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Nutrient Content of Tomato as Influenced by Different Sources and Levels of Boron

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A field experiment was conducted to evaluate different sources and levels of boron (B) on nutrient content in tomato in a randomized complete block design with ten treatments and three replications. Boron was applied through borax as soil application and boric acid or boron metalosate as foliar spray. Application of B enhanced the nutrient content in tomato crop (haulm and fruits). The treatment receiving recommended dose of fertilizer (RDF) with 1.1 kg B ha^{-1} as soil application and 0.05% B (boron metalosate) as foliar spray recorded the highest nutrient contents in both haulm and fruits. The concentration of B in leaf at one day before spray was recorded higher in the treatment T_4 receiving RDF + 2.2 kg B ha^{-1} through borax as soil application, whereas at one week after 1st spray at vegetative stage, one day before 2nd spray and one week after 2nd spray at fruit setting stage significantly higher B content was recorded in T_{10} treatment consists of RDF + 1.1 kg B ha^{-1} through borax as soil application followed by 0.05% B through boron metalosate as foliar application compared to RDF (T_1). At harvest, concentration of B was significantly reduced in the treatments with respect to other weeks of interval of spray.

Key words: Tomato, boric acid, boron metalosate and foliar application

Tomato (*Solanum lycopersicum*) crop is very important in terms of diet and economy of India. It is most popular vegetable as it ranks third in the world's vegetable production, next to potato and sweet potato, and placing itself first as processing crop among the vegetables. As it is a heavy feeder, availability of nutrients in sufficient and balanced quantities throughout the plant growth period is very important to maintain productivity. For improving plant growth and yield application of organic and inorganic fertilizers is very important.

Boron (B) is one of the eight essential micronutrients needed for plant growth and development. It has an important role in the plant activities and foliar application of it improves the vegetative growth, fruit set and yield of tomato by increasing photosynthesis in green plants. It helps in regulation of sugar concentration and pollen development in plants and is responsible for the cell wall formation. It has emerged as an important micronutrient in Indian agriculture, next to zinc (Zn) in the context of its deficiency (Sathya *et al.* 2009). Boron deficiency has been realized as the second most important micronutrient constraint in crops after Zn on global scale (Ahmad *et al.* 2012). In India, B deficiency was initially reported to 2% of soils in the year 1980 (Katyal *et al.* 2004), which has increased at present to 52% (Singh 2012).

Micronutrients have an important role in the plant activities and foliar application can improve the vegetative growth, fruit set and yield of tomato (Adams 2004) by increasing photosynthesis of green plants (Mallick and Muthukrishnan 1980). Soil application of B through borax has resulted in greater loss of B by leaching loss thereby less availability to crops. The study on use of different sources and levels of B on tomato crop is very limited. Among the micronutrients, B plays an important role directly and indirectly in improving the yield of tomato in addition to checking various diseases and physiological disorders (Magalhaes *et al*. 1980). In this context, the present study was undertaken to evaluate effect of different sources and levels of B on nutrient content of tomato under irrigated condition.

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Material and Methods

The experiment was conducted during 2016-2017 at Nayanhalli village, Chintamani taluk, Chickaballapur district, Karnataka, India in a randomized completely block design with ten treatments and three replications. The experimental site is situated in Eastern Dry Zone (Zone 5) of Karnataka at 11°53′ N latitude and 76°57′ E longitude at an elevation of 600 m above mean sea level. The average rainfall during cropping period (July-November) was 267 cm with mean maximum and minimum temperature of 30.2 and 18.5 °C, respectively. The soil of the experimental site was sandy clay in texture (Piper 1966) with pH 6.8 (Jackson 1973), 0.32 dS m^{-1} electrical conductivity (EC) (Jackson 1973) and 7.2 g kg^{-1} organic carbon (OC) (Jackson 1973). The initial available nitrogen (N) (Subbiah and Asija 1956) was medium (286.3 kg ha^{-1}) in soil with high available phosphorus (P) (Jackson 1973) and potassium (Page *et al.* 1982) of 27.5 and 254.3 kg ha^{-1}, respectively. Whereas, exchangeable calcium (Ca) and magnesium (Mg) (Jackson 1973) were 4.50 and 2.10 cmol(p^+)kg^{-1}, respectively with 11.7 kg ha^{-1} of available sulphur (S) (Black 1965). The DTPA extractable iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) (Lindsay and Norvell 1978) and B (John *et al.* 1975) were 42.3, 29.2, 0.52, 0.8 and 0.32 mg kg^{-1}, respectively.

