zn	0.658	0.462	0.41	1.304	1.304	1.30	1.896	1.896	1.90	0.404	0.407	0.26	45.412	45.900	73.70	7.678	8.490	8.04
CD (0.05) B	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CD (0.05) Zn	1.139	0.800	0.71	*	*	*	*	*	*	0.700	0.705	0.45	78.595	79.441	127.554	*	*	*
CD (0.05) B X Zn	1.973	1.386	1.24	*	*	*	5.684	5.684	5.68	*	1.221	0.78	*	*	*	23.015	*	*
CV (%)	22.07	17.47	14.68	4.40	5.10	4.73	5.52	5.92	5.72	21.83	19.15	13.12	22.13	23.49	36.80	12.24	15.38	13.63

Treatments: T_1: only recommended dose of fertilizer (control); T_2: RDF+ zinc foliar @0.5%; T_3: RDF+ zinc soil application @ 6kg/ha; T_4: RDF+ boron foliar application @ 0.25%; T_5: RDF + combined application of boron foliar @0.25% and zinc foliar @0.5%; T_6: RDF + combined application of boron foliar @0.25% and zinc soil @6 kg/ha; T_7: RDF + boron soil application @2 kg/ha; T_8: RDF + combined application boron soil application @2 kg/ha and zinc foliar @0.5%; T_9: RDF + combined application for boron soil @2 kg/ha + zinc soil @6 kg/ha. Recommended dose of fertilizer: N: P_2O_5: K_2O:100:50:50 (kg/ha) were applied through urea, DAP and muriate of potash.

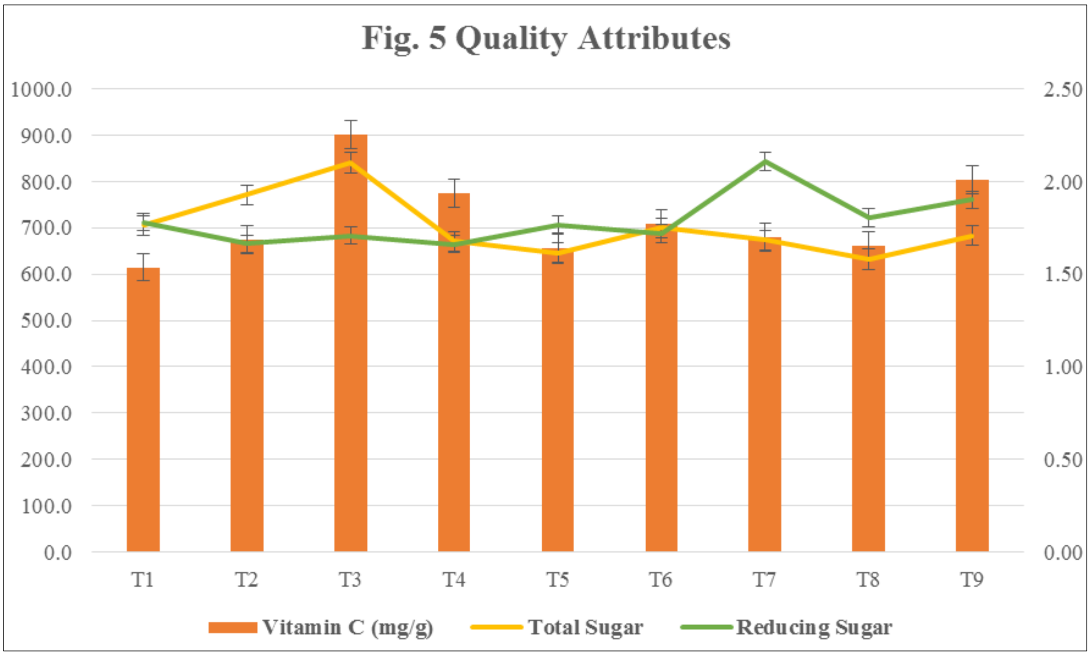


Fig 5: illustrates Quality attributes as influenced by Zinc and Boron with different application methods (on the basis of pooled data)

