Efficacy of Soil Salinity Corrector and Boron for Better Growth and Yield of Broccoli *Brassica oleraceae var. Italica*

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Abstract

This study aimed to evaluate the effects of applying the organic soil salinity corrector Neutra-Sol 335 and boron fertilization at different levels on vegetative growth characteristics and yield performance of broccoli (*Brassica oleracea var. italica*). The experiment was conducted during the winter growing season of 2023–2024 in the vegetable field of the Department of Horticulture and Landscape Engineering, College of Agriculture, Al-Qasim Green University. The study was arranged in a randomized complete block design (RCBD) with a factorial layout and three replications. The treatments included three levels of salinity corrector (0, 10, and 20 mL L^{-1}) and three levels of boron (0, 5, and 10 mL L^{-1}), which were applied through the drip irrigation system. The results showed significant effects of salinity corrector and boron application, as well as their interaction, on most of the evaluated growth and yield parameters. Application of the salinity corrector at 20 mL L^{-1} significantly increased leaf number, chlorophyll content, and dry matter percentage compared with the control treatment. Boron fertilization, particularly at 10 mL L^{-1}, improved photosynthetic performance and increased head weight and head diameter. The combined treatment of 20 mL L^{-1} salinity corrector and 10 mL L^{-1} boron produced the highest values for most measured traits, including maximum head weight (497.7 g) and total yield (9.707 t ha^{-1}), significantly exceeding most other treatment combinations. These findings highlight the role of salinity corrector and boron fertilization in improving soil physicochemical properties, enhancing nutrient availability, and ultimately promoting plant growth and yield.

Keywords: Brassicaceae, green vegetables. soil salinity, organic fertilization, Broccoli

Significance | This study demonstrates integrated salinity correction and boron nutrition strategy improving broccoli productivity, soil quality, and nutrient efficiency under salinity-affected agricultural conditions.

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1. Introduction

Broccoli (*Brassica oleracea var. italica*) is one of the most important winter vegetables in the Brassicaceae plant family. Its cultivation dates back approximately 2,700 years in the Mediterranean region and parts of Asia. Globally, broccoli ranks 31st in production, with China leading the world with 37.21% of global output. Iraq's production is estimated at 12,361 tons, representing about 0.05% of the world total (FAO, 2020).

Broccoli is primarily cultivated for its edible flower heads, which are consumed at the bud stage along with their thick, tender stalks. Broccoli is highly nutritious and contains numerous nutrients and vitamins (Thapa & Rair, 2012), including proteins, carbohydrates, glycosides, and antioxidants, particularly glucosinolates, which are present in high concentrations. Glucosinolates are broken down into sulforaphane, which has shown effectiveness against cancer as well as osteoporosis. Broccoli is also a vitamin-rich vegetable containing vitamins A and C, folic acid, niacin, and riboflavin (Roni et al., 2015). In addition to essential elements such as calcium, iron, sodium, phosphorus, and potassium, broccoli possesses both nutritional and therapeutic value. It acts as a natural antimicrobial agent, helps regulate blood sugar levels, lowers cholesterol, supports

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bone formation, and protects against heart and retinal diseases (Kirsh et al., 2007). Due to its nutritional and medicinal importance, improving both qualitative and quantitative yield performance of broccoli is necessary through various agronomic practices. Among these practices is the application of certain organic compounds to soil during broccoli growth stages. Salt correctors consist of blends of organic materials capable of reacting with and breaking down calcium carbonate present in the soil. The released calcium, along with calcium supplied by the compound itself, displaces sodium from clay complexes, allowing sodium to move into the soil solution and subsequently be leached out. This process improves physicochemical soil properties, increases aeration, and enhances cation exchange capacity.

Broccoli also contains zinc, which plays a critical role in root growth and development, as well as plant salinity resistance, since it is involved in enzyme formation and the synthesis of proteins and nucleic acids (Taheri et al., 2020).

Boron, on the other hand, is an essential micronutrient for all plants. It is relatively immobile within the plant (Oertli & Richardson, 1970) and plays an important role in maintaining soluble calcium and regulating the absorption of calcium and potassium. Boron also facilitates sucrose and carbohydrate transport within the plant body (Mohammed & Younes, 1991). Furthermore, boron contributes to nitrogen metabolism, RNA synthesis, and plant hormone formation. It also helps maintain water balance and increases vitamin C and vitamin B complex content within cell sap (Mahler, 2004).

The present study was conducted to evaluate the effects of different levels of organic salt corrector compounds applied in combination with boron fertilization on growth and yield parameters of broccoli.

2. Materials and Methods

The experiment was conducted in the vegetable field of the Department of Horticulture and Landscape Engineering, College of Agriculture, Al-Qasim Green University, during the winter growing season of 2023–2024. The study aimed to evaluate the effects of salt corrector and boron corrector applications on broccoli plant growth and yield.

