Indian Journal of Ecology (2025) 52(6): 1442-1446
DOI: https://doi.org/10.55362/IJE/2025/4671

Manuscript Number: 4671
NAAS Rating: 5.38

Growth and Yield Response of Broccoli (*Brassica oleracea* var. *italica*) to Application of Calcium, Boron and Zinc in Alkaline Soils of Indo-Gangetic Plains of India

Prabhjot Kaur, Abhishek[1*], Chhatar Pal Mehla, Jaspreet Kaur and Mangat Ram[2]

Department of Agriculture, Sri Guru Granth Sahib World University (SGGSWU), Fatehgarh Sahib-140 407, India
[1]Maharana Pratap Horticultural University, Karnal-132 116, India
[2]Department of Agronomy, Haryana Agricultural University, Hisar-125 004, India
**E-mail: abhishekmehla888@gmail.com*

Abstract: The field experiment was conducted during winter (*rabi*) season of 2022-23 and 2023-24 at Shri Guru Granth Sahib World University, Fatehgarh Sahib, Punjab (India) to evaluate the effect of soil application of calcium (gypsum) and soil or foliar application of boron (B) and zinc (Zn) on growth and yield of broccoli on alkaline soils under sub-tropical conditions of central Punjab. Soil application of boron (1.5 kg B/ha) or zinc (5 kg Zn/ha) as well as foliar application of B (0.3% borax) or Zn (0.5% zinc sulphate), alone or in combination, increased the growth (plant height, number of leaves plant^{-1}, leaf length, leaf width and plant spread), yield attributing characters (number of secondary heads plant^{-1}, weight of main head plant^{-1}, weight of secondary heads plant^{-1} and total weight of heads plant^{-1}) and total marketable head yield (t ha^{-1}) of broccoli significantly over their no application (control) during both the years. Foliar application of both B and Zn was better than their soil application in increasing the crop growth and productivity. Combined application of B and Zn was better than their sole application, irrespective of their mode of application. The highest value of growth parameters, yield attributes and marketable head yield was obtained with combined foliar application of B and Zn. Foliar application of B or Zn alone were at par with each other in terms of growth, yield attributes and the yield, proving significantly better than soil application of B or Zn alone or combined while their combined application in soil was significantly better than their sole application in soil. However, soil application of Zn alone performed better than soil application of B alone. Application of calcium (100 kg ha^{-1}), however, could not increase the growth and yield of the crop over its no application. The combined application of B and Zn, preferably through foliar spray (B as 0.3% borax and Zn as 0.5% zinc sulphate), may be suggested for obtaining higher marketable yield of broccoli in micronutrient (B and Zn) deficient alkaline soils of central Punjab.

Keywords: Broccoli, Calcium, Boron, Foliar spray, Marketable yield

Broccoli (*Brassica oleracea* var. *italica*) is a cruciferous vegetable of the *Brassicaceae* family and is one of the under-exploited vegetable crops in India. Plant nutrition is an important factor for increasing productivity of a crop. Broccoli requires not only major plant nutrients such as nitrogen, phosphorus, potassium and calcium and but also vital micronutrients such as boron and zinc to produce a bountiful harvest. Hence there is need to supply these nutrients for the plants if these are not available in sufficient quantities in soil. Calcium is an important secondary macro-nutrient which is not only a structural component of cell wall and membranes but also serves as a second messenger in many developmental and physiological processes (Thor 2019) and hence helps in overall plant growth and development. Broccoli has as much Ca as milk (Dhotra et al., 2018) and hence is expected to have higher Ca requirement. Although available in plenty in most cultivated soils, availability of Ca is reduced due to its conversion into insoluble form by reacting with other applied nutrients like phosphorous, particularly at high soil pH, and also due to Ca adsorption on clay particles in fine textured soils (Prasad and Shivay 2020), necessitating its application for promoting plant growth and yield. Boron is development of reproductive tissues in plants and its deficiency is associated with poor quality seeds and fruits (Prasad et al., 2014). Zinc is another important micronutrient which is a component of different enzymes catalysing many metabolic reactions in plants and plays a significant role in enhancing disease resistance, photosynthesis, protein synthesis, pollen formation and chlorophyll formation in plants (Hussain et al., 2015).

