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EFFECT OF BORON AND SILICON NUTRITION ON THE PERFORMANCE OF GROWTH AND YIELD OF TOMATO IN COASTAL SALINE SOIL

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Abstract

To find out the effect of boron and silicon nutrition on the performance of growth and yield of tomato in coastal saline soil, a pot experiment was carried out in the department of Soil Science and Agricultural Chemistry, Annamalai University during January –April 2018. The texture of the soil was sandy loam and taxonomically classified as *Typic Ustifluvent* with pH-8.41, EC-4.17 dS m^{-1} and represented low status of organic carbon (2.31 g kg^{-1}). The soil had low alkaline $KMnO_4$-N (134.56 kg ha^{-1}), low in Olsen- P (9.43 kg ha^{-1}) and medium in NH_4OAc-K (159.31 kg ha^{-1}). The available B (Hot water soluble B) content (0.07 mg kg^{-1}) and silicon content (84.0 mg kg^{-1}) in soil. The twenty five treatments consisted of five levels of boron *viz.*, 0, 2.5, 5.0, 7.5 and 10 mg kg^{-1} B as factor-A (B Levels) and five levels of silicon fertilizer *viz.*, 0, 2.5, 5.0, 7.5 and 10 mg kg^{-1} B as factor-B (Si Levels). The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with three replications using tomato variety Shivam Hybrid as test crop. The results revealed that the combined application of B @ 7.5 mg kg^{-1} through borax along with Si @10 mg kg^{-1} (B_4 Si_5) through silixol granules significantly increased the growth, yield characters and yield of tomato.

Key words : Borax, Silixol granules, Growth, Yield, Tomato, Coastal Saline Soil.

Introduction

Around the world, nearly one billion people live along 3,12,000 km long coastline. The Indian coastal region stretching over a length of 8129 km long, over the eastern and western border are severely degraded and, pose serious problems for agricultural production. Out of 10.78 M ha of land under coastal agro ecosystem in India, there exist 3.1 M ha of coastal saline soil and nearly 2.04 L ha in Tamil Nadu. Almost the entire coastal tracts suffer from soil salinity, sodicity and seawater intrusion, which resulted in the low productivity of crops (Laxminarayana and Archana, 2016). Nearly one billion people in the world live along the coastline and contribute to the national economy to a significant extent through farming. Soil salinity hampers crop production in the coastal ecosystem to a greater extent. Further, Soil fertility is the most limiting factor for crop production in coastal soil. Coastal saline soils have specific soil constraints *viz.,* light texture, poor exchange property, low nutrient and water retention capacity, low status of organic carbon and deficiency of both macro and micronutrients. These problems severely affect the productivity of crops in this region. Even the applied nutrients are leached to the lower layers due to poor physical properties, poor nutrient retention and low organic carbon content, which further aggravates the problem of nutrient deficiency. The coastal farmers are cultivating the lands by adopting traditional management practices and realizing very low yield of crops as compared to other regions (Veeramani, 2014).

Coastal salt affected soils are most commonly

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suffered due to boron deficiency. Zinc, iron, manganese and copper are also deficient in some locations. Boron plays an important role in various enzymatic activities in the growth and development of tomato (Salim, 2014). It is now established that micronutrient deficiency is the prime factor responsible for that low productivity of tomato in coastal areas. Silicon is a beneficial or quasi element to alleviate the salinity stress and enhance the boron availability and also increased the available beneficial cations (Asgharipour and Mosapour, 2016). Hence, inclusion of boron as micronutrient and silicon as beneficial nutrient in the fertilization programme becomes an imperative need to improve the yield of tomato. Further, the poor nutrient retention and leaching of applied nutrients necessitates the application of increased rate of nutrients and bulky organic manures. It is more vivid that application of organic manure along with boron and silicon fertilization sustains soil health and crop productivity in coastal saline soil. Hence, the present investigation was conducted to optimize the level of boron and silicon application to tomato as well as to identify the best optimized dose of B and Si for improving the growth and yield of tomato in coastal saline soil.

