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Influence of soil and foliar application of borax on fractions of boron under tomato cultivation in boron deficient soil of Typic Haplustalf

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Boron (B) is a micronutrient which plays an important role in crop production. Tomato is one of the crops which respond well to B application. Blossom end rot of tomato is due to the deficiency symptom of B which affects the economic value of tomato. The present investigation was undertaken with tomato (PKM 1) as the test crop to study the effect of application of boron on boron fractions *viz*., readily soluble, specifically adsorbed, oxide bound, organically bound, residual and total boron in boron deficient soil of Madukkur soil series. There were twelve treatments viz., soil application of boron as borax at 0, 5, 10, 15, 20 and 25 kg ha^{-1} and foliar application of boron as borax at 0.25 and 0.50% spray twice at 50th and 80th, 60th and 90th and 50th and 90th days after transplanting which were replicated thrice in randomized block design (RBD). The results indicated that the application of 20 kg borax ha^{-1} recorded the highest mean value of boron fractions *viz*., readily soluble (0.33 ppm), specifically adsorbed (0.27 ppm), oxide bound (0.85 ppm), organically bound (0.12 ppm), residual (34.03 ppm) and total boron (35.59 ppm). Among all five fractions, residual boron contributed nearly 96.36 to 97.83% to total boron at harvest stage of crop. The results also revealed that all the five fractions of boron were decreased with progressive growth stages of crop.

Key words: Boron application, boron fractions, tomato (PKM 1).

INTRODUCTION

Tomato is an important mineral, protein and vitamin rich vegetable crop. It plays a vital role in Indian economy by virtue of its various modes of consumption in human diet. Micronutrients are very much essential for the growth, development and reproduction of plants. Micronutrients are required by plants in very small quantities, yet they are very effective in regulating plant growth due to enzymatic action. Different crops require varied quantities of micronutrients in their different stages of growth. Multiple cropping with high yielding varieties of crop is one of the most important causes of removal of micronutrients from the soil. Under deficiency of micronutrients, the growth of plant is hampered; the plants are subjected to attack by disease and the yield of the crops decreases accordingly (Das, 2008). Plants have grown in micronutrient deficient soils which exhibit similar reductions in productivity as those grown in macronutrient deficient soils. Also, repeated application of one trace element induces deficiency of other elements.

Boron (B) is one of the micronutrient; the primary function of B is in plant cell wall structural integrity. Boron provides cross links between cell wall polysaccharides that gives structure to cell wall – important for cell

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expansion, regulation of H^+ transport, retention of cellular Ca^{2+} and control of lignin production following cell expansion. Cell wall structure is important for normal transport of water, nutrients and organic compounds to new growth. Besides, essential during pollen tube growth that is essential for seed development (Havlin et al., 2006). Under B deficiency, normal cell wall expansion is disrupted. Blossom end rot and fruit cracking is specific deficiency symptom of Ca and B, respectively which affects the economic value of tomato. Boron nutrition of vegetable crops has greater impact in Tamil Nadu due to large scale cultivation of tomato in vegetable growing areas covering an extent of 22924 ha with a total production of three lakh tonnes of tomato per annum (Season and Crop Report, 2009). Boron is found in soils in various forms and is distinguished in many categories (Hou et al., 1994). Boron exists in the soil was organic and inorganic forms. The proportion between these two varies based on soil properties. The predominant fractions of inorganic B are readily soluble B, specifically adsorbed B, oxide bound boron, organically bound B and residual B. These fractions have marked influence on B availability in soil. Most of the available B is held largely in the organic matter and is released by the microbial decomposition of organic matter for the use of plants. The relative concentration of these fractions in a soil at a given time depends on soil properties like amount and nature of clay, pH, lime status, organic matter, soil moisture and plant factors (Somani et al., 2008). Boron containing fertilizers when applied to the soil are transformed into various forms according to the principle of solubility product. However, only a few forms are available to plants and their determination is important for estimation of its availability to plants. An attempt has been made in this study to estimate the application of boron on different forms of boron. With this preview, the present investigation was programmed to quantify the different forms of B in soil.