Alkaline soils in many areas of Indo Gangetic Plains (IGP) in India, including the state of Punjab situated in western part of IGP, are prone to deficiency of micronutrients like zinc and boron due to several reasons such as poor solubility of these micronutrients at higher soil pH, low organic carbon in soil, intensive cultivation practices, adoption of exhaustive cropping systems like rice-wheat, growing of high yielding varieties of crops and excessive use of micronutrient-free high analysis fertilizers (Shukla et al., 2021, Khurana 2022). Therefore, it is essential to apply sufficient quantities of the micronutrients, particularly B and Zn, for the crop plants as these two are the most deficient micronutrients in such soils (Thapa et al., 2016, Mondal and Ghosh 2023). Moreover, the research work on B and Zn application in broccoli is scanty, particularly in intensively cultivated alkaline fine textured soils of Punjab under sub-tropical climate. The present field investigations

were, therefore, carried out to assess the response of broccoli to application of calcium and micronutrients (B and Zn) in alkaline soils of central Punjab in order to find out their optimum combination and method of application to obtain higher yield of the crop under sub-tropical conditions.

MATERIAL AND METHODS

The field experiment on broccoli was conducted at the Farm of Department of Agriculture, Sri Guru Granth Sahib World University, Fatehgarh Sahib, Punjab (India) during winter season of 2022-23 and 2023-24 with variety Palam Samridhi. The soil of experimental field was clay loam in texture, alkaline in reaction (pH 7.9) and low in organic carbon (0.54%), available nitrogen (160 kg N ha^{-1}), boron (0.34 mg kg^{-1}) and zinc (0.60 mg kg^{-1}) but medium in available phosphorus (14 kg P ha^{-1}) and potassium (280 kg K ha^{-1}). The experimental treatments consisted of two levels of calcium viz. C_1: soil application of calcium @ 100 kg ha^{-1} and C_0: no calcium and seven different treatments of B and Zn viz. B_1: soil application of boron @ 1.5 kg ha^{-1}; B_2: foliar spray of B (0.3% borax); Z_1: soil application of Zn @ 5 kg ha^{-1}; Z_2: foliar spray of Zn (0.5% zinc sulphate); B_1+Z_1: soil application of B @ 1.5 kg ha^{-1} + Zn @ 5 kg ha^{-1}; B_2Z_2: foliar spray of B (0.3% borax) + Zn (0.5% zinc sulphate) and B_0Zn_0 (Control). The treatments were arranged in factorial randomized block design with three replications on plots of size 3.6 x 3.6 m for each replication of a treatment. Calcium was applied in soil through agricultural grade gypsum (22.5% Ca) a week before transplanting of broccoli seedlings and mixed well in soil. Boron and zinc in soil were applied through disodium tetraborate (20% B) and zinc sulphate (21% Zn), respectively one day before transplanting and mixed in the soil. Foliar spray of B was done using 0.3% borax (11% B) whereas 0.5% zinc sulphate (21% Zn) was used for foliar spray of Zn. Foliar spray of both B and Zn was done at 20, 35 and 50 days after transplanting. Recommended dose of NPK used for crop was 125: 75: 75 kg ha^{-1} with N, P and K supplied through urea, diammonium phosphate and muriate of potash, respectively in all the treatments. Full dose of P and K was applied at transplanting whereas N was applied in three equal splits at 0, 20 and 40 days after transplanting. The crop was sown in nursery beds on 15 September, 2022 and 10 September, 2023 and the seedlings (28 days old) were transplanted in the main field at 45 x 45 cm spacing. The other recommended cultural practices were followed for raising the crop successfully. The data on various growth parameters (plant height, number of leaves $plant^{-1}$, leaf length, leaf width and plant spread), yield attributes and yield were recorded from five randomly selected plants in each plot. The growth observations were recorded at 60 days after transplanting. The commercially matured primary heads were separated from each plant to record average primary head weight $plant^{-1}$. The secondary heads or sprouts arising from leaf axils of each plant, after removal of its primary head, were also harvested later on (as and when commercially matured), counted and weighed to record their total number and weight $plant^{-1}$. Total head weight (weight of primary + secondary heads) $plant^{-1}$ as well as total yield (marketable yield) in tonnes per hectare (t ha^{-1}) were also worked out. The data were subjected to statistical analysis at 5% level of significance using online statistical analysis tool (OPSTAT) accessible at the website of Chaudhary Charan Singh Haryana Agricultural University, Hisar (www. hau.ac.in).