The field was prepared by removing weeds and other plant residues, followed by two perpendicular plowings, and then harrowing and leveling to obtain a uniform soil surface. The field was divided into three replicates, each containing nine experimental units, resulting in a total of 27 experimental units. Each experimental unit measured 3 m in length and 1 m in width and contained 12 plants. The distance between experimental units was 1 m. The total number of plants in all experimental units was 324. Each experimental unit was labeled with an identification plate.

Seeds were sown in peat moss using Styrofoam trays and maintained for 35 days. Seedlings were then transplanted to the experimental field at the four-true-leaf stage. Five seedlings were planted per hill at a spacing of 35 cm. The crop was maintained until full maturity and harvest. Weed control was performed through continuous weeding and hoeing. Drip irrigation was applied throughout the growing period.

The treatments consisted of two factors: salt corrector and boron application. Salt corrector was applied at concentrations of 0, 10, and 20 mL L^{-1} at transplanting with the first irrigation. Three days after transplanting, boron treatments were applied through the irrigation system at concentrations of 0, 5, and 10 mL L^{-1}.

2.1 Indicators Under Study

At the end of the experiment, data were collected from three plants per experimental unit to evaluate vegetative growth parameters, including number of leaves (leaves $plant^{-1}$), leaf chlorophyll content, leaf dry matter content (%), head diameter (cm), and total head weight (g $plant^{-1}$). Total yield was then estimated.

2.2 Determination of Total Leaf Chlorophyll Content

Total leaf chlorophyll content (mg 100 g^{-1} fresh matter) was determined by estimating chlorophyll pigments in the middle leaf of the head. Three leaf samples were randomly collected from each experimental unit. One gram of fresh leaf tissue was homogenized with 10 mL of 85% acetone. The leaf tissue was crushed twice using a ceramic mortar. The pigment solution was separated from plant tissue using filter paper to collect the filtrate while discarding the residue. The extract volume was then adjusted to 20 mL using acetone (Goodwin, 1976).

A spectrophotometer was used to measure pigment absorbance at wavelengths of 645 nm and 663 nm, and chlorophyll concentration was calculated using the following equation:

Total chlorophyll = [20.2 × D(645) + 8.02 × D(663)] × (V / (W × 1000)) × 100

Where:

D(663) = Absorbance at 663 nm

D(645) = Absorbance at 645 nm

V = Final volume of extract (20 mL)

W = Weight of plant tissue (1 g)

The percentage of dry matter in the leaves (%) was calculated for 5 fresh-tender broccoli leaves that were air-dried and then placed in an oven at 68°C until the weight stabilized:

$$Dry\ matter\ (\%) = \frac{samplr\ dry\ weight}{sample\ fresh\ weight} x\ 100$$

The total plant yield (tons ha^{-1}) was also estimated:

Total yield (per hectare)

$= plantyield\ x\ \ Number\ of\ plants\ per\ hectare\ (20{,}000)$

2.3 Experimental Design and Data Analysis

The experimental treatments were arranged in a two-factor factorial experiment (humic acid and SWE) using a completely randomized

block design (CRBD) with three replications. The data were analyzed using GenStat 12th edition software (VSN International) (Payne, 2009). Analysis of variance (ANOVA) was performed, and treatment means were compared using Duncan's multiple range test at a significance level of 0.05 (Hoshmand, 2018).

3. Results and Discussion

The results (Table 1) indicate that the addition of the salt corrector Neutra-Sol 335 and boron significantly affected the number of leaves. The salt corrector at a concentration of 20 ml/L resulted in the highest number of leaves, with an average of 23.67 leaf plant^{-1}, significantly higher than the untreated control. Similarly, boron treatment, particularly at 10 ml L^{-1}, showed a significant effect on the number of leaves, reaching 24.50 leaf plant^{-1}, compared to the lower concentration and the untreated control. The interaction of the salt corrector and boron also significantly affected the number of leaves, as the 20 ml L^{-1} × 5 ml L^{-1} treatment exhibiting the highest average number of leaves, 26.41 leaf plant^{-1}, significantly higher than most other treatments.

The results indicate a significant effect of the Neutra-Sol 335 in the leaf content of total chlorophyll (Table 2). The 20 ml L^{-1} salinity corrector resulted in a chlorophyll content of 40.93 mg 100g^{-1} FW, significantly different from the lower concentration and the control (29.45 mg 100g^{-1} FW). Drip application with boron at a concentration of 5 or 10 ml L^{-1} significantly increased chlorophyll content to 35 to 37 mg 100g^{-1} FW, compared to the untreated control (32.09 mg 100g^{-1} FW). The interaction between the two treatments showed significant results for this trait, as the combined treatment 20 ml L^{-1} salinity corrector and boron at 10 ml L^{-1} yielding the highest chlorophyll level of 46.44 mg 100g^{-1} FW, compared to the control which resulted in the lowest value of 26.51 mg 100g^{-1} FW.

In case treatment effect on head diameter, the highest mean value of 18.00 cm was recorded due to application of salinity corrector at 20 ml L^{-1} which did not differ from the control 17.07 cm. Similarly, soil application with boron at a concentration of 10 ml L^{-1} also enhanced head diameter to 17.87 cm, which was close to the control which produced a mean of 17.40 cm (Table 3). Generally, the highest head dimeter was 18.60 cm resulted from the interaction treatment of 10 ml L^{-1} boron in the presence of Neutra-Sol 335 at 20 ml L^{-1}.

The salt corrector showed a significant effect on head weight, with the 10 ml/L treatment achieving the highest average head weight of 464.4 g compared to the control, which did not exceed 439.2 g (Table 4). Similarly, the boron treatment at a concentration of 10 ml/L also showed a significant advantage, achieving a head weight of 462.8 g compared to the average head weight of 433.3 g for the control treatment of the same factor. The highest head weight, 497.7 g, was recorded in the interaction treatment (20 ml/L salt corrector and 10 ml/L boron).

The findings indicated that both studied factors, the salt corrector Neutra-Sol 335 and boron, significantly affected the percentage of dry matter (Table 5). The 20 ml L^{-1} salinity corrector resulted in a higher dry matter%, with an average of 8.930%, significantly higher than the untreated control. Likewise, boron treatment, particularly at 10 ml L^{-1}, showed a significant effect on total dry matter, reaching 9.519%, compared to the lower concentration and the untreated control. The interaction of the salt corrector and boron also resulted in the highest value, as the 20 ml L^{-1} × 5 ml L^{-1} treatment recorded 11.690%, which was significantly higher than most other treatments.

Regarding treatments effects on total broccoli yield (tons h^{-1}), findings revealed a significant effect of the Neutra-Sol 335 in the total yield (Table 6). The 10 ml L^{-1} salinity corrector resulted in a total yield of 8.918 tons h^{-1}, significantly different from the 20 ml L^{-1} concentration and the control. Drip application with boron at a concentration of 10 ml L^{-1} significantly increased total yield to 9.271 tons h^{-1}, compared to the untreated control (8.703 tons h^{-1}). The interaction of the two factors showed significant increase in total yield, as the combined treatment 20 ml L^{-1} salinity corrector and boron at 10 ml L^{-1} yielded in the highest total yield of 9.707 tons h^{-1}, compared to significantly lower values in most the treatments and the control.

The marked improvement in growth indicators and yield components in the salt corrector treatments suggests the effectiveness of fertilization with the product and the role of its nutrient components. This points to the specific role of humic acid in the salt corrector, apparently being the most important agent which contributed to an increase of vegetative growth in broccoli by better nutrition and enhancement of photosynthetic efficiency leading eventually to a larger amount of food produced manifested through the plant's vegetative characteristics as well as yield (Mohammed & Istaifo, 2012).

Alternatively, boron and calcium from the salt corrector are involved in RNA synthesis, increased potassium uptake addition of cell division hence number of leaves head weight yield increase. Abu Dhahi (1988) and Dell (1997) support this fact since they reported an increased yield due to boron and calcium fertilization. A further explanation for such good results can be that more sucrose is formed by enhanced potassium uptake and translocation of sugar when a borate-sugar complex is formed, (Suticliffe & Baker 1981).

The results show an apparent increase in growth and yield parameters of broccoli treated with boron. This could be attributed to the major role of boron because it is required for cell wall integrity, cell division, and reproductive growth; basically, involved in sugar transport, flowering process, pollen tube formation as well

Table 1. Effect of soil salinity corrector and boron on number of leaves in broccoli *Brassica oleracea* var. *italica* grown under ambient conditions

Salinity corrector ml L^{-1}	**Boron ml L^{-1} 0**	**5**	**10**	**Average**
0	19.00	18.55	25.10	20.88
10	23.42	21.56	23.10	22.69
20	19.30	26.41	25.30	23.67
Average	20.57	22.17	24.50	
LSD ($P \leq 0.05$)	Salinity corrector		Boron	Interaction
	2.160		2.160	3.740

Table 2. Effect of soil salinity corrector and boron on leaf content of chlorophyll in broccoli *Brassica oleracea* var. *italica* grown under ambient conditions

Salinity corrector ml L^{-1}	**Boron ml L^{-1} 0**	**5**	**10**	**Average**
0	26.51	34.41	27.44	29.45
10	35.34	34.24	33.61	34.39
20	33.48	42.86	46.44	40.93
Average	32.09	37.17	35.52	
LSD ($P \leq 0.05$)	Salinity corrector		Boron	Interaction
	0.854		0.854	1.479

Table 3. Effect of soil salinity corrector and boron on head diameter in broccoli *Brassica oleracea* var. *italica* grown under ambient conditions

Salinity corrector ml L^{-1}	Boron ml L^{-1} 0	5	10	Average
0	15.56	18.25	17.40	17.07
10	17.80	17.60	17.60	17.67
20	17.53	17.87	18.60	18.00
Average	16.96	17.91	17.87	
LSD ($P \leq 0.05$)	Salinity corrector		Boron	Interaction
	1.216		**1.216**	2.106

Table 4. Effect of soil salinity corrector and boron on head weigh in broccoli *Brassica oleracea* var. *italica* grown under ambient conditions

Salinity corrector ml L^{-1}	Boron ml L^{-1} 0	5	10	Average
0	422.0	462.3	433.3	439.2
10	451.5	484.4	457.3	464.4
20	434.7	415.0	497.7	449.1
Average	436.0	453.9	462.8	
LSD ($P \leq 0.05$)	Salinity corrector		Boron	Interaction
	15.55		**15.55**	26.94

as seed production (Pereira et al., 2021). The adequate application improves productivity by facilitating the transportations such as calcium conducts all over plant tissues where Ca has been reported a function mainly on upper parts or new organs formed above older ones thus indicating its upward mobility within xylem stream only.[43] Boron needed-for synthesis/strengthening/stabilization-binding-pectin(rhamnogalacturonanII)-forming stable compound (Vera-Maldonado et al.,2024). Generally speaking, about re B plays vital importance! Pollen germination&tube dev fertilization hence fruit&seed dev!

Boron aids the transport association between sugars and energy from the leaves to other actively growing parts such as roots and stems, with carbohydrate metabolism within the plant involving boron (Vera-Maldonado et al., 2024). Other than its known requirement in cell division and growth, a major function of boron is apical meristem formation. Its functions include hormone

Table 5. Effect of soil salinity corrector and boron on total dry matter (%) in broccoli *Brassica oleracea* var. *italica* grown under ambient conditions

Salinity corrector ml L^{-1}	Boron ml L^{-1}			Average
	0	5	10	
0	6.440	9.267	8.247	7.984
10	11.450	5.693	8.620	8.588
20	7.367	7.733	11.690	8.930
Average	8.419	7.564	9.519	
LSD ($P \leq 0.05$)	Salinity corrector		Boron	Interaction
	0.337		**0.337**	**0.585**

Table 6. Effect of soil salinity corrector and boron on total yield (tons h^{-1}) in broccoli *Brassica oleracea* var. *italica* grown under ambient conditions

Salinity corrector ml L^{-1}	Boron ml L^{-1}			Average
	0	5	10	
0	7.963	8.957	8.703	8.541
10	8.907	9.520	9.403	9.277
20	8.740	8.307	9.707	8.918
Average	8.537	8.928	9.271	
LSD ($P \leq 0.05$)	Salinity corrector		Boron	Interaction
	0.349		0.349	0.605

regulation wherein it plays a vital role in plant hormone synthesis particularly auxin levels besides helping maintain the structure of biological membranes (Day & Aasim, 2020). Environmentally friendly effects attributed to this element include increased ability by legume roots found within environments containing this element at their root environment to form bacterial nodules on their own hence fixing more atmospheric nitrogen into soils where they grow (Mehboob et al., 2021). Narrow range between deficiencyand toxicity. Its common application is as a fertilizer, added to the soil or sprayed on the leaves of such crops as alfalfa, potatoes and sunflowers mostly in sandy soils poor in organic matter. Thus, it is considered an important application for promoting vegetative growth and improving quality of vegetables yield (Arrobas et al., 2023).

4. Conclusion

This study demonstrates that integrated application of the organic soil salinity corrector Neutra-Sol 335 and boron fertilization significantly enhances the vegetative growth, physiological performance, and yield of broccoli grown under salinity-affected conditions. The combined treatment of 20 mL L^{-1} salinity corrector with 10 mL L^{-1} boron consistently produced superior outcomes in leaf number, chlorophyll content, head weight, dry matter percentage, and total yield. These improvements are attributed to enhanced soil physicochemical properties, improved nutrient availability, and optimized metabolic functions. Overall, the findings support this integrated nutrient management strategy as an effective, sustainable approach for improving broccoli productivity in saline soils

Author contributions

Z.T.A.T. contributed to the conceptualization of the study, conducted the field experiment, collected data, and prepared the original draft of the manuscript. T.F.K.S. was responsible for methodology development, laboratory analyses, statistical analysis, and interpretation of results. A.A.M.A.A.Z. supervised the research, contributed to experimental design and data interpretation, critically revised the manuscript, and approved the final version for publication. All authors have read and approved the final manuscript and take responsibility for the integrity of the work.

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Competing financial interests

The authors have no conflict of interest.

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