MATERIALS AND METHODS

Field experiment was undertaken in modern orchard of Agricultural College and Research Institute, Madurai in B deficient soils of Madukkur soil series with tomato variety PKM 1 as the test crop during the year 2006. Soil samples were collected from various fields of Agricultural College and Research Institute farm to locate boron deficient soils. For this, by following Azomethine – H method (Gupta, 1967), the available boron status of soil was estimated. Based on the analytical results, the experimental field is located in modern orchard, which is situated at an altitude of 147 M above MSL, 9°54' N latitude and 78°84'E longitude. Experimental soil was sandy loam in texture and is taxonomically grouped under Typic Haplustalf. Available nutrient status of pre transplanting soil of tomato was low (185 kg ha^{-1}) in available nitrogen, medium (18 kg ha^{-1}) in available phosphorus and medium (185 kg ha^{-1}) in available potassium. Soil was neutral in reaction (pH 7.5), non saline and non calcareous. The available B (0.36 ppm) was found to be lower than critical value of 0.46 ppm and the total B was 27.5 ppm. Field experiment consisted of 12 treatments which were laid out in randomized block design (RBD) with three replications with net plot size 2.0 × 4.0 m under irrigated conditions. Standard agronomic practice and needed plant protection measures were followed as per the guidelines given in Horticultural Crop Production Guide, Tamil Nadu Agricultural University, Coimbatore. Treatment schedules are T_1- Control, T_2 - 5 kg borax ha^{-1}, T_3 - 10 kg borax ha^{-1}, T_4 - 15 kg borax ha^{-1}, T_5 - 20 kg borax ha^{-1}, T_6 - 25 kg borax ha^{-1} and T_7 - 0.25% borax spray twice at flowering stage (50th and 80th day), T_8 – 0.50% borax spray twice at flowering stage (50th and 80th day), T_9 - 0.25% borax spray twice at fruit initiation stage (60th and 90th day), T_{10} - 0.50% borax spray twice at fruit initiation stage (60th and 90th day), T11 - 0.25% borax spray twice at flowering and fruit initiation stage (50th and 90th day), T12 - 0.50% borax spray twice at flowering and fruit initiation stage (50th and 90th day). All plots received uniformly recommended fertilizer dose of N, P_2O_5 and K_2O at 120:60:50 kg ha^{-1}. Seeds were sown in nursery bed and then transplanted to main field in ridges and furrows with spacing of 60 × 45 cm. Randomly soil samples were collected in all experimental plots at three stages *viz*., vegetative (30 DAT), flowering stage (60 DAT) and harvesting stage (90 DAT) dried in shade and then in air oven at 105°C, processed and stored in labelled containers for analysis of different boron fractions.

Boron fractions were analyzed by adopting standard procedure outlined by Hou et al. (1996). The readily soluble, specifically adsorbed, oxide bound, organically bound, and residual boron was extracted with 0.01 M $CaCl_2$, 0.05 M KH_2PO_4, 0.175 M NH_4-oxalate (pH 3.25), 0.5 M NaOH and HF + H_2SO_4 + $HClO_4$ respectively. The data obtained from the investigation were subjected to statistical scrutiny by adopting randomized block design as described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Boron fractions *viz*., readily soluble, specifically adsorbed, oxide bound, organically bound and residual B was significantly influenced by various levels of soil and foliar application of B irrespective of all growth stages. The mean value of readily soluble B varied from 0.12 to 0.33 ppm. The highest value of 0.33 ppm was registered under soil application of 20 kg borax ha^{-1} whereas the lowest value of 0.05 ppm recorded in control at harvest stage of tomato (Table 1). The readily soluble boron content decreased with increasing stages of crop growth and it could be attributed to increased uptake and other losses that occurred during the crop growth stages. The percentage distribution of readily soluble boron fraction to total B is ranged from 0.43 to 0.83% at harvest stage of crop (Table 4).

Application of 20 kg borax ha^{-1} as soil application recorded higher value of 0.27 ppm specifically adsorbed B than all other treatment. The highest value 0.37 ppm recorded in same treatment at vegetative stage whereas the lowest value of 0.05 ppm observe din control at harvest stage (Table 2). This might be due to the increase in uptake of boron from soil particularly the higher demand of boron during vegetative and flowering stages, which resulted in decrease in specifically adsorbed boron content of soil in harvest stage. Specifically adsorbed B is easily available for plant uptake as this fraction got adsorbed on anion exchange site on the surface of clay minerals. The exchangeable boron fraction accounted for 0.29 to 0.76% of total boron at harvest stage of crop

Table 1. Application of borax on readily soluble and specifically adsorbed boron (ppm) in various growth stages of PKM 1 tomato.

Treatment (T)	Readily soluble boron				Specifically adsorbed boron			
	Vegetative (S1)	Flowering (S2)	Harvest (S3)	Mean	Vegetative (S1)	Flowering (S2)	Harvest (S3)	Mean
T_1	0.15	0.11	0.09	0.12	0.11	0.08	0.05	0.08
T_2	0.31	0.22	0.18	0.24	0.25	0.18	0.11	0.18
T_3	0.33	0.24	0.20	0.26	0.27	0.19	0.12	0.19
T_4	0.39	0.28	0.23	0.30	0.31	0.22	0.14	0.22
T_5	0.43	0.31	0.25	0.33	0.37	0.27	0.17	0.27
T_6	0.41	0.29	0.24	0.31	0.33	0.24	0.15	0.24
T_7	0.17	0.13	0.10	0.13	0.13	0.09	0.06	0.09
T_8	0.24	0.18	0.15	0.19	0.19	0.14	0.09	0.14
T_9	0.19	0.14	0.12	0.15	0.14	0.1	0.06	0.10
T_{10}	0.21	0.15	0.12	0.16	0.18	0.13	0.08	0.13
T_{11}	0.29	0.21	0.17	0.22	0.23	0.17	0.11	0.17
T_{12}	0.28	0.20	0.16	0.21	0.21	0.15	0.10	0.15
Mean	0.28	0.21	0.16		0.23	0.16	0.10	
Variable	**SEd**	**CD (P = 0.05)**			**Variable**	**SEd**	**CD (P = 0.05)**	
S	0.001	0.002			S	0.001	0.002	
T	0.002	0.004			T	0.002	0.005	
SXT	0.003	0.007			SXT	0.004	0.008	

Table 2. Application of borax on oxide and organically bound boron (ppm) in various growth stages of PKM 1 tomato.

Treatment (T)	Oxide bound boron				Organically bound boron			
	Vegetative (S1)	Flowering (S2)	Harvest (S3)	Mean	Vegetative (S1)	Flowering (S2)	Harvest (S3)	Mean
T_1	0.59	0.52	0.48	0.53	0.07	0.03	0.01	0.04
T_2	0.83	0.73	0.67	0.74	0.16	0.07	0.02	0.08
T_3	0.85	0.75	0.69	0.76	0.17	0.07	0.02	0.09
T_4	0.89	0.78	0.72	0.79	0.19	0.08	0.03	0.11
T_5	0.95	0.84	0.77	0.85	0.22	0.10	0.03	0.12
T_6	0.91	0.8	0.74	0.82	0.21	0.09	0.03	0.11
T_7	0.62	0.55	0.51	0.56	0.09	0.04	0.01	0.04
T_8	0.72	0.63	0.58	0.64	0.13	0.06	0.02	0.07
T_9	0.69	0.61	0.56	0.62	0.11	0.05	0.02	0.06
T_{10}	0.7	0.62	0.57	0.63	0.12	0.05	0.02	0.06
T_{11}	0.76	0.67	0.62	0.68	0.15	0.06	0.02	0.08
T_{12}	0.73	0.64	0.59	0.65	0.15	0.06	0.02	0.08
Mean	0.77	0.68	0.63		0.15	0.06	0.02	
Variable	**SEd**	**CD (P = 0.05)**			**Variable**	**SEd**	**CD (P = 0.05)**	
S	0.001	0.003			S	0.001	0.002	
T	0.003	0.006			T	0.002	0.004	
SXT	0.005	0.014			SXT	0.003	0.007	

(Table 4). A similar finding was reported by Rahmatullah et al. (1999).

Oxide bound (0.85 ppm) and organically bound B (0.12 ppm) was found to also be higher in soil application of 20 kg borax ha^{-1} irrespective of the growth stages of tomato than other treatments (Tables 2 and 3). Sesquioxides

Table 3. Application of borax on residual and total boron (ppm) in various growth stages of PKM 1 tomato.

Treatment (T)	Residual boron				Total Boron			
	Vegetative (S1)	Flowering (S2)	Harvest (S3)	Mean	Vegetative (S1)	Flowering (S2)	Harvest (S3)	Mean
T_1	27.50	27.23	26.73	27.15	28.42	27.97	27.36	27.92
T_2	30.05	29.75	29.16	29.65	31.60	30.95	30.14	30.89
T_3	31.69	31.37	30.74	31.27	33.31	32.62	31.77	32.57
T_4	33.70	33.36	32.69	33.25	35.48	34.72	33.81	34.67
T_5	34.48	34.14	33.46	34.03	36.45	35.66	34.68	35.59
T_6	34.41	34.07	33.39	33.96	36.27	35.49	34.55	35.44
T_7	27.81	27.53	26.98	27.44	28.82	28.34	27.66	28.27
T_8	28.92	28.63	28.34	28.63	30.2	29.64	29.18	29.67
T_9	28.01	27.73	27.18	27.64	29.14	28.63	27.94	28.57
T_{10}	28.55	28.27	27.70	28.17	29.76	29.22	28.49	29.16
T_{11}	29.72	29.42	28.83	29.32	31.15	30.53	29.75	30.45
T_{12}	29.11	28.81	28.43	28.78	30.48	29.86	29.1	29.88
Mean	30.33	30.03	24.47		31.76	31.19	30.41	
Variable	**SEd**	**CD (P = 0.05)**			**Variable**	**SEd**	**CD (P = 0.05)**	
S	0.029	0.005			S	0.032	0.065	
T	0.058	0.116			T	0.065	0.130	
SXT	0.101	0.020			SXT	0.113	0.225	

Table 4. Application of borax on percentage distribution of mean values of B fractions to the total B content.

Treatment	Readily soluble boron	Specifically adsorbed boron	Oxide bound boron	Organically bound boron	Residual boron
T_1	0.43	0.29	1.90	0.14	97.24
T_2	0.78	0.58	2.40	0.26	95.99
T_3	0.80	0.58	2.33	0.28	96.01
T_4	0.87	0.63	2.28	0.32	95.90
T_5	0.93	0.76	2.39	0.34	95.62
T_6	0.87	0.68	2.31	0.31	95.82
T_7	0.46	0.32	1.98	0.14	97.06
T_8	0.64	0.47	2.16	0.24	96.49
T_9	0.53	0.35	2.17	0.21	96.74
T_{10}	0.55	0.45	2.16	0.21	96.60
T_{11}	0.72	0.56	2.23	0.26	96.29
T_{12}	0.70	0.50	2.18	0.27	96.32

bound boron content in soil made available to the plant uptake when boron desorbed from oxides of iron and aluminium. Approximately 1.90 to 2.39% of the total boron was associated with ammonium oxalate extractable boron (oxide bound boron). Organic matter content could also be bound by the boron and releases the boron when it is decomposed in soil during growth of crops (Jin-Yun Jin et al., 1987). Organically bound B fraction was 0.14 and 0.34% to total boron at harvest stage of crop (Table 4).

The residual B of soil had also influenced by various soil and foliar treatments and the value ranged from 27.15 to 34.03 ppm. The highest value recorded in soil application of borax at 20 kg ha^{-1} at vegetative stage whereas the lowest value recorded in control at harvest stage (Table 3). This might be due to increased in uptake at various growth stages and losses that occurred due to leaching and other pathways. Residual boron constituted 95.62 to 96.24% of total boron at harvest stage of crop (Table 4). The major portion of boron in soil existed as residual forms as reported by Datta et al. (2002) and Chaudhary and Shukla (2004).

Total B content at different growth stages of tomato ranged from 30.41 to 31.76 ppm. The highest value of 31.76 ppm of total B was noticed at vegetative stage whereas the lowest value of 30.41 ppm noticed at harvest stage. Total B content decreased towards the advancement of growth stage of tomato. Soil applications of B had higher total B content than foliar applications of B and no B application (control). Total B content was recorded the highest of 36.45 ppm at vegetative stage, 35.66 at flowering stage and 34.68 ppm at harvest satge in soil application of borax at 20 kg ha^{-1} (Table 1). The results also revealed that the nature of parent material, clay content, organic matter level, intensity of cropping and exhaustive nature of the crop influenced the total boron content of soil.

Conclusions

The different fractions of B are in dynamic equilibrium with each other and their availability to growing crop mainly depends on their intensities, soil conditions and plant growth stage. This implies that depleted levels of readily available B in soil could be replenished by the other pools of soil B. With this, it can be concluded that soil application of 20 kg borax ha^{-1} increased the above B fractions irrespective of growth stages of tomato. Regarding foliar application of borax failed to influence the various fraction of boron as like that of soil application irrespective of treatments. The total B and its fractions decreased progressively with the advancement of crop growth stages. Hence from this study, soil application of 20 kg B as borax ha^{-1} along with 100% recommended dose of N, P_2O_5 and K_2O at 120:60:50 hg ha^{-1} can be recommend to farmers to get higher yield in Typic Haplustalf.

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