RESULTS AND DISCUSSION

Growth parameters: Soil application of calcium @ 100 kg ha^{-1} (through gypsum) could not increase any of the crop growth parameters (plant height, number of leaves $plant^{-1}$, leaf length and leaf width and plant spread) significantly over no calcium application (Table 1). But all these growth parameters registered significant increase with the application of both B and Zn alone or combined, irrespective of mode of their application (soil or foliar), over the control (B_0Z_0). Among various treatments comprising micronutrients, maximum plant height, number of leaves $plant^{-1}$, leaf size (length and width) and plant spread were observed in plants treated with foliar spray of both B and Zn (B_2Z_2) and the values were significantly higher than that obtained with all other treatments. Foliar application of either Zn (B_2) or B (Z_2), though at par with each other, proved to be significantly better than combined application of B and Zn in soil (B_1+Z_1). The combined application of B and Zn in soil (B_1+Z_1) also registered significantly higher value of all these growth parameters than their sole application in soil (B_1 or Z_1). Sole application of Zn in soil (Z_1) recorded significantly higher plant height and number of leaves $plant^{-1}$ than the sole application of B in soil (B_1) but these two treatments were at par in respect of their effect on leaf width and plant spread. Response of boron can be attributed to the fact that it is required in structure of cell wall and is also essential for translocation of carbohydrates to developing organs in plants (Prasad et al., 2014). Zinc might have promoted the crop growth because of the fact that it assists in formation of carbohydrates and chlorophyll (Mahmoud et al., 2019). Therefore, comparatively higher vegetative growth of the crop with combined application of both B and Zn might be due to their dual positive effect. The results are in agreement with that of Ain et al. (2016), Patel et al. (2017) and Mondal and Ghosh (2023).

Yield attributes and yield: Application of calcium in soil did

not increase the yield attributes and head yield (marketable) of broccoli over no application, indicating that availability of Ca in the soil was sufficient to meet the crop requirement. But application of both of B and Zn, alone or in combination, increased the yield attributes and marketable yield of the crop significantly over their no application (control), irrespective of their mode of application (Table 2). Various treatments of micronutrients also differed significantly in respect of their effect on the yield attributes and yield. The highest primary head weight plant^{-1}, number of secondary heads plant^{-1} (7.97 to 8.13), weight of secondary heads plant^{-1} (119.8 to 126.2 g), total head weight plant^{-1} (495.8 to 520.3 g) and consequently the marketable yield (23.33 to 24.81 t ha^{-1}) was obtained with combined foliar application of B and Zn (B_2Z_2), which proved significantly better than all other treatments. Combined application of B and Zn in soil (B_1Z_1) was significantly better than sole application of B (B_1) or Zn (Z_1) in soil, suggesting that the B x Zn interaction was synergistic on plant growth and ultimately the yield as also observed by Halim et al. (2023). Foliar application of B alone (B_2) or Zn alone (Z_2) were, however, statistically at par with each other but both proved significantly better than their sole (B_1 or Z_1) or

Table 1. Effect of application of calcium and micronutrients on plant height, number of leaves per plant, leaf length, leaf width and plant spread in broccoli

Treatments	Plant height (cm)		Number of leaves		Leaf length (cm)		Leaf width (cm)		Plant spread (cm)	
	22-23	23-24	22-23	23-24	22-23	23-24	22-23	23-24	22-23	23-24
Calcium levels										
C_1	44.1	47.2	19.8	21.3	24.8	27.4	17.1	17.5	40.7	44.5
C_0	42.7	45.5	19.2	20.7	24.7	26.6	16.6	17.0	39.0	43.5
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Micronutrients										
B_1	39.1	41.2	17.1	18.2	21.9	23.9	15.6	16.1	34.7	39.2
B_2	46.8	50.3	21.4	22.9	27.1	29.5	18.2	18.4	44.7	48.3
Z_1	41.8	44.0	18.6	19.8	23.5	25.8	15.7	16.1	35.5	39.8
Z_2	46.9	50.5	21.4	23.4	27.2	29.6	18.2	18.5	44.8	48.5
$B_1 + Z_1$	44.3	47.6	20.1	21.4	25.2	27.6	16.9	17.2	39.8	44.3
$B_2 + Z_2$	49.4	53.2	22.7	24.9	29.2	31.6	19.3	19.7	48.7	52.7
B_0Zn_0	35.4	37.8	15.0	16.4	19.2	21.0	14.0	14.9	30.8	35.1
CD (p=0.05)	2.3	2.5	1.2	1.3	1.6	1.7	1.0	1.1	3.3	3.8