Materials and Methods

A pot experiment was conducted to find out the effect of boron and silicon nutrition on the performance of growth and yield of tomato in coastal saline soil. The pot experiment was carried out in the Department of Soil Science and Agricultural Chemistry, Annamalai University during January- April 2018 using the soil collected at Perampattu coastal village, near Chidabaram Taluk in Cuddalore District, Tamilnadu. The experimental soil was sandy loam texture with pH–8.41 and EC– 4.17 d Sm^{-1}. The initial experimental soil status of alkaline $KMnO_4$-N, Olsen-P and NH_4OAC-K were 134.56, 9.43 and 159.31 kg ha^{-1}, respectively. The treatments consisted of different levels of Boron like B_1-control, B_2- 2.5 mg kg^{-1}, B_3 – 5.0 mg kg^{-1}, B_4 – 7.5 mg kg^{-1} and B_5 – 10 mg kg^{-1} as factor- A (B Levels) and different levels of Silicon fertilizers *viz.*, Si_1-control, Si_2- 2.5 mg kg^{-1}, Si_3 – 5.0 mg kg^{-1}, Si_4 7.5 mg kg^{-1} and Si_5 – 10 mg kg^{-1} as factor- B (Si Levels). The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with three replications. A uniform NPK dose of 100:125:125 mg kg^{-1} was supplied through urea, super phosphate and muriate of potash to all pots. The entire dose of N, P_2O_5 and K_2O were applied as basal. Calculated amount of B and Si was applied through borax and silixol granules as per the treatment schedule just before sowing. Various growth components like plant height, number of branches $plant^{-1}$, dry matter production (DMP) and yield components *viz.*, number of fruits $plant^{-1}$, fruit length and single fruit weight were recorded at harvest stage. The yield of fruits and stover yield were recorded separately and expressed in g pot^{-1}.

Results and Discussion

Growth Characters

Application of different levels of boron and silicon nutrition favourably increased the growth parameters of tomato *viz.*, plant height, number of branches $plant^{-1}$ and dry matter production. Tomato responded to B upto 7.5 mg kg^{-1} and Si application upto 10 mg kg^{-1} in coastal saline soil. Among the different levels of boron evaluated, application of

B @ 10 mg kg^{-1} through borax recorded the maximum plant height (111.67 cm), number of branches $plant^{-1}$ (13.15) and dry matter production (1238.66 g pot^{-1}) of tomato. However, it was found to be comparable with B @ 7.5 mg kg^{-1}, which recorded 110.41 cm plant height, 12.87 number of branches $plant^{-1}$ and 1220.39 g pot^{-1} of dry matter production, respectively. Among the different levels of silicon studied, application of Si @ 10 mg kg^{-1} through silixol granules recorded the maximum plant height (117.61 cm), number of branches $plant^{-1}$ (13.96) and dry matter production (1275.26 g pot^{-1}) of tomato. This was followed by the application of Si @ 7.5, 5.0 and 2.5 mg kg^{-1}, respectively.

Interaction effect due to different levels of boron and silicon fertilizers on the growth characters of tomato was significant. Application of B @ 10 mg kg^{-1} through borax along with Si @10 mg kg^{-1} (B_5Si_5) through silixol granules registered the highest plant height (124.16 cm), number of branches $plant^{-1}$ (15.32) and dry matter production (1384.51 g pot^{-1}). However, it was found to be onpar with borax @ 7.5 mg kg^{-1} and silicon @ 10 mg kg^{-1} (B_4Si_5). This was followed by the treatment pair of B_5Si_4, which received boron @ 10 mg kg^{-1} through borax and silicon @ 7.5 mg kg^{-1} through silixol granules. The lowest plant height, number of branches $plant^{-1}$ and dry matter production was noticed in control (without boron and silicon/RDF alone).

In coastal soil, the tomato responded to a level of 10 mg kg^{-1} of silicon through silixol granules. Whereas, various levels of boron treatments, application of borax @ 10 mg kg^{-1} through soil was established as the best treatment in increasing plant height, number of branches $plant^{-1}$ and dry matter production. However, it was comparable with borax @ 7.5 mg kg^{-1}. Increased growth characters, might be due to application of silicon as silixol granules which improved the plant growth, through enhancement of total chlorophyll contents in leaves as well as increased in the photosynthetic rate due to improved erectness of leaves by proper silicon management which resultant in higher dry matter production of tomato. This observation was in accordance with Kaya *et al*., (2006) and Pei *et al*., (2010).

Further, the improvement in growth characters with the combined application of borax @ 7.5 mg kg^{-1} + silixol granules @ 10 mg kg^{-1} along with recommended dose of NPK registered highest plant growth characters. This might be due to the reason that boron is an important constituent of nucleotides, chlorophyll and enzymes involved in various metabolic processes, which had a direct impact on vegetative phase of plants. Further more, the improvement in growth characters namely plant height as a result of application of borax + silixol granules along with recommended dose of NPK might be due to the greater availability of macro and micronutrients in borax and silicon applied plots which might have enhanced photosynthetic and other metabolic activity. This led to an increase in various plant metabolites responsible for cell division and elongation (Ali *et al*., 2013). The increase in number of branches may be due to higher nutrient use efficiency, physiological efficiency and photosynthetic rates (Ma *et al*., 2001), whereas, dry matter accumulation increased due to increase in plant height, number of branches and greater nutrient availability and increase in photosynthetic rate. The result obtained was in accordance with the findings of Shen *et al*., (2010).

