Effect of adding salt corrector and boron on the growth and yield of broccoli *Brassica oleraceae* var. Italica

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Abstract

This study was conducted during the winter agricultural season of 2023–2024 at the vegetable research field within the Department of Horticulture and Landscape Engineering, College of Agriculture, Al-Qasim Green University. The research aimed to evaluate the influence of a salt corrector and boron application on the growth and yield characteristics of broccoli. The study was set up as a factorial experiment within a randomized complete block design (RCBD) with three replications. Treatments included three levels of salt corrector Amino Start Bio stimulator (0, 10, and 20 mL L^{-1}) and three levels of boron (0, 5, and 10 mL L^{-1}), applied to the soil in the early morning. The results revealed that both salt corrector and boron significantly enhanced most studied traits, with the highest number of leaves (24.50 leaves $plant^{-1}$) obtained at 10 mL L^{-1} boron, while salt corrector at 20 mL L^{-1} gave 23.67 leaves $plant^{-1}$. The interaction between 20 mL L^{-1} salt corrector and 5 mL L^{-1} boron recorded the maximum number of leaves (26.41 leaves $plant^{-1}$). Similarly, significant improvements were observed in head weight (497.7 g $plant^{-1}$), dry matter percentage (11.69%), total yield (9.70 t ha^{-1}), and chlorophyll content (46.44 mg 100 g^{-1} fresh weight) under combined application. The findings highlight the synergistic role of salt corrector, which provides calcium, zinc, and humic substances, together with boron in enhancing nutrient uptake, photosynthetic efficiency, and assimilate partitioning.

Keywords: Broccoli; Salt corrector; Boron fertilization; Growth and yield

1. Introduction

Broccoli (*Brassica oleracea* var. italica) is a cold-season vegetable from the Brassicaceae family. It has been grown for approximately 2700 years in the Mediterranean area and certain regions of Asia. Morphologically, it resembles cauliflower and is considered one of the less common crops in Iraq, ranking 31st worldwide in terms of production. Broccoli is highly valued for its nutritional content, as it provides essential vitamins, proteins, carbohydrates, glycosides, and antioxidant compounds. It is particularly rich in glucosinolates, which upon hydrolysis yield sulforaphane—a compound known for its role in cancer prevention and bone health. Moreover, broccoli is an excellent source of vitamins A and C, folic acid, niacin, and riboflavin (Thapa and Rair, 2012; Roni *et al.*, 2015).

Given its nutritional and medicinal importance, improving both qualitative and quantitative performance of broccoli is essential. One approach is through the use of organic soil amendments during different growth stages. Salt correctors contain a blend of organic compounds capable of interacting with soil calcium carbonate, breaking it down, and releasing calcium. This released calcium, in addition to that provided by the amendment itself, replaces sodium on clay–organic complexes. Consequently, sodium is displaced into the soil solution, where it can be leached away. This process enhances soil physical and chemical properties, improves aeration, and increases cation exchange capacity. Furthermore, the amendment supplies zinc, which promotes root growth, enhances plant tolerance to salinity, and plays a role in enzyme activity, protein synthesis, and nucleic acid formation (Taheri *et al.*, 2020).

Boron, on the other hand, is a vital micronutrient required by all plants. Being immobile within plant tissues (Oertli and Richardson, 1970), its continuous supply is crucial. Boron maintains calcium in a soluble form, regulates the uptake of calcium and potassium, and contributes to carbohydrate translocation—particularly sucrose transport (Mohammed and Younis, 1991). It also plays a critical role in biological nitrogen fixation, RNA synthesis, hormone formation, water balance in plant cells, and enhances vitamin C and B-complex content (Mahler, 2004).

To examine the impact of varying concentrations of the organic salt corrector on the growth and productivity of broccoli. To determine the role of boron supplementation in improving growth and yield of broccoli, To evaluate the contribution of calcium, boron, and zinc in enhancing chlorophyll content in broccoli.

2. Materials and Methods

The field study took place in the vegetable research field at the Department of Horticulture and Landscape Engineering, College of Agriculture, Al-Qasim Green University, throughout the winter growing season of 2023–2024. The study aimed to evaluate the effect of salt corrector Amino Start Biostimulator and boron application on the growth and yield of broccoli.

The experimental soil was prepared using agricultural machinery. After removing weeds and plant residues, the field was plowed twice in perpendicular directions, followed by uniform harrowing and leveling. The land was subsequently partitioned into three blocks, each comprised of nine experimental units. Each unit represented a raising bed measuring 3.5 m × 0.75 m (length × width), with 0.75 m spacing between beds. Buffer zones were left at the beginning and end of each block. A drip irrigation system was installed to ensure uniform water supply.

Broccoli seeds were first sown in polystyrene trays filled with peat moss under favorable growth conditions. Once the saplings reached the four true-leaf stage, they were transplanted into the field on October 15, at a rate of ten saplings per experimental unit, with 35 cm spacing between plants. Crop management practices were applied from the first day of transplanting until maturity, including regular hoeing and weeding. Irrigation was carried out twice weekly during establishment, then adjusted according to crop water requirements through the drip system. Harvesting was conducted on January 2, once the broccoli heads reached maturity.

Amino Start Biostimulator Composition (Calcium humate) from (Agricover) and known as Salt corrector

- Free amino acids: 10%
- Polysaccharides: 10%
- Phosphorus (P): 6%
- Potassium (K): 2.5%

Chelated trace elements: Iron (Fe), Manganese (Mn), Zinc (Zn).

This formulation enhances vegetative growth in spring, especially effective during early developmental stages across various crops

Experimental design

The study was structured as a factorial experiment using (RCBD) with three blocks. Treatment means were compared using the Least Significant Difference test (LSD) at a 0.05 probability level (Al-Rawi and Khalaf-Allah, 2000). The study included two factors:

1. **Salt corrector application** at three levels:
   - A0 = Control (no application)
   - A1 = 10 mL L^{-1} salt corrector
   - A2 = 20 mL L^{-1} salt corrector
2. **Boron application** at three levels:
   - B0 = Control (no application)
   - B1 = 5 mL L^{-1} boron
   - B2 = 10 mL L^{-1} boron

Fertilizers (salt corrector and boron) were applied directly to the soil in the early morning.

Traits measured

1. **Leaf number (leaves plant^{-1}):** Counted as the total number of fully developed leaves per plant at head maturity.
2. **Head diameter (cm):** Measured using a measuring tape on

randomly selected plants from each experimental unit at maturity.

3. **Head weight (g plant⁻¹):** Determined using a field balance for randomly selected mature heads.
4. **Leaf dry matter content (%):** Five fresh leaves were collected from broccoli plants, air-dried for three days in a ventilated room, then oven-dried at 68°C until constant weight. The dry matter percentage was computed as

$$\text{Dry matter \%} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \text{ x } 100$$

5. **Total yield (t ha⁻¹):** Calculated from individual plant yield and scaled to the plant density of 20,000 plants ha⁻¹, using the formula: **Total yield (ha^{-1}) = yield plant^{-1} x plant ha^{-1} (20000)**
6. **Determination of Leaf Total Chlorophyll Content (mg per 100 g of fresh weight):** Chlorophyll was extracted from the middle leaves of the broccoli head by using three randomly selected leaf samples for each experimental unit. A 1 g sample of fresh tissue was homogenized in 10 mL of 85% acetone using a porcelain mortar, filtered, and the extract volume was adjusted to 20 mL with acetone. The concentration of chlorophyll was analyzed spectrophotometrically at 645 and 663 nm following the method described by Goodwin (1976)**.,** using the equation:

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

Where:

- D663D = absorbance at 663 nm
- D645D = absorbance at 645 nm
- V = final extract volume (20 mL)
- W = tissue weight (1 g)

3. Results and Discussion

The results indicated that the application of both salt corrector and boron had a significant effect on the number of leaves per plant (Table 1). The highest mean value (23.67 leaves plant⁻¹) was obtained with the application of 20 mL L⁻¹ salt corrector, compared with the lowest values recorded under the control treatment. Similarly, boron application showed a significant effect, where 10 mL L⁻¹ resulted in the highest mean value of 24.50 leaves plant⁻¹ compared to the control.

A significant interaction was also observed between salt corrector and boron treatments. The combination of 20 mL L⁻¹ salt corrector with 5 mL L⁻¹ boron produced the highest number of leaves (26.41 leaves plant⁻¹), while the control treatment recorded the lowest values. However, the experimental factors and their interactions did not show any significant superiority in the head diameter trait of broccoli plants.

Regarding head weight per plant, both salt correctant and boron showed significant positive effects. The salt correctant at 10 mL/L (A_1) produced the highest head weight (464.4 g), significantly exceeding the control. Similarly, the 10 mL/L boron treatment (B_2) significantly increased head weight, reaching 462.8 g per plant. The interaction between the two factors was also significant, with the combination of 20 mL/L salt correctant × 10 mL/L boron (A_2 × B_2) yielding the heaviest heads (497.7 g), significantly surpassing all other treatments.

Table 1: Effect of salt corrector and boron foliar application on vegetative traits and chlorophyll content of broccoli

Leaf chlorophyll content (mg 100 g dry matter)	Yield (t ha⁻¹)	Dry matter percentage (%)	Head weight (g)	Head diameter (cm)	Number of leaves (leaves plant⁻¹)	The treatment	
29.45	8.541	7.984	439.2	17.07	20.88	**A0**	**salt corrector**
34.39	9.277	8.588	464.4	17.67	22.69	**A1(10)**	
40.93	8.918	8.930	449.1	18.00	23.67	**A2(20)**	
0.854	**0.349**	**0.337**	**15.55**	**N.S.**	**2.160**	**L.S.D (0.05)**	
32.09	8.537	8.419	436.0	16.96	20.57	**B0**	**Boron**
37.17	8.928	7.564	453.9	17.91	22.17	**B1(5)**	
35.52	9.271	9.519	462.8	17.87	24.50	**B2(10)**	
0.854	**0.349**	**0.337**	**15.55**	**N.S.**	**2.160**	**L.S.D (0.05)**	
27.44	7.963	6.440	422.0	15.56	19.00	**B0**	
34.41	8.957	9.267	462.3	18.25	18.55	**B1 A0**	
26.51	8.703	8.247	433.3	17.40	25.10	**B2**	
35.34	8.907	11.450	451.5	17.80	23.42	**B0**	
34.24	9.520	5.693	484.4	17.60	21.56	**B1 A1**	**Interaction**
33.61	9.403	8.620	457.3	17.60	23.10	**B2**	
33.48	8.740	7.367	434.7	17.53	19.30	**B0**	
42.86	8.307	7.733	415.0	17.87	26.41	**B1 A2**	
46.44	9.707	11.690	497.7	18.60	25.30	**B2**	
1.479	**0.605**	**0.585**	**26.94**	**N.S.**	**3.740**	**L.S.D (0.05)**	

For dry matter percentage, both salt corrector at 20 mL L⁻¹ and boron at 10 mL L⁻¹ significantly increased values, reaching 8.93% and 9.51%, respectively. The interaction between 20 mL L⁻¹ salt corrector and 10 mL L⁻¹ boron was superior, giving the highest dry matter content of 11.69%, compared with the lowest values recorded under the control treatment.

Regarding total yield, the application of 10 mL L⁻¹ salt corrector significantly increased broccoli yield to 9.27 t ha⁻¹. Similarly, boron application at 10 mL L⁻¹ resulted in a comparable significant yield increase (9.27 t ha⁻¹). The interaction between 20 mL L⁻¹ salt corrector and 10 mL L⁻¹ boron produced the maximum yield of 9.70 t ha⁻¹.

A significant effect was also recorded on total chlorophyll content in broccoli leaves. Salt corrector at 20 mL L⁻¹ resulted in the highest chlorophyll content of 40.93 mg 100 g⁻¹ fresh weight, while boron at 5 mL L⁻¹ recorded the maximum chlorophyll concentration of 37.17 mg 100 g⁻¹ fresh weight. The interaction between 20 mL L^{-1} salt corrector and 10 mL L^{-1} boron was superior, achieving the highest chlorophyll content of 46.44 mg 100 g^{-1} fresh weight.

The significant improvements observed in growth and yield traits can be attributed to the role of humic acid present in the salt corrector, which enhances vegetative growth by improving nutrient uptake and photosynthetic efficiency. This, in turn, increases assimilate production and positively reflects on vegetative characteristics and yield (Mohammed and Istayfo, 2012). The positive effects may also be linked to the roles of boron and calcium contained in the salt corrector. These elements contribute to RNA synthesis, enhance potassium uptake, and stimulate cell division, ultimately leading to increases in leaf number, head weight, and yield. This interpretation is consistent with the findings of Abu Dhahi (1988) and Dell (1997), who reported yield improvement following boron and calcium fertilization. Additionally, the results may be explained by enhanced sugar production and translocation, as potassium absorption facilitates sugar movement through the formation of borate–sugar complexes (Sutcliffe and Baker, 1981).

4. Conclusion

The study conclusively demonstrates that the individual and combined applications of an organic salt corrective and boron significantly improve the growth, yield, and physiological attributes of broccoli plants. The most pronounced positive effects were observed with the interaction treatment, highlighting a strong synergistic relationship between the two amendments. The improvements are likely due to enhanced soil health from the salt corrective, leading to better nutrient availability and uptake, coupled with the crucial role of boron in key physiological processes such as cell division, sugar transport, and hormone synthesis.

5. Recommendations

Based on the findings, the following recommendations are made:

1. For Farmers: To maximize broccoli yield and quality, it is recommended to apply a combined treatment of salt corrective at a rate of 20 ml L^{-1} and boron at a rate of 10 ml L^{-1}.
2. For Future Research: Further studies should investigate:
   - The economic feasibility of this treatment combination for large-scale broccoli production.
   - The specific soil types and conditions where this interaction is most effective.
   - The impact of these amendments on the nutritional and antioxidant content of the harvested broccoli heads.
   - The underlying molecular and enzymatic mechanisms responsible for the observed synergistic effects.

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