

Effect of foliar spray of boron and their time of application on yield, quality and economics of beetroot (*Beta vulgaris* L.)

ABSTRACT

The present investigation was carried out at Hi-Tech Unit, Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur. The twelve treatments comprising of various combinations of 4 levels of boron, i.e., B₀ - 0, B₁ - 100, B₂ - 150 and B₃ - 200 ppm and three spray application times, i.e., D₁ - 30, D₂ - 45 and D₃ - 60 DAS. The treatments for beetroot crop were evaluated with three replications under factorial randomized block design. The experimental results show that different concentrations of boron, application times and their combinations significantly affected yield and quality of beetroot. Among treatments with different concentration of boron maximum yield per plot (45.44 kg), yield of root (454.45 q/ha), dry matter (18.08 %), protein on dry weight basis (2.54 %), ascorbic acid content (3.48 mg 100g⁻¹), total soluble solids (16.10 °Brix) and beta carotene content (1438.34 IU) were recorded with treatment B₃D₁ (200 ppm boron spray at 30 DAS) and also significantly produced higher gross return (₹ 238340.00), maximum net return (₹ 170230.00) and benefit cost ratio of 2.50, i.e., generating highest net return of ₹ 2.50 per rupee invested.

Key words: Beetroot, Boron, Foliar application, Time of spray, yield & quality etc.

Introduction

Boron is involved in cell wall and cell membrane's structural and functional integrity, ion fluxes (H⁺, K⁺, PO₄³⁻, Rb⁺ and Ca²⁺) across membranes, cell division and elongation, nitrogen and carbohydrate metabolism, sugar transport, cytoskeletal proteins and plasmalemma-bound enzymes, nucleic acid, indole acetic acid, polyamines, ascorbic acid and phenol metabolism and transport (Shireenet *al.*, 2018). N fixation, is involved in the metabolism of protein and carbohydrate (Blevins and Lukaszewski 1998), sugar translocation (Armin and Asgharipour 2012) as well as the synergistic influence on N, phosphorus, and potassium uptake (Turanet *al.* 2010, Padbhushan and Kumar 2015). Boron is required in the plant to facilitate sugar transport, it

increases root weight and diameter, increases dry matter accumulation and enhances quality, these changes together result in an increase in sugar beet yield (Eweidaet *al.*, 1994). Boron deficiency, on the other hand, is linked to a disruption in plant hormone synthesis and nucleic acid metabolism. As all of these functions are essential to meristematic tissues, boron deficiency primarily causes harm to actively growing organs such as shoot and root tips, causing the entire plant to be stunted or rosetting (Motagally, 2015). The method of fertilizer application has a significant impact on its efficiency, foliar sprays are known to be an efficient alternative to soil fertilization, especially in the case of micronutrients (Eichert and Fernández, 2012). It has several advantages, including convenience, quick plant response and prevention of toxicity caused by excessive soil deposition of these nutrients over soil application (Obrezaet *al.*, 2010). Sugar beet uptake boron (B) in the form of $B(OH)_3$ or H_3BO_3 from the soil by roots (Marschner 1993). Also, B is one of the seven basic micro-nutrients required for the regular and balanced growth of most plant species (Turanet *al.* 2010. The higher quantities of free calcium carbonate, too higher quantities of phosphorus, and lower soil organic matter along with high soil pH decrease B uptake of plants and obtaining maximum benefit from B application (Niazet *al.* 2016). Sugar beet continuously required relatively high levels of soil available B as compared to other crops (Dridiet *al.* 2018).