Yield Characters

Yield components such as number of fruits $plant^{-1}$, single fruit weight and fruit set per cent were significantly increased due to different levels of boron and silicon fertilizers. Among the different levels of B studied, the application of B @ 10 mg kg^{-1} (B_5) recorded the highest mean number of fruits $plant^{-1}$ (27.86), single fruit weight (74.29 g) and fruit set percentage (61.86 %) of tomato. However, it was found to be equally efficacious with application of B @ 7.5 mg kg^{-1} (B_4), which recorded 27.16 number of fruits $plant^{-1}$, with single fruit weight of 72.19 g and fruit set percentage of 59.79 per cent. This was followed by the treatments B_3 and B_2. The lowest yield component was noticed in treatment B_1 (without boron application). With regard to silicon levels tried, application of silicon as silixol granules @ 10 mg kg^{-1} (Si_5) recorded the highest number of fruits $plant^{-1}$ (28.31), single fruit weight (76.56 g) and fruit set percentage (63.03%) of tomato, respectively. This was followed by the treatments, which received Si @ 7.5 mg kg^{-1} (Si_4), Si @ 5.0 mg kg^{-1} (Si_3) and Si @ 2.5 mg kg^{-1} (Si_2). The lowest yield component of tomato was noticed in treatment not applied with silicon (control).

The interaction effect between levels of boron and silicon fertilizers on yield characters of tomato was significant. The treatment (B_5Si_5), which received B as borax @ 10 mg kg^{-1} along with Si as silixol granules @ 10 mg kg^{-1}, recorded a highest number of fruits $plant^{-1}$ (31.57), single fruit weight (84.55 g) and fruit set percentage (69.69 %) of tomato, respectively. However, it was found to be on par with borax @ 7.5 mg kg^{-1} along with silixol granules @ 10 mg kg^{-1} (B_4Si_5). This was followed by the treatment pairs like B_5Si_4, B_4Si_4 and B_3Si_5. The control treatment $B_1Si_{1,}$ registered the lowest yield components of tomato.

All the yield characters of tomato increased significantly with silixol granules application. Among the various levels of silicon treatments, the application of silixol granules @ 10 mg kg^{-1} recorded the higher number of fruits $plant^{-1}$, single fruit weight and fruit setting percentage of tomato. This fact was attributed to the increased availability of silicon in the soil. The increased yield characters of the tomato plants can be attributed to the beneficial effects of silicon in the plants resulted in improvement of architecture with more erect leaves, which intercept high solar luminosity increasing the photosynthetic efficiency and higher chlorophyll content. These findings are in conformity with those of Marodin *et al*., (2014).

Further, yield characters increased with the increasing levels of boron application upto 7.5 mg kg^{-1}. The increased yield characters might be due to greater accumulation of carbohydrates owing to greater photosynthesis, which resulted in increased fruit setting percentage, fruit yield and increase in fruit weight. The improvement in yield characters with boron application might have finally been reflected through higher yields as reported by Meena *et al*., (2015). Higher stover yields might also be due to efficient translocation of assimilated boron (Figen *et al*. 2007). Moreover, boron took part in the division and expansion of cells and enhanced the volume of intercellular space in mesocarpic cells and quicker translocation of metabolites from the source to sink (fruits). Significant improvement in weight of fruits by the borax application has been reported by Dutta *et al*., (2000). Whereas, the higher dose of boron concentrations reduced fruit yield and yield components of tomato plants. It has been reported that high boron reduces yield of tomato. These findings are in agreement with the earlier works of Sathya *et al*., (2013).

Tomato Yield

The crop responded well for the different levels of boron and silicon fertilizer application. The effect was very clearly reflected in fruit and stover yield of tomato.

Table 1: Effect of different levels of boron and silicon nutrition on the growth characters of tomato.