The experimental site was converted into each plot size of 1.5 m × 0.9 m and levelling was ensured within each plot. Tomato (var Hybrid Alankar) seedlings of 25-days-old with vigorous and uniform size were transplanted on first fortnight of July with a spacing of 120 cm × 45 cm at 2.0 to 2.5 cm soil depth. Recommended dose of fertilizers (250:250:250 N, P_2O_5 and K_2O kg ha^{-1}) and farmyard manure (25 t FYM ha^{-1}) for tomato crop were applied to all the plots uniformly. Nitrogen in the form of urea, P in the form of single superphosphate (SSP) and K in the form of muriate of potash (MOP) were applied. Whole quantities of P and K fertilizers and half of N fertilizer were mixed with the soil at the time of transplanting, while the remaining amount of N fertilizer was applied two weeks after transplanting. Ten treatments combinations *viz.*, T_1: Recommended dose of NPK fertilizers and FYM (RDF), T_2: RDF + 1.1 kg B ha^{-1} as borax (soil application), T_3: RDF +1.6 kg B ha^{-1} as borax (soil application), T_4: T_1 + 2.2 kg B ha^{-1} as borax (soil application), T_5: T_1 + 0.55 kg B ha^{-1} as borax (soil application) followed by 0.05% B as boric acid solution (foliar spray), T_6: T_1 + 0.82 kg B ha^{-1} as borax (soil application) followed by 0.05% B as boric acid solution (foliar spray), T_7: T_1 + 1.1 kg B ha^{-1} as borax (soil application) followed by 0.05% B as boric acid solution (foliar spray), T_8: T_1 + 0.55 kg B ha^{-1} as borax (soil application) followed by 0.05% B as boron metalosate solution (foliar spray), T_9: T_1 + 0.82 kg B ha^{-1} as borax (soil application) followed by 0.05% B as boron metalosate solution (foliar spray) and T_{10}: T_1 + 1.1 kg B ha^{-1} as borax (soil application) followed by 0.05% B as boron metalosate solution (foliar spray) were used. Boron in the form of borax alone or with boric acid or boron metalosate were applied as per the treatments. Borax was applied to soil during application of major nutrients, while foliar application of boric acid and boron metalosate were applied during vegetative stage and fruit set stage as per the treatments. Plant samples were collected and analyzed for macro- and micronutrients at the time of harvesting following standard protocol.

Index leaves (during intervals for B estimation) and haulm (at harvest) were randomly collected from each treatment, cleaned with water, air-dried and then dried in hot-air oven at 60 °C for 18 h. The samples were then powdered and stored in polythene bags and subsequently analyzed for total N using Kjeldahl distillation method (Jackson 1973). Plant samples were digested by di-acid (HNO_3:$HClO_4$ at 9:4) digestion on an electric hot plate (Piper 1966). The total P content in the acid digest was determined by spectrophotometrically after developing vanado-molybdo-phosphate yellow colour method, while total K was determined by a flame photometer, Ca and Mg were estimated by EDTA titration method and S by turbidimetric method (Jackson 1973). Total contents of Fe, Zn, Mn and Cu in the extract were estimated by atomic absorption spectrophotometer. The B content in the acid digest was determined using Azomethine-H reagent (Page *et al*. 1982) and the intensity of colour was measured spectro-photometrically.