MATERIAL AND METHODS

The present experiment on beetroot was conducted during winter season of the year 2020-21 at Hi-tech Unit, Department of Horticulture, Rajasthan College of Agriculture, Udaipur which is situated at $24^{\circ}35'N$ and $74^{\circ}42'E$ latitude at 585.5 meters above mean sea level. The data recorded for evaluation of different treatments in beetroot was statistically analyzed using standard procedure as suggested by Panse and Sukhatme (1985) for analysis of variance of Factorial RBD in order to test the significance of experimental findings. The experiment comprised of 12 treatment combinations of 4 levels of boron and 3 application times as following $T_1-B_0D_1$ -Boron application @ 0 ppm on 30 DAS, $T_2-B_0D_2$. Boron application @ 0 ppm on 45 DAS, $T_3-B_0D_3$. Boron application @ 0 ppm on 60 DAS, $T_4-B_1D_1$. Boron application @ 100 ppm on 30 DAS, $T_5-B_1D_2$ -Boron application @ 100 ppm on 45 DAS, $T_6-B_1D_3$ -Boron application @ 100 ppm on 60 DAS, $T_7-B_2D_1$. Boron application @ 150 ppm on 30 DAS, $T_8-B_2D_2$. Boron application @ 150 ppm on 45 DAS, $T_9-B_2D_3$ -Boron application @ 150 ppm on 60 DAS, $T_{10}-B_3D_1$. Boron

application @ 200 ppm on 30 DAS, T₁₁-B₃D₂. Boron application @ 200 ppm on 45 DAS, T₁₂-B₃D₃. Boron application @ 200 ppm on 60 DAS.

Results and Discussion

Data in Table 1 manifest that a significant effect that various treatments with varying concentration of boron significantly influenced yield. Maximum yield per plot and total yield (45.44 kg and 454.45 q/ha, respectively) was recorded with treatment B₃ (boron spray at 200 ppm). These results may be due to the increased foliage fresh weight, root diameter and root length which can be attributed to the positive role of boron on translocation of photosynthates from leaves to roots. Nemeata (2017) also concluded that increased concentration of boron applied as foliar spray led to an increase in yield per plot and total yield. Similar findings were also reported by Makhoulf *et al.* (2020). Yield per plot and total yield had significant divergence for different combinations and maximum yield per plot and total yield (47.67 kg and 476.68 q/ha, respectively) was recorded for treatment B₃D₁ (200 ppm boron spray at 30 DAS). Similar results were found by Abbas *et al.* (2014).

Results also suggested that among different concentrations of boron spray, highest dry matter (18.08 %) was recorded with application of boron spray at 200 ppm in treatment B₃, while lowest value for this parameter was found with treatment B₀ (boron spray at 0 ppm). This may be due to the fact that boron plays an important role in the physiological functioning of higher plants. It is involved in the structural and functional integrity of the cell wall and membranes. This might have led to an increased thickness in the cell wall of the roots. Boron also affects ion fluxes across the membranes. This may interact to increase the cell permeability leading to easier movement of water outside of the cell. These results are in line with the results found by Enan *et al.* (2016) and El-Tantawy (2017) they recorded increased dry weight of roots in sugar beet with increasing concentration of boron. Different spray application times also had significant effect, with maximum dry matter percentage (17.40 %) was recorded with treatment D₁ (boron spray at 30 DAS), while minimum value was found in treatment D₃ (boron spray at 60 DAS). Data presented in Table 1 clearly showed that dry matter % was significantly influenced by different combinations of boron concentration and time of application of foliar spray. The maximum value for dry matter (19.47 %) was measured with application of boron at 200 ppm concentration sprayed on 30 DAS, *i.e.*, treatment B₃D₁, whereas minimum dry matter percentage was observed in treatment B₀D₃ (0 ppm boron spray at 60 DAS).