Table 5: Quality attributes as influenced by Zinc and boron with different application methods

Treatments	Vitamin C			Total sugar			Reducing sugar		
	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data	2018-19	2019-20	Pooled data
T_1	580.0	650.0	615.0	1.60	1.92	1.76	1.52	2.03	1.78
T_2	720.0	630.0	675.0	1.87	1.98	1.93	1.61	1.72	1.66
T_3	910.0	895.0	902.5	2.78	1.42	2.10	1.92	1.50	1.71
T_4	920.0	630.0	775.0	1.71	1.65	1.68	1.67	1.66	1.66
T_5	720.0	590.0	655.0	1.75	1.48	1.61	2.22	1.31	1.77
T_6	840.0	580.0	710.0	1.83	1.67	1.75	1.78	1.66	1.72
T_7	760.0	600.0	680.0	1.62	1.75	1.68	2.15	2.07	**2.11**

T_8		810.0	515.0	662.5	1.74	1.43	1.58	1.97	1.64	1.80
T_9		1040.0	570.0	805.0	1.69	1.73	1.71	2.14	1.66	1.90
Mean		811.11	628.89	720.00	1.84	1.67	1.76	1.89	1.70	1.79
SEM	B	37.64	15.74	21.99	0.07	0.05	0.04	0.08	0.05	0.05
	Zn	37.64	15.74	21.99	0.07	0.05	0.04	0.08	0.05	0.05
	B X Zn	65.20	27.26	38.08	0.12	0.09	0.06	0.13	0.09	0.08
CD (0.05)	B	*	47.18	*	0.21	*	0.11	0.23	0.16	0.15
	Zn	112.84	47.18	65.90	0.21	*	0.11	*	0.16	*
	B X Zn	195.45	81.73	114.15	0.37	0.28	*	0.39	0.28	*
CV (%)		13.92	7.51	9.16	11.65	9.79	6.28	12.06	9.53	8.12

Treatments:T_1: only recommended dose of fertilizer (control); T_2:RDF+ zinc foliar @0.5%; T_3: RDF+ zinc soil application @ 6kg/ha; T_4: RDF+ boron foliar application @ 0.25%; T_5: RDF + combined application of boron foliar @0.25% and zinc foliar @0.5%; T_6: RDF + combined application of boron foliar @0.25% and zinc soil @6 kg/ha; T_7: RDF + boron soil application @2 kg/ha; T_8: RDF + combined application boron soil application @2 kg/ha and zinc foliar @0.5%; T_9: RDF + combined application for boron soil @2 kg/ha + zinc soil @6kg/ha. Recommended dose of fertilizer: N: P_2O_5: K_2O:100:50:50 (kg/ha) were applied through urea, DAP and muriate of potash.

Conclusion

The present study was conducted to investigate the different application methods (*viz*. soil and foliar) of zinc and boron on tomato with special emphasis on growth, yield and quality. Plant height and number of branches were affected by treatment application whereas chlorophyll content of leaves was significantly improved with boron soil application @2 kg/ha at 30 DAT and boron foliar application @0.25% at 60 DAT except chl. A which was influenced by zinc foliar application @0.5% at 60 DAT. Yield of tomato fruit was influenced by combined application of boron in soil @2kg/ha and zinc as foliar @0.5%. Fruit length and average fruit weight per palnt was influenced by combined soil application of boron @2 kg/ha and zinc @6 kg/ha whereas number of fruits per plant and fruit yield per plant was influenced by foliar application of boron @0.25% and zinc @0.5%. Fruit quality of tomato like Ascorbic acid content (Vitamin C), Total Sugar and Reducing Sugar was mostly influenced by zinc sulphate application in soil @6 kg/ha. Thus, combined application of boron as foliar and zinc in soil would be the best treatment to improve plant growth, fruit yield and its attributes and quality of tomato fruits over single application.

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