ISSN: 2073-9524
eISSN: 2310-8746

Effect of Foliar Spraying with Boron and Ascorbic Acid on Growth and Yield Traits of Chili Pepper Grown in Plastic House

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Article history:

Received: 13 August 2024
Accepted: 19 November 2024
Published: 30 December 2024

Keywords: *Chili Pepper, Boron, Ascorbic Acid, Growth, Yield.*

Abstract

This study evaluated the effect of foliar spraying with boron (0, 50, and 100 mg L^{-1}) and ascorbic acid (0, 100, and 200 mg L^{-1}) on the growth and yield of chili pepper plants grown in a plastic house. The treatment spraying boron at a rate of 100 mg L^{-1} had significantly better results in terms of relative chlorophyll content in leaves, main stem diameter, plant height, branch count, leaf count, fruit count, fruit weight, and plant yield (48.23 Spad, 21.02 mm, 70.02 cm, 4.500 branches, 156.81 leaves, 74.88 fruits, 19.00 g, and 1492.5 g $plant^{-1}$ respectively). A concentration of 200 mg L^{-1} ascorbic acid sprayed on plants produced the best results in terms of plant height, number of branches, number of leaves, number of fruits, weight of fruits, and plant yield (21.88 mm, 72.79 cm, 4.878 plant branches, 166.59 leaves, 77.74 fruits, 21.97 g, 1745.7 g $plants^{-1}$ respectively). The study found that the main stem diameter, plant height, branches number, leaves number, fruits number, fruit weight, and plant yield were all best increased by an interaction treatment consisting of spraying boron at 100 mg L^{-1} and ascorbic acid at 200 mg L^{-1}. compared with the control group, the values reached 22.47, 74.38 cm, 5,000 branches, 170.76 leaves, 90.46 fruits, 26.38 g, and 2430.4 g $plant^{-1}$ respectively.

https://dx.doi.org/10.52951/dasj.24160211

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Introduction

Chili Pepper (*Capsicum frutescens* L.) is an economically important crop belonging to the Solanaceae family. Chili pepper contains important pigments chlorophyll, anthocyanin and lutein which give it important health benefits; it also contains vitamins, minerals, flavonoids, carotenoids, and capsaicin, it is considered a major compound responsible for the pungent taste of chili pepper which gives a positive role in health (Al-nussairawi and Alnadawy, 2024). Peppers are considered one of the most important vegetables in the world because they contain flavonoids and phenolic acids in addition to beta-carotene, anthocyanins, and lycopene, which are beneficial compounds of health importance to humans, (Abd Elhak *et al.*, 2022). Because of its role in regulating the amount of water that plants absorb and the transport of sugars within the plant to their storage locations, boron is a crucial mineral element for plant nutrition. Since its absence affects many crops, researchers have focused on determining its function in cell wall formation in particular (Power and Woods, 1997). Boron deficiency is one of the main obstacles to plants grown in acidic soil, and foliar spraying with this element has a positive effect on the biological yield of the plant (Dhokne *et al.*, 2022). Boron works to control the percentage of water present inside the plant and its relationship to transporting sugars to their storage places. Boron encourages the absorption of other elements such as N, K,

and Ca, in addition to its importance in the formation of hormones in the plant and its role in cell division, especially the cells of the growing apices (Poza-viejo *et al.*, 2018). In a study conducted by Mosleh and Abdul Rasool (2019), Pepper plants treated with boron as a boric acid sprayed on them increased plant yields, fruits per plant, leaves per plant, chlorophyll content, and fruit weight. Ascorbic acid is one of the organic acids that are considered as plant growth regulations which have many physiological and biochemical effects on plants. These include increasing plant biomass, leaf pigments, photosynthetic efficiency, and antioxidant activities (both enzymatic and non-enzymatic). By enhancing the activities of many antioxidants, including enzymatic and non-enzymatic antioxidants, polyphenols, soluble sugars, and proline levels, it also increases the plant's resistance to oxidative stress and salt stress (Azeem *et al.*, 2023). The foliar spraying pepper plants with ascorbic acid at concentrations of 1.200 mM increased the vegetative and yield traits compared with the control treatment (El-Beltagi *et al.*, 2022). On the other hand, Talaat (2003) detected that foliar application of ascorbic acid increased the content of macronutrients (NPK) of sweet pepper fruits. The application of ascorbic acid can reduce the harmful effects of salt stress and may have stimulatory effects on plants (Persajoo and Dashti, 2023). Ascorbic acid is synthesized in the higher plants and improves plant growth, it is a product of D-glucose metabolism which affects some nutritional cycle activities in higher plants and plays an important role in the electron transport system (El-Kobisy *et al.*, 2005). The aim of this research was to investigate how spraying chili pepper plants grown in plastic houses with boron and ascorbic acid affected various vegetative growth and yield characteristics.