It is clear from the results presented (Table 2) in preceding chapter that various concentrations of boron significantly affected protein on dry weight basis of beetroot. The data showed that maximum protein on dry weight basis (2.54 %) was recorded with application of boron at 200 ppm in treatment B₃ whereas, minimum value for protein content (1.94 %) was recorded with B₀ (boron spray at 0 ppm). Nemeata *et al.* (2019) also recorded an increase in nitrogen content with increasing boron concentration, which corresponds with an increase in protein content. According to the collected data maximum protein percentage (2.42%) reported in treatment D₁ (spray at 30 DAS) as compared to minimum protein percentage (2.11%) found in the treatment D₃ (boron spray at 60 DAS). The timely availability of boron at the earlier stage of development might have added to the better quality. In interaction of varied boron levels and timing of spray according to the analysed data, maximum protein percentage (2.74 %) was recorded in treatment B₃D₁ (200 ppm boron spray at 30 DAS) while, minimum value (1.89 %) was noticed with the treatment B₀D₂ (0 ppm boron spray at 45 DAS). In case of treatment with different boron levels, highest ascorbic acid content (3.48 mg/100 g) was found with treatment B₃ (boron spray at 200 ppm), which was closely followed (3.34 mg/100 g) by treatment B₂ (boron spray at 150 ppm). Similar results showing an increase in ascorbic acid content with an increase in rate of boron application to the soil were obtained by Yatsenko *et al.* (2020) while working with garlic. Treatment of roots with spray at different times also had a significant impact on ascorbic acid content in roots. Maximum ascorbic acid content in roots (3.33 mg/100 g) was derived from treatment D₁ (boron spray at 30 DAS) while minimum ascorbic acid content (2.95 mg/100 g) was recorded in those treated with D₃ (boron spray at 60 DAS). Various treatment combinations also had positive impact with respect to ascorbic acid content. Maximum value (3.62 mg/100 g) was found in B₃D₁ (200 ppm boron spray at 30 DAS) while minimum value (2.72 mg/100 g) was in B₀D₂ (0 ppm boron spray at 45 DAS). While, ascorbic acid content (3.58 g/100 g) with treatment B₂D₁ (150 ppm boron spray at 30 DAS) was at par (3.62 mg/100 g) with B₃D₁.

Analysis of collected data showed that highest TSS (16.10 °Brix) was obtained with the treatment B₃ (boron spray at 200 ppm), whereas minimum TSS (13.81 °Brix) was observed in the treatment B₀ (boron spray at 0 ppm). Time of spray also had a significant effect on TSS, and maximum TSS (15.61 °Brix) was found in the treatment D₁ (boron spray at 30 DAS). In different treatment combinations a significant difference was observed in the TSS. The maximum TSS content (16.97 °Brix) was recorded with treatment B₃D₁ (200 ppm boron spray at 30 DAS),

while minimum TSS (13.73°Brix) was reported with treatment B₀D₂ (0 ppm boron spray at 45 DAS). Makhlofet *al.* (2020) reported that extracted sugar (%) was increased when boron concentration was increased from 75 ppm to 100 ppm. Concentration of boron also had a significant impact on beta carotene content of beetroot with maximum value (1438.84 IU) being recorded with treatment B₃ (boron spray at 200 ppm), while minimum value (1326.19 IU) was recorded with B₀ (boron spray at 0 ppm). This is in accordance with the findings by Makhlofet *al.* (2020) when they observed that increase in boron concentration led to an increase in carotenoid content of sugar beet. Application of spray at different time also had a significant effect on the beta carotene content of beetroot. Maximum value of beta carotene (1429.83 IU) was recorded with treatment D₁ (boron spray at 30 DAS), while minimum (1358.63 IU) was recorded with treatment D₃ (boron spray at 60 DAS). Highest beta carotene content (1522.53 IU) was reported with treatment B₃D₁ (200 ppm boron spray at 30 DAS) while lowest beta carotene content (1316 IU) was recorded with B₀D₂ (0 ppm spray of boron at 45 DAS). Improved quality characters might be due to the fact that boron is an essential element which has varied important physiological and metabolic roles. Boron is actively involved in sugar metabolism, sugar transport, metabolism and transport of ascorbic acid, nitrogen metabolism and stability of cytoskeletal proteins. The economics of beetroot production is a very important part of cultivation. Higher profits and less cultivation cost are expedient for getting higher returns. Economic evaluation of different treatments for beetroot under one hectare area, are given in Table 3. Economic analysis showed that application of boron spray at 200 ppm under treatment B₃, registered highest benefit cost ratio of 2.34. Findings of Attia *et al.* (2018) also concur with the our economic analysis, as they also recorded higher net returns from the sugar beet crop which was under treatment of boron at 0.20 g/l. Economic analysis also showed that among different combinations of boron concentration and spray time, treatment B₃D₁ (200 ppm boron spray at 30 DAS) significantly produced higher gross return (₹ 238340.00), maximum net return (₹ 170230.00) and benefit cost ratio of 2.50, *i.e.*, generating highest net return of ₹ 2.50 per rupee invested.

CONCLUSION:

On the basis of experiment it may be concluded that among different combinations of concentrations of boron and time of application of boron spray also had a significant effect on

beetroot, treatment B₃D₁ (200 ppm boron spray at 30 DAS) was found to have superior performance in terms of yield, quality and economic of beetroot then the rest of treatments.

REFERENCES

- Abbas, M.S., Dewdar, M.D.H., Gaber, E.I. and El-Aleem, H.A.A. 2014. Impact of foliar application on quantity and quality traits of sugar beet (*Betavulgaris* L.) in Egypt. *Research Journal Of Pharmaceutical, Biological and Chemical Sciences*, **5**: 143-151.
- Abdel-Motagally, F.M.F. 2015. Effect concentration and spraying time of boron on yield and quality traits of sugar beet grown in newly reclaimed soil conditions. *Assiut Journal of Agricultural Sciences*, **46**: 15-26.
- Armin, M., and M. Asgharipour. 2012. Effect of time and concentration of boron foliar application on yield and quality of sugar beet. *American-Eurasian Journal of Agricultural & Environmental Sciences*, **12**:444–448
- Attia, Z.M., El-Mehy, A.A. and Badr, K.S. 2018. Effect of preceding catch crop with the boron foliar application on yield and quality of beet (*Beta vulgaris* L.). *Menoufia Journal of Plant Production*, **3**: 287-301.
- Blevins, D. G., and K. M. Lukaszewski. 1998. Boron in plant structure and function. *Annual Review of Plant Physiology and Plant Molecular Biology*,**49**:481–500.
- Dewdar, M.D.H., Abbas, M.S., Gaber, E.I. and El-Aleem, H.A.E.A. 2015. Influence of time addition and rates of boron foliar application on growth, quality and yield traits of sugar beet. *International Journal of Current Microbiology and Applied Sciences*, **4**: 231-238.
- Dridi, I., A. Tlili, S. Fatnassi, H. Hamrouni, and M. Gueddari. 2018. Effects of boron distribution on sugar beet crop yield in two Tunisian soils. *Arabian Journal of Geosciences*,**11**:400.
- Eichert, T. and Fernández, V. 2012. Uptake and release of elements by leaves and other aerial plant parts. *Marschner's mineral nutrition of higher plants* pp. 71-84.