Results and Discussion

Nutrient content in tomato haulm (leaves and stem) at harvest

a) Total macronutrients

Data on total concentration of macronutrients *viz.*, N, P, K, Ca, Mg and S in tomato haulm varied significantly due to soil and foliar application of B at harvest (Table 1). Total N (3.09%), P (0.40%), K (2.48%), Ca (1.31%), Mg (0.75%) and S (0.86%) concentrations in tomato haulm were recorded

Table 1. Effect of sources and levels of boron on macronutrients content in tomato haulm (leaves and stem) at harvest

Treatments	Macronutrients content (%) of tomato haulm					
	N	P	K	Ca	Mg	S
T_1	2.20	0.19	1.68	0.76	0.39	0.49
T_2	2.32	0.21	1.75	0.81	0.45	0.55
T_3	2.41	0.23	1.86	0.86	0.49	0.60
T_4	2.54	0.26	1.90	0.91	0.53	0.63
T_5	2.65	0.29	2.14	0.94	0.57	0.68
T_6	2.72	0.33	2.28	0.99	0.62	0.74
T_7	2.86	0.35	2.30	1.21	0.66	0.78
T_8	2.75	0.31	2.21	0.97	0.59	0.72
T_9	2.99	0.37	2.37	1.25	0.69	0.81
T_{10}	3.09	0.40	2.48	1.31	0.75	0.86
S.Em.±	0.19	0.02	0.17	0.08	0.04	0.05
CD (P=0.05)	0.56	0.07	0.49	0.24	0.13	0.16

significantly higher in T_{10} treatment consisting of RDF + 1.1 kg B ha^{-1} through borax as soil application, followed by 0.05% B through boron metalosate as foliar application compared to recommended dose of fertilizer. The lowest contents of total N (2.20%), P (0.19%), K (1.68%), Ca (0.76%), Mg (0.39%) and S (0.49%) were recorded in RDF (T_1). The treatment T_7 which received boric acid as foliar application was on par with treatments T_8, T_9 and T_{10} which received boron metalosate as foliar application. Application of B along with RDF increased macronutrient contents in the haulm which might be due to positive effect of B with these nutrients. Boron also plays a key role in increasing the activity of specific enzymatic system in roots that significantly contributes to nutrient uptake. This system creates gradients in root cells and works as the driving force for active uptake and translocation of minerals. The results are in conformity with the findings of Singh and Singh (1983, 1984), who reported positive correlation between B and N in leaves. The macronutrients N, P, K and Ca responded positively to the dosage of B to tobacco crop, notably increasing in concentration (López *et al.* 2002).

b) Total iron, copper and manganese content

The data on concentration of Fe, Mn and Cu in tomato haulm did not differ significantly due to soil and foliar application of B at harvest (Table 2).

c) Total zinc and boron content

The concentrations of Zn and B in tomato haulm at harvest varied significantly due to soil and foliar application of B (Fig. 1). Concentrations of Zn (36.0 mg kg^{-1}) and B (38.1 mg kg^{-1}) in tomato haulm were significantly highest due to application of RDF with B as basal (1.1 kg ha^{-1} as borax) and foliar spray (0.05% B as boron metasolate) and lower Zn (23.1 mg kg^{-1}) and B (25.1 mg kg^{-1}) content was recorded in NPK+FYM treatment (T_1). The treatments which received B through soil and foliar application are significantly different than those treatments which received only soil application of B. Application of B through boron metalosate which significantly enhanced the B concentration in tomato haulm, since it is an amino acid chelated product, neutral in pH and 100% soluble in water, thereby, it enhance the Zn content in tomato haulm. Foliar or soil applied B increased tissue concentrations of Zn and B (Davis *et al*. 2003). Hassanein *et al.* (1999) reported that B content in different parts of pea plants increased with increasing B concentration.