C_1: Ca @ 100 kg ha^{-1}; C_0: without Ca; B_1: soil application of B @ 1.5 kg ha^{-1}; B_2: foliar spray of B (0.3% borax); Z_1: soil application of Zn @ 5 kg ha^{-1}; Z_2: foliar spray of Zn (0.5% zinc sulphate) and B_0Z_0: control; NS: not significant

Table 2. Effect of application of calcium and micronutrients on weight of primary head, number of secondary heads, weight of secondary heads, total head yield plant^{-1} and marketable yield of broccoli

Treatments	Primary head weight (g)		Number of secondary heads (g)		Weight of secondary head (g)		Total head yield plant^{-1}		Marketable yield (t ha^{-1})		
	22-23	23-24	22-23	23-24	22-23	23-24	22-23	23-24	22-23	23-24	Mean
Calcium levels											
C_1	327.9	340.5	5.76	6.04	103.9	111.5	431.8	452.0	20.46	21.59	21.03
C_0	317.8	330.0	5.51	5.81	100.7	108.3	418.5	438.3	19.97	20.96	20.47
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Micronutrients											
B_1	288.6	296.2	4.09	4.35	91.7	99.5	380.3	395.7	18.15	18.83	18.49
B_2	349.9	362.5	6.82	7.20	110.3	118.1	460.2	480.6	21.94	23.09	22.52
Z_1	308.3	318.4	4.78	5.13	98.4	105.8	406.7	424.2	19.41	20.26	19.84
Z_2	352.3	372.5	6.94	7.31	111.0	119.5	463.3	492.0	22.04	23.39	22.72
$B_1 + Z_1$	330.2	340.1	5.52	5.95	103.7	111.8	433.9	451.9	20.66	21.71	21.19
$B_2 + Z_2$	376.0	394.1	7.97	8.13	119.8	126.2	495.8	520.3	23.33	24.81	24.07
B_0Zn_0	255.1	263.2	3.29	3.41	81.4	88.5	336.5	351.7	16.01	16.90	16.46
CD (p=0.05)	18.3	19.8	0.53	0.68	5.1	5.7	23.1	24.5	1.21	1.31	

See Table 1 for details

combined application in soil (B_1+Z_1). Tundu et al. (2020) also obtained significantly higher response of broccoli with combined application of B and Zn, irrespective of their mode of application. However, soil application of Zn alone (Z_1) was more effective in increasing the growth and yield of the crop than the soil application of B alone (B_1). There was no significant interaction between calcium and micronutrients in respect of any parameter of the crop. The crop response was of similar nature during both the years. Favourable response of B and Zn is attributable to their role improving production and translocation of assimilates to the storage organs (heads) of the plants which improved the growth (Table 1) and ultimately the yield attributes and yield of the crop (Table 2). Favourable response of B and Zn on yield attributes and yield of broccoli has also been documented earlier (Islam et al., 2015, Patel et al., 2017, Mondal and Ghosh 2023). The response to foliar application of the micronutrients was significantly better than their soil application which may be attributed to the fact that the nutrients applied on plant foliage are easily available for absorption by plant system, avoiding soil constraints to availability and absorption of the micronutrients applied in soil (Alshaal and El-Ramady 2017).

CONCLUSION

Broccoli responded significantly to soil or foliar application of both B and Zn but foliar application was better than their soil application in increasing the crop growth and productivity. Combined application of B and Zn was better than their sole application, irrespective of their mode of application. However, combined application of B (0.3% borax) and Zn (0.5% zinc sulphate) as foliar spray was found to be the best treatment in increasing the growth and yield of broccoli and hence can be suggested for obtaining higher yield of broccoli in micronutrient (B and Zn) deficient alkaline fine textured soils of Punjab.

AUTHORS CONTRIBUTION

Prabhjot Kaur: Conducting the experiment, collection of the data and statistical analysis and writing of initial manuscript. Abhishek: Literature contribution, providing critical feedback and shaping the analysis and manuscript communication with editor and incorporation of comments. Dr. C. P. Mehla: Conceptualization, planning of the experiment and guiding the research trial. Dr. Jaspreet Kaur: Supervision of the research project, agricultural inputs and involvement in planning and supervision of the work. Dr. Mangat Ram: Contribution to the final version of the manuscript and supplementing the literature and references required for the manuscript.