- El-Tantawy, E.M. 2017. Improving growth, top root yield and betanin pigment of table beet as a result of spraying with magnesium, copper and boron under El-Arish region. *Journal of Plant Production*, **8**: 231-238.
- Enan, S.A.A.M., El-Saady, A.M. and El-Sayed, A.B. 2016. Impact of foliar feeding with alga extract and boron on yield and quality of sugar beet grown in sandy soil. *Egyptian Journal of Agronomy*, **38**: 319-336.
- Eweida, M.H.T., El-Gharabawy, A.A., Besheit, S.Y. and El-Shenawy K. 1994. Growth, quality and yield of sugar beet as affected by foliar applications of some micronutrients. Proc. 6th Conf. Agron. Al-Azhar Univ., Cairo, Egypt, Sept. II: 859-869.
- Makhlouf, B.S.I., Gadallah, A.F.I. and El-Laboudy, E.H.S. 2020. Effect of phosphorus, boron and magnesium fertilization on yield and quality of sugar beet grown in a sandy soil. *Journal of Plant Production*, **11**:575-583.
- Marschner, H. 1993. Zinc uptake from soils. In *Zinc in soils and plants*, 59–77. Dordrecht: Springer.
- Motagally, A.F.M.F. 2015. Effect concentration and spraying time of boron on yield and quality traits of sugar beet grown in newly reclaimed soil conditions. *Assiut Journal of Agricultural Sciences*, **46**: 15-26.
- Nemeata A, H.E.A. 2017. Effect of boron level and time of application on yield and quality of sugar beet. *Journal of Plant Production*, **8**: 1071-1075.
- NemeataAlla, H.E.A., El-Sherief, A.E. and El-Gamal, I.S.H. 2019. Impact of compost and boron fertilization on yield and quality of sugar beet grown in a sandy soil. *Journal of Plant Production*, **10**: 1065-1070.
- Niaz, A., A. Nawaz, S. Ehsan, I. Saleem, M. Ilyas, A. Majeed, A. Muhmood, A. M. Ranjha, and A. N. Rahmatullah. 2016. Impacts of residual boron on wheat applied to previous cotton crop under alkaline calcareous soils of Punjab. *Science Letters* 4:33–9
- Obreza, T.A., Zekri, M., Hanlon, E.A., Morgan, K., Schumann, A. and Rouse, R. 2010. Soil and leaf tissue testing for commercial citrus production. *University of Florida Extension Service*, SL: 253.04.

- Padbhushan, R., and D. Kumar. 2015. Yield and nutrient uptake of green gram (*Vignaradiata* L.) as influenced by boron application in boron-deficient calcareous soils of Punjab. *Communications in Soil Science and Plant Analysis* 46 (7):908–923
- Panse, V.G. and Sukhatme, P.V. 1985. Statistical methods for agricultural workers. ICAR, New Delhi, pp. 145-155.
- Shireen, F., Nawaz, M. A., Chen, C., Zhang, Q., Zheng, Z., Sohail, H., Sun, J., Cao, H., Huang, Y. and Bie, Z. 2018. Boron: functions and approaches to enhance its availability in plants for sustainable agriculture. *International Journal of Molecular Sciences*, **19**:1856.
- Turan, M., Q. M. Ketterings, A. Gunes, N. Ataoglu, A. Estringu, A. V. Bilgili, and Y. M. Huang. 2010. € Boron fertilization of Mediterranean aridisols improves lucerne (*Medicago sativa* L.) yields and quality. *Acta Agriculturae Scandinavica, Section B - Plant Soil Science* 60 (5):427–436.
- Yatsenko, V., Ulianych, O. and Yanowskiy, Y. 2020. Effect of iron, zinc and boron on the growth, physiological state, productivity and storability of *Allium sativum* L. *Ukrainian Journal of Ecology*, **10**: 33-42.

Table: 1 Main effects and interaction effects of concentration of boron, time of application and their combinations on dry matter percentage, Yield per plot (kg), Total yield of root (q/ha).

Treatment	Yield per plot (kg)	Total yield of root (q/ha)	Dry matter percentage (%)
Boron			
B₀	37.99	379.96	14.53
B₁	41.89	418.89	16.27
B₂	44.75	447.50	17.62
B₃	45.44	454.45	18.08
SEm_±	0.807	8.074	0.129
CD at 5%	2.368	23.680	0.379
Time of application			
D₁	43.88	438.83	17.40
D₂	42.60	426.04	16.72
D₃	41.07	410.72	15.76
SEm_±	0.699	6.992	0.112
CD at 5%	2.051	20.507	0.329
B x D			
T₁-B₀D₁	37.61	376.12	14.59
T₂-B₀D₂	38.08	380.82	14.63
T₃-B₀D₃	38.30	382.92	14.37
T₄-B₁D₁	43.58	435.84	16.93
T₅-B₁D₂	41.33	413.33	16.24
T₆-B₁D₃	40.75	407.48	15.65
T₇-B₂D₁	46.67	466.68	18.61
T₈-B₂D₂	45.17	451.67	17.80
T₉-B₂D₃	42.41	424.15	16.45
T₁₀-B₃D₁	47.67	476.68	19.47
T₁₁-B₃D₂	45.83	458.34	18.20
T₁₂-B₃D₃	42.83	428.33	16.59
SEm_±	1.398	13.98	0.224
CD at 5%	NS	NS	0.657

Table: 2 Main effects and interaction effects of concentration of boron, time of application and their combinations on dry matter percentage, protein on dry weight basis, ascorbic acid content in roots, TSS and beta carotene of beetroot.