Materials and Methods

To study the effects of foliar spraying boron acid and ascorbic acid on the growth and yield of chili pepper plants, a field experiment was conducted at the greenhouses affiliated with the research station of the Department of Horticulture and Landscape Design, College of Agriculture, University of Diyala, during the agricultural season 2022–2023. Barbarian F1 pepper seedlings were used for this study. The soil of the greenhouse was divided into five lines, the width of the terrace was 80 cm, then drip irrigation pipes were extended, two lines were placed in each terrace and then covered. The terraces were covered with black plastic mulching, and then the seedlings were planted in two lines of terrace. The distance between the lines was 60 cm and the seedlings were 30 cm, eight plants were allocated to each experimental unit. Three different concentrations of boron (0, 50, and 100 mg L^{-1}) and three different concentrations of ascorbic acid (0, 100 and, 200 mg L^{-1}) were sprayed on plants in the experiment. The solutions were applied to the plants three times during the growing season. The seedlings were sprayed for the first time 21 days after planting, and then repeated for the second time after 21 days.

Studied Traits

Vegetative Growth Traits:

1- **Relative content of chlorophyll in leaves (SPAD):** The relative chlorophyll content in the leaves was estimated by using the SPAD-502 device manufactured by Minolta.

2-**Stem diameter (mm):** The stem diameter of each plant was measured with a Vernier, the average was determined.

3- **Plant height (cm):** It was measured with a tape measure at the end of the experiment.

4- **Number of branches:** It was manually counted and then the average was calculated.

5- **Number of leaves in plant:** It was manually counted during different stages of the growing season.

Yield Traits:

6- **Number of fruits (fruit plant^{-1}):** It was calculated cumulatively for each experimental unit, and then the average was calculated.

7- **Fruit weight (g):** It was calculated cumulatively, divided by the number of fruits, and then the average was taken.

8- **Plant yield (gm plant^{-1}):** It was calculated by dividing the total weight of fruits by the number of plants in the experimental unit.

Statistical Analysis

This study used a Randomized Complete Block Design (RCBD) for its experimental design; SAS (2003) was used for data analysis; and a Duncan multinomial test 0.05 significance level was used to compare means.

Results and Discussion

Vegetative Growth traits

Relative content of chlorophyll in leaves (SPAD)

According to Table 1, the control treatment had the lowest relative chlorophyll content of 44.52 SPAD, while the boron spray treatment at 100 mg L^{-1} had the highest relative chlorophyll content of 48.23 SPAD without significant difference between it and 50 mg L^{-1} treatment. This suggests that the boron spray treatment has a substantial impact. Although the differences between the ascorbic acid treatments did not reach the level of significance, they are nonetheless shown by the results of the same table.

The results demonstrate that the interaction treatments differ significantly from one another. The control treatment had the lowest chlorophyll content at 41.83 SPAD, while the spraying treatment with boron and ascorbic acid at 100 mg L^{-1} and 200 mg L^{-1}, respectively, produced the highest relative chlorophyll content in the leaves, 48.87 SPAD without significant different between them.