Table 2. Effect of sources and levels of boron on iron, copper and manganese content in tomato haulm (leaves and stem) at harvest

Treatments	Iron content	Copper content	Manganese content
	(mg kg^{-1})		
T_1	106.0	18.9	59.3
T_2	108.6	17.9	58.5
T_3	104.3	19.3	58.6
T_4	108.3	19.0	60.0
T_5	109.2	20.3	59.0
T_6	112.0	19.0	61.4
T_7	110.1	21.0	58.1
T_8	114.2	18.7	61.9
T_9	104.2	18.1	59.3
T_{10}	106.2	17.7	59.8
S.Em.±	7.26	0.81	4.67
CD (P=0.05)	NS	NS	NS

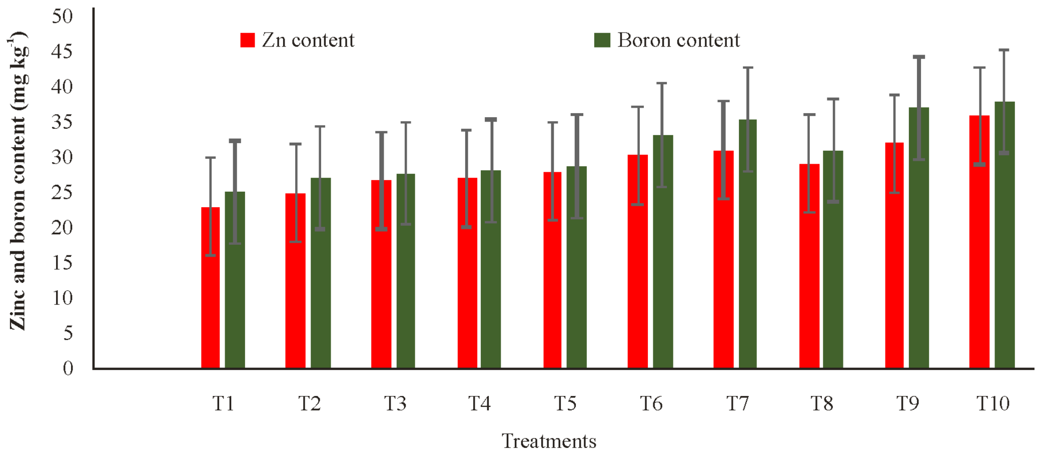

Fig. 1. Effect of sources and levels of boron on zinc and boron (mg kg^{-1}) content of tomato haulm (leaves and stem) at harvest. Error bars are critical difference at 5%

Table 3. Effect of sources and levels of boron on macronutrients (%) content of tomato fruit at harvest

Treatments	Macronutrients (%) content of tomato fruit					
	N	P	K	Ca	Mg	S
T_1	2.24	0.31	1.96	1.00	0.51	0.61
T_2	2.57	0.35	2.15	1.15	0.58	0.65
T_3	2.68	0.38	2.16	1.21	0.64	0.72
T_4	2.82	0.42	2.28	1.28	0.71	0.78
T_5	2.98	0.46	2.30	1.35	0.77	0.84
T_6	3.02	0.55	1.75	1.45	0.89	0.94
T_7	3.18	0.59	2.56	1.50	0.92	1.02
T_8	3.06	0.51	2.32	1.39	0.84	0.89
T_9	3.32	0.63	2.42	1.58	0.98	1.08
T_{10}	3.43	0.69	2.49	1.67	1.08	1.12
S.Em.±	0.19	0.04	0.15	0.11	0.06	0.06
CD (P=0.05)	0.56	0.11	0.45	0.33	0.18	0.19

Nutrient content in tomato fruit at harvest

a) Total macronutrients

The data on concentration of total N, P and K, Ca, Mg and S in tomato fruits varied significantly due to soil and foliar application of B at harvest (Table 3). Nitrogen (3.43%), P (0.69%), K (2.49%), Ca (1.67%), Mg (1.08%) and S (1.12%) concentration in tomato fruits were recorded significantly higher in T_{10} treatment which consists of RDF + 1.1 kg B ha^{-1} through borax as soil application + 0.05% B through boron metalosate as foliar application compared to soil application of borax alone with RDF and lowest total N (2.24%), P (0.31%), K (1.96%), Ca (1.00%), Mg (0.51%) and S (0.61%) content was recorded in NPK+FYM treatment (T_1). Among the three different sources of B, application of B through boron metalosate recorded higher nutrient content. The increase in macronutrients content in tomato fruit might be due to application of N, P and K to soils as basal dose and foliar application of B were effectively utilized by the crop and in turn NPK content in tomato fruit increased. The increased B concentration enhanced the Ca, Mg and S content in tomato fruits as it has synergetic effect with these nutrients. The increased B plays vital role in nutrient absorption and root growth there by it enhance the nutrient content in tomato (Singh *et al*. 2018). Regardless of application methods, addition of B increased the tissue concentration of Ca, K and B in tomato fruits (Davis *et al*. 2003). At lower rates, B improved the chemical composition of tomato fruits (Naresh 2002). Foliar spray of B significantly increased the concentration of N, P, K and S in fruits compared to control (Lalit and Srivastava 2004). Similar findings were also observed by Prabha and Singaram (1996).

Table 4. Effect of sources and levels of boron on iron, copper and manganese content in tomato fruit at harvest

Treatments	Iron content	Copper content (mg kg^{-1})	Manganese content
T_1	118.4	20.0	67.8
T_2	118.8	18.0	66.9
T_3	117.6	17.8	67.1
T_4	118.2	19.3	68.6
T_5	117.8	20.0	67.5
T_6	82.5	20.0	70.2
T_7	119.6	19.9	66.5
T_8	118.2	16.2	70.8
T_9	117.2	16.5	67.8
T_{10}	118.0	16.0	68.4
S.Em.±	13.4	1.23	4.55
CD (P=0.05)	NS	NS	NS

b) Iron, Manganese and Copper

The data on concentration of Fe, Mn and Cu in tomato fruit was not significantly influenced due to soil and foliar application of B at harvest as presented in table 4.

c) Zinc and boron content

The data on concentration of Zn and B in tomato fruits varied significantly due to soil and foliar application of B at harvest (Fig. 2). Concentration of Zn (38.0 mg kg^{-1}) and B (39.6 mg kg^{-1}) in tomato fruits recorded significantly higher in T_{10} treatment containing T_1 + 1.1 kg B ha^{-1} through borax as soil application + 0.05% B through boron metalosate as foliar application compared to Zn (25.9 mg kg^{-1}) and B (27.2 mg kg^{-1}) content in NPK+FYM treatment (T_1). The results are similar with the findings of Lalit and Srivastava (2004) stated that application of B micronutrient significantly enhances the Zn and B content in tomato fruit compared to control. Davis *et al*. (2003) reported that foliar application of B to fruits contain more B than no B applied fruits, indicating that B was translocated from leaves to fruit. Boron fertilizer application had effects on plant fruit tissue B concentration and increased with increasing the B fertilizer rate. The greatest B concentrations of plants were obtained from 2.0 kg ha^{-1} doses (Atilla *et al*. 2010).

Boron content in index leaf at one day before each spray and one week after each spray

The data on concentration of B in tomato leaves differed significantly due to soil and foliar application of B (Table 5). Leaves were collected one day before spray and one week after first, second spray and at harvest of crop. The concentration of B in leaf at one day before spray was recorded higher (45.2 mg kg^{-1}) in the treatment receiving T_4 (T_1 + 2.2 kg B ha^{-1} through borax as soil application) and lower (33.2 mg kg^{-1}) in T_1 treatment (RDF+FYM). The higher B content in T_4 treatment might be due to the fact that higher doses of soil application of B resulted in higher B solubility and availability to tomato crop hence higher concentrations of B was observed in tomato leaf.