Treatment	Protein on dry weight basis (%)	Ascorbic acid content in roots (mg/100 g)	TSS (°Brix)	Beta Carotene (IU)
Boron				
B₀	1.94	2.73	13.81	1326.19
B₁	2.11	3.05	14.82	1369.74
B₂	2.41	3.34	15.56	1415.78
B₃	2.54	3.48	16.10	1438.84
SEm₊	0.028	0.0240	0.116	11.22
CD at 5%	0.081	0.071	0.341	32.91
Time of application				
D₁	2.42	3.33	15.61	1429.83
D₂	2.21	3.17	15.02	1374.45
D₃	2.11	2.95	14.58	1358.63
SEm₊	0.024	0.021	0.101	9.717
CD at 5%	0.070	0.062	0.295	28.500
B x D				
T₁ -B₀D₁	1.92	2.75	13.83	1328.05
T₂ -B₀D₂	1.89	2.72	13.73	1316.93
T₃ -B₀D₃	2.00	2.74	13.86	1333.60
T₄ -B₁D₁	2.34	3.37	15.63	1408.39
T₅ -B₁D₂	2.01	2.98	14.60	1353.43
T₆ -B₁D₃	1.98	2.80	14.23	1347.39
T₇ -B₂D₁	2.70	3.58	16.00	1460.68
T₈ -B₂D₂	2.37	3.46	15.77	1411.72
T₉ -B₂D₃	2.18	2.98	14.90	1374.93
T₁₀ -B₃D₁	2.74	3.62	16.97	1522.53
T₁₁ -B₃D₂	2.60	3.53	16.00	1415.73
T₁₂ -B₃D₃	2.28	3.29	15.33	1378.58
SEm₊	0.048	0.042	0.201	19.430
CD at 5%	0.140	0.124	0.591	57.001

Table: 3 Main effects and interaction effects of concentration of boron, time of application and their combinations on economics of beetroot

Treatment	Total yield of root (q/ha)	Total cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C Ratio
Boron					
B₀	379.96	67510.00	189980.00	122470.00	1.81
B₁	418.89	67810.00	209445.00	141635.00	2.09
B₂	447.50	67960.00	223750.00	155790.00	2.29
B₃	454.45	68110.00	227225.00	159115.00	2.34
Time of application					
D₁	438.83	67510.00	219415.00	151905.00	2.25
D₂	426.04	67510.00	213020.00	145510.00	2.16
D₃	410.72	67510.00	205360.00	137850.00	2.04
B x D					
T₁ -B₀D₁	376.12	67510.00	188060.00	120550.00	1.79
T₂ -B₀D₂	380.82	67510.00	190410.00	122900.00	1.82
T₃ -B₀D₃	382.92	67510.00	191460.00	123950.00	1.84
T₄ -B₁D₁	435.84	67810.00	217920.00	150110.00	2.21
T₅ -B₁D₂	413.33	67810.00	206665.00	138855.00	2.05
T₆ -B₁D₃	407.48	67810.00	203740.00	135930.00	2.00
T₇ -B₂D₁	466.68	67960.00	233340.00	165380.00	2.43
T₈ -B₂D₂	451.67	67960.00	225835.00	157875.00	2.32
T₉ -B₂D₃	424.15	67960.00	212075.00	144115.00	2.12
T₁₀ -B₃D₁	476.68	68110.00	238340.00	170230.00	2.50
T₁₁ -B₃D₂	458.34	68110.00	229170.00	161060.00	2.36
T₁₂ -B₃D₃	428.33	68110.00	214165.00	146055.00	2.14