B \ Si	Plant height (cm)						No. of branches plant^{-1}						Dry matter production (g pot^{-1})					
	Si_1	Si_2	Si_3	Si_4	Si_5	Mean	Si_1	Si_2	Si_3	Si_4	Si_5	Mean	Si_1	Si_2	Si_3	Si_4	Si_5	Mean
B_1	80.90	89.59	95.91	102.88	108.89	95.63	7.58	8.79	9.94	10.95	11.84	9.82	825.89	909.04	977.25	1053.22	1126.82	978.44
B_2	87.05	94.89	101.44	108.18	114.11	101.13	8.49	10.11	11.42	12.39	13.18	11.12	933.35	1005.04	1074.37	1142.19	1212.23	1073.43
B_3	92..46	99.15	105.99	112.24	118.00	105.56	9.47	10.89	12.25	13.30	14.22	12.03	1003.07	1076.22	1147.87	1221.08	1290.56	1147.76
B_4	96.13	104.75	111.19	117.06	122.93	110.41	10.37	11.42	12.99	14.35	15.24	12.87	1075.72	1150.40	1220.27	1293.41	1362.19	1220.39
B_5	97.67	105.52	112.73	118.27	124.16	111.67	10.80	11.87	13.32	14.44	15.32	13.15	1087.58	1165.80	1241.42	1314.01	1384.51	1238.66
Mean	90.84	98.78	105.45	111.72	117.61		9.34	10.61	11.98	13.09	13.96		985.12	1061.30	1132.23	1204.78	1275.26	
		SE_D			CD (p=0.05)			SE_D			CD (p=0.05)			SE_D			CD (p=0.05)	
B		1.48			3.05			0.15			0.31			28.07			57.83	
Si		2.11			4.35			0.21			0.43			28.70			59.14	
B × Si		2.62			5.41			0.32			0.67			31.91			65.75	

Table 2: Effect of different levels of boron and silicon nutrition on the yield characters of tomato.

B \ Si	No. of fruits plant^{-1}						Single fruit weight (g)						Fruit set per cent (%)					
	Si_1	Si_2	Si_3	Si_4	Si_5	Mean	Si_1	Si_2	Si_3	Si_4	Si_5	Mean	Si_1	Si_2	Si_3	Si_4	Si_5	Mean
B_1	16.24	18.58	20.52	22.38	23.99	20.34	43.35	50.65	56.62	61.84	66.35	55.76	33.54	40.51	45.75	50.53	54.42	44.95
B_2	19.37	21.26	23.14	24.73	26.57	23.01	52.13	57.51	62.52	67.63	72.22	62.40	43.09	47.25	51.96	56.07	59.64	51.60
B_3	21.45	23.76	25.39	27.19	28.74	25.30	56.65	62.19	67.50	72.49	77.18	67.20	46.97	51.66	55.63	59.98	63.76	55.60
B_4	23.33	25.39	27.33	29.09	30.68	27.16	61.16	67.14	72.68	77.45	82.52	72.19	51.25	56.00	60.11	63.98	67.65	59.79
B_5	23.83	26.07	28.08	29.73	31.57	27.86	63.38	69.46	74.42	79.67	84.55	74.29	53.49	58.05	62.26	65.85	69.69	61.86
Mean	20.84	23.01	24.89	26.62	28.31		55.33	61.39	66.74	71.81	76.56		45.66	50.69	55.14	59.28	63.03	
		SE_D			CD (p=0.05)			SE_D			CD (p=0.05)			SE_D			CD (p=0.05)	
B		0.55			1.15			1.24			2.56			1.27			2.63	
S		0.62			1.29			1.46			3.01			1.48			3.05	
B × Si		0.69			1.43			2.01			4.15			1.55			3.21	

B- Boron levels: B_1 – Control; B_2 – 2.5 mg kg^{-1}; B_3 – 5.0 mg kg^{-1}; B_4 – 7.5 mg kg^{-1} and B_5 – 10 mg kg^{-1}.

Si- Silicon levels: Si_1 – Control; Si_2 – 2.5 mg kg^{-1}; Si_3 – 5.0 mg kg^{-1}; Si_4 – 7.5 mg kg^{-1} and Si_5 – 10 mg kg^{-1}.

Table 3: Effect of different levels of boron and silicon nutrition on the yield of tomato.