Received 31 July, 2025; Accepted 07 November, 2025

REFERENCES

Ain Q, Ayub G, Ilyas M, Ahmad M, Begum F, Luqman, Saeed A, Khan MI and Shah K 2016. Response of broccoli to foliar application of zinc and boron concentrations. *Pure and Applied Biology* **5**(4): 841-846.

Alshaal T and El-Ramady H 2017. Foliar application: from plant nutrition to biofortification. The *Environment, Biodiversity and Soil Security* **1**: 71-83.

Dhotra B, Sharma KR, Sharma MK and Chopra S 2018. Effect of micronutrient and organic fertilizer on plant growth and yield of broccoli (*Brassica oleracea* Var. Italica) cv. Palam Samridhi. *SRG International Journal of Agriculture & Environmental Science* **5**(4): 47-51.

El-Mogy MM, Mahmoud AWM, El-Sawy MBI and Parmar A 2019. Pre-harvest foliar application of mineral nutrients to retard chlorophyll degradation and preserve bioactive compounds in broccoli. *Agronomy* **9**(11): 1-15.

Halim A, Paul SK, Sarkar MAR, Rashid MH, Perveen S, Mia ML, Islam MS and Islam AKMM 2023. Field assessment of two micronutrients (zinc and boron) on the seed yield and oil content of mustard. *Seeds* **2**(1): 127-137.

Hussain A, Arshad M, Zahir ZA and Asghar M 2015. Prospects of zinc solubilizing bacteria for enhancing growth of maize. *Pakistan Journal of Agricultural Research* **52**(4): 915-922.

Islam M, Hoque MA, Reza MM and Chakmai SP 2015. Effect of boron on yield and quality of broccoli genotypes. *International Journal of Experimental Agriculture* **5**(1): 1-7.

Khurana MPS 2022. Boron in soil plant system and its significance in Indian agriculture. *Ecology Environment and Conservation* **28**(2): 395-405.

Mahmoud SH, Abd-Alrahman HA, Marzouk NM and EL-Tanahy AMM 2019. Effect of zinc and boron foliar spray on growth, yield, quality and nutritional value of broccoli heads. *Plant Archives* **19**(2): 2138-2142.

Mondal S and Ghosh GK 2023. Effect of zinc and boron on yield, quality and nutritional value of broccoli head (*Brassica oleracea* var. italica) with different application methods in red and lateritic soils of Birbhum district, India. *International Journal of Plant and Soil Science* **35**(18): 1132-1141.

Patel A, Maji S, Meena KR and Malviya NK 2017. Use of boron and molybdenum to improve broccoli production. *Journal of Crop and Weed* **13**(2): 20-24.

Prasad R, Kumar D, Shivay YS and Rana DS 2014. Boron in Indian agriculture: A review. *Indian Journal of Agronomy* **59**(4): 511-517.

Prasad R and Shivay YS 2020. Calcium as a plant nutrient. *International Journal of Bio-resource and Stress Management* **11**(5): 1-3.

Qader NW, Salim NS, and Khalo SA 2024. The role of boron in the growth and productivity of broccoli. *Future Journal of Agriculture* **1**: 41-46.

Shukla AK, Behera SK, Prakash C, Patra AK, Rao CS, Chaudhari SK, Das S, Singh AK and Green A 2021. Assessing multi-micronutrients deficiency in agricultural soils of India. *Sustainability* **13**(16): 9136.

Thapa U, Prasad PH and Rai R 2016. Studies on growth, yield and quality of broccoli (*Brassica oleracea* L. var. italica Plenck) as influenced by boron and molybdenum. *Journal of Plant Nutrition* **39** (2): 261-267.

Thor K. 2019. Calcium-Nutrient and Messenger. *Frontiers in Plant Science* **10**: 440.

Tundu R, Tripathy P, Sahu GS, Dash SK, Nayak RK, Rojalin M, Sahu P, Tripathy B and Nayak NJ 2020. Response of lime, B and Zn on growth and yield of broccoli (*Brassica oleracea* var. *italica*) var. Palam Samridhi. *International Journal of Current Microbiology and Applied Science* **9**(9): 817-824.