At one week after 1st spray, one day before 2nd spray and one week after 2nd spray significantly higher (46.2, 44.2 and 49.1 mg kg^{-1}, respectively) B content was recorded in treatment (T_{10}) which consists of T_1 + 1.1 kg B ha^{-1} through borax as soil application followed by 0.05% B through boron metalosate as

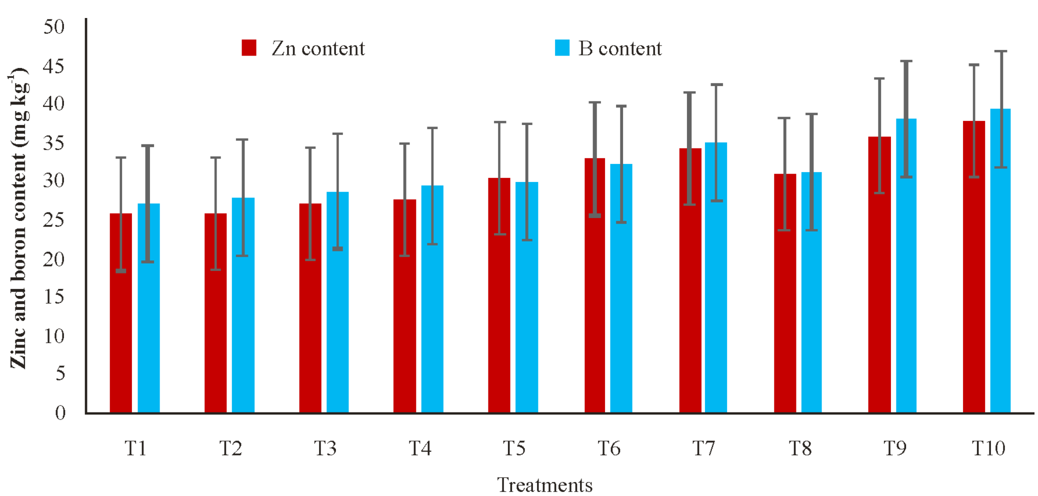

Fig. 2. Effect of sources and levels of boron on zinc and boron (mg kg^{-1}) content of tomato fruit at harvest. Error bars are critical difference at 5%

Table 5. Boron content in index leaf (mg kg^{-1}) of tomato as influenced by different sources and levels of boron

Treatments	Leaf B content (mg kg^{-1})				
	One day before 1st spray	One week after 1st spray	One day before 2nd spray	One week after 2nd spray	At harvest
T_1	33.2	29.1	28.4	25.3	21.7
T_2	38.2	36.2	34.2	33.2	23.5
T_3	41.2	37.5	36.5	34.1	24.0
T_4	45.2	38.1	34.1	35.3	24.3
T_5	32.3	40.1	38.2	43.2	24.9
T_6	35.1	42.2	40.1	46.2	28.7
T_7	37.2	43.2	42.1	47.2	30.6
T_8	34.6	41.1	39.2	42.3	26.8
T_9	38.4	44.2	42.1	48.3	32.0
T_{10}	42.1	46.2	44.2	49.1	32.9
S.Em.±	2.54	2.51	2.44	2.75	1.81
CD (P=0.05)	7.53	7.47	7.25	8.17	5.39

foliar application compared to T_1 (NPK+FYM treatment), which recorded lower B content (29.1, 28.4 and 25.3 mg kg^{-1}). The B content was increased progressively with increase in age of the tomato crop. It might be due to foliar application of B through boron metalosate significantly enhanced the B concentration in index tissue. Gunes *et al*. (2015) observed that foliar application of B @ 0.2% significantly increased N, P, K, Ca and B concentration in leaves and berry tissue of grape compared to control. At harvest stage, B content in index tissue was reduced that may be due to effective utilization of these nutrients for various metabolic activity during crop growth stage from leaves to stem, then to the fruits. Similar was the result observed by Dar (2017).

Conclusions

Based on the above findings, it may be concluded that foliar application of boron enhances the nutrient content in both haulm and fruits of tomato. The treatment which received NPK+FYM along with 1.1 kg B ha^{-1} through borax as soil application and 0.05% B through boron metalosate as foliar application was recorded higher nutrient content in both haulm and fruits. The treatments which received boron through boric acid as foliar application were on par with the treatments which received boron metalosate. One more outcome from the study that the treatments which received boron through soil and foliar application were significantly different compared to treatments received boron through only soil application. Conclusively, combination of soil and foliar application of boron has got advantageous over only soil application of boron.

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