Si / B	Fruit yield (g pot^{-1})						Stover yield (g pot^{-1})					
	Si_1	**Si_2**	**Si_3**	**Si_4**	**Si_5**	**Mean**	**Si_1**	**Si_2**	**Si_3**	**Si_4**	**Si_5**	**Mean**
B_1	1437.77	1569.88	1691.29	1817.59	1935.91	1690.48	711.84	790.78	867.21	938.90	1007.45	863.23
B_2	1582.65	1714.22	1829.54	1949.05	2065.25	1828.14	816.54	887.88	955.82	1022.53	1093.33	955.22
B_3	1716.40	1839.54	1958.66	2074.64	2192.35	1956.31	889.16	960.49	1028.48	1097.70	1162.80	1027.72
B_4	1833.49	1956.71	2078.11	2195.45	2313.67	2075.48	951.92	1021.79	1098.19	1168.81	1237.36	1095.61
B_5	1860.49	1988.84	2113.71	2234.07	2352.61	2110.01	968.68	1047.79	1123.67	1196.93	1265.68	1120.55
Mean	1686.22	1813.83	1934.26	2054.16	2171.95		867.62	941.74	1014.67	1084.97	1153.31	
SE_D		CD (p=0.05)			SE_D			CD (p=0.05)				
B		50.47			103.97			27.82			57.31	
S		52.97			109.12			28.99			59.72	
B × Si		55.23			113.79			29.73			61.25	

The effect of different levels of boron (B) and silicon (Si) in increasing the tomato yield was well evidenced in the present study. Increase in the level of B from 0 to 10 mg kg^{-1} in increased the fruit and stover yield from 1690.48 to 2110.01 g pot^{-1} and 863.23 to 1120.55 g pot^{-1}, respectively. Among the various levels of boron, application of B @ 10 mg kg^{-1} was excelled the other four levels. Application of B @ 10 mg kg^{-1} (B_5) registered a fruit and stover yield of 2110.01 and 1120.55 g pot^{-1}, respectively which was on par with application of B @ 7.5 mg kg^{-1} (B_4) by registering 2075.48 and 1095.61 g pot^{-1} of fruit and stover yield of tomato, respectively. This was followed by the treatments B_3 (B @ 5 mg kg^{-1}) and B_2 (B @ 2.5 mg kg^{-1}). Among the different levels of silicon fertilizers, the application of silicon through silixol granules @ 10 mg kg^{-1} (Si_5) recorded the highest mean fruit (2171.95 g pot^{-1}) and stover yield (1153.31 g pot^{-1}) of tomato. This was followed by the treatments Si_4 (application of Si @ 7.5 mgkg^{-1}), Si_3 (application of Si @ 5 mg kg^{-1}) and Si_2 (application of Si @ 2.5 mg kg^{-1}).

The interaction effect due to levels of boron and silicon fertilizer significantly increased the fruit and stover yield of tomato. Application of B through borax @ 10 mg kg^{-1} along with Si through silixol granules @ 10 mg kg^{-1} (B_5Si_5) recorded the highest fruit and stover yield of 2352.61 g pot^{-1} and 1265.68 g pot^{-1} which was 38.88 and 43.75 per cent increase over control (without boron and silicon). This treatment was closely on par with the treatment which received borax @ 7.5 mg kg^{-1} along with silixol granules @ 10 mg kg^{-1} (B_4Si_5). Application of borax @ 7.5 mg kg^{-1} and silixol granules @ 10 mg kg^{-1} registered a fruit and stover yield of 2313.67 and 1237.36 g pot^{-1} which was 37.85 and 42.47 per cent increase over control (RDF alone).

The combined application of borax @ 10 mg kg^{-1} and silixol granules @ 10 mg kg^{-1} (B_5Si_5) excelled all other treatments in improving the higher yield of tomato. However, it was found to be onpar with treatment B_4Si_5, which supplied with borax @ 7.5 mg kg^{-1} and silixol granules @ 10 mg kg^{-1}. The treatment B_1Si_1 registered the lowest fruit and stover yield of tomato. This might be due to increased nutrient availability, which resulted in better vegetative growth coupled with better partitioning of photosynthates in vegetative and reproductive parts. Silicon plays a key role in retaining the water capacity in plant cells and also corrects the level of endogenous growth hormone *viz.* auxins, gibberellins and cytokinins under stress conditions. The earlier report of Ahmed *et al*., (2008) and Cruscio *et al*., (2009) confirm the present findings. In addition, the supply of boron needed for reproductive growth ovary development, seed development and maturity of fruit yield were due to the significant increase of boron availability, which in turn induced more flowering and minimized the flower drops and finally yield gets increased in tomato. These findings were comparatively with similar research of Chaudry *et al*., (2007) and Sultana *et al.,* (2016).

Conclusion

The results of the present investigation clearly concluded the beneficial effect of silicon and boron fertilizers for increasing tomato production in coastal saline soil. Among the boron and silicon levels, the best level of B and Si were selected based on the yield performance of tomato. Soil application of boron as borax @ 7.5 mg kg^{-1} and silicon as silixol granules @ 10 mg kg^{-1} was the optimum dose of boron and silicon identified and yield maximization of tomato.

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