Table 1. Formulation of culture media

Boron concentration (mg L$^{-1)}$	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	41.83 b	45.10 ab	46.63 ab	44.52 B
50	46.80 a	47.46 a	47.70 a	47.32 A
100	47.83 a	48.00 a	48.87 a	48.23 A
Means of Ascorbic acid	45.43 A	46.85 A	47.73 A	

*Values that have different letters are significantly different from each other according to Duncan's multiple range test at 0.05 probability level.

*Values that have the same letters are not significantly different from each other according to Duncan's polynomial test at 0.05. Probability level.

Stem diameter (mm)

Table 2 shows that the 100 mg L^{-1} boron spray treatment significantly increased the main stem diameter, which was 21.02 mm, without a significant difference between it and the 50 mg L^{-1} treatment 20.39 mm compared with 19.55 mm for the control

treatment, indicating a considerable effect of boron. According to the same table, the spray treatment with 100 mg L^{-1} ascorbic acid produced a superior stem diameter of 21.88 mm compared to the control treatment's 18.17 mm. A stem diameter of 22.47 mm was achieved with an interaction treatment consisting of 100 mg L^{-1} of boron and 200 mg L^{-1} of ascorbic acid, as compared to 16.83 mm with the control treatment, demonstrating a statistically significant difference.

Table 2. Effect of spraying with boron and ascorbic acid and their interaction on the diameter of the main stem of chili pepper plants (mm)

Boron concentration (mg L^{-1})	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	16.83 b	20.33 ab	21.5 ab	19.55 B
50	18.50 b	21.00 ab	21.67 ab	20.39 A
100	19.17 ab	21.43 ab	22.47 a	21.02 A
Means of Ascorbic acid	18.17 B	20.92 A	21.88 A	

Plant height (cm)

Table 3 shows that the 100 mg L^{-1} boron spray treatment significantly affected the main plant height, which was 70.02 cm without significant different between it and 50 mg L^{-1} treatment, compared to 66.97 cm for the control treatment, indicating a substantial effect. According to the same table, the spray treatment with 200 mg L^{-1} ascorbic acid produced a superior plant height of 72.79 cm without a significant difference between it and the 50 mg L^{-1} treatment compared with the control treatment's 64.43 cm. The interaction treatment consisting of 100 mg L^{-1} of boron and 200 mg L^{-1} of ascorbic acid achieved a higher value of plant height which was 74.83 cm, as compared to 60.40 cm with the control treatment, demonstrating a statistically significant effect.

Table 3. Effect of spraying with boron and ascorbic acid, and their interaction on plant height of chili pepper (cm)

Boron concentration (mg L^{-1})	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	63.40 b	66.67 ab	70.83 ab	66.97 B
50	63.73 b	69.33 ab	73.17 ab	68.74 AB
100	66.17 ab	69.50 ab	74.38 a	70.02 A
Means of Ascorbic acid	64.43 B	68.50 AB	72.79 A	

Number of main branches

According to Table 4, the control treatment produced 4.100 branches, whereas the spraying treatment with boron at a concentration of 100 mg L^{-1} was superior on the control produced 4.500 branches, making it the most effective without significant difference between it and 50 mg L^{-1} treatment. According to the same data, the spraying treatment with ascorbic acid at 200 mg L^{-1} was superior, as it produced 4.878 branches, compared to 3.833 branches in the control treatment. Table results demonstrate statistically significant differences between the interaction treatments; for example, a spraying treatment with 100 mg L^{-1} of boron and 200 mg L^{-1} of ascorbic acid resulted in 5.000 branches, significantly more than the control treatment's 3.500 branches.

Table 4. Effect of spraying chili peppers plants with boron and ascorbic acid, on the number of the branches

Boron concentration (mg L^{-1})	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	3.500 c	4.000 ab	4.800 a	4.100 B
50	4.000 b	4.500 ab	4.833 a	4.443 AB
100	4.000 ab	4.500 ab	5.000 a	4.500 A
Means of Ascorbic acid	3.833 C	4.333 B	4.878 A	

Number of the leaves (leaf plant^{-1})

Table 5 indicate that the boron spraying treatment at 100 mg L^{-1} performed exceptionally well, giving 156.81 leaves was superior on control compared with control treatment, which gave 146.17 leaves. The data from the same table also demonstrate that the spray treatment with 200 mg L^{-1} ascorbic acid was superior on the control and 50 mg L^{-1} treatment since it produced 166.59 leaves compared with the control treatment which gave 136.00 leaves. The table shows that the interaction treatment with 100 mg L^{-1} boron and 200 mg L^{-1} ascorbic acid significantly increased the leaves number to 170.76 compared with the control treatment which gave the lowest number of leaves in plant 133.17 leaves.

Table 5. Effect of spraying with boron and ascorbic acid and their interaction on the number of leaves of chili pepper

Boron concentration (mg L^{-1})	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	133.17 b	144.17 ab	161.17 ab	146.17 B
50	134.50 b	150.83 ab	167.83 a	151.05 A
100	140.33 ab	159.33 ab	170.76 a	156.81 A
Means of Ascorbic acid	136.00 C	151.44 B	166.59 A	

Indicators of vegetative development and productivity of chili peppers were found to be enhanced by foliar application of boron. This could be because boron helps plants develop efficient root systems that absorb macro- and micronutrients and store them more effectively (Vaidya *et al*., 2023). According to Annie (2005) Boron participates in the rooting system activity of absorbing most nutrient elements from the soil solution like nitrogen which promotes vegetative growth, and increases the number of branches, the leaf area, and the number of leaves overall. One beneficial function of boron is to activate and enhance the efficacy of growth hormones, including auxins and cytokines. Plants rely on boron for a variety of protein-building processes, including RNA synthesis, membrane function, nitrogen metabolism, photosynthesis, and an increase in the production of carbohydrates and proteins in the leaves (Abu Dahi and Al-Younis, 1988). In addition Inhibiting meristematic tissues, boosting cell division and elongation, and raising the generation and efficiency of growth regulators are just a few of the numerous physiological and biochemical processes that boron enhances. As a result, vegetative indicators and their rise are positively impacted (Ali *et al*., 2014). Spraying plants with ascorbic acid improves their vegetative traits. This could be because the acid encourages the growth of many plant organs, such as the plant's height, stem diameter, branching, and leaf number, which in turn increases the plant's capacity to absorb soil nutrients, particularly nitrogen, in greater quantities (El-Kobisy *et al*., 2005). Furthermore, ascorbic acid spraying has the potential to cause root organic acid release into the soil (Abdelkader and Hamad, 2014).

Yield Traits

Number of fruits (fruit plant $^{-1}$)

Table 6 indicates that the control treatment produced the fewest number of leaves (55.90 fruits), compared with the boron treatment at 100 mg L^{-1}, which was superior to other treatments by giving 74.88 fruits. According to the same Table, the spraying treatment with 100 mg L^{-1} of ascorbic acid produced the most fruits (77.74 fruits) superior on all treatments compared with the control treatment (48.23 fruits plant $^{-1}$). Based on the data in the table, it can be concluded that the interaction treatment of 100 mg L^{-1} of boron and 200 mg L^{-1} of ascorbic acid produced the best

results, giving 90.46 fruits, as compared to 37.66 fruits in the control treatment.

Table 6. Effect of spraying with boron and ascorbic acid and their interaction on the number of fruits in chili pepper

Boron concentration (mg L^{-1})	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	37.66 g	62.70 e	67.36 d	55.90 C
50	48.32 f	70.52 cd	75.27 bc	64.70 B
100	58.07 e	76.13 b	90.46 a	74.88 A
Means of Ascorbic acid	48.23 C	69.78 B	77.74 A	

Fruit weight (g)

Table 7 shows that the highest fruit weight of 19.00 g was achieved with the boron spraying treatment at 100 mg L^{-1} which was the most statistically superior treatment, while the control treatment the lowest fruit weight of 14.65 g. According to the same table, the spraying treatment with 100 mg L^{-1} of ascorbic acid was the most superior, by giving the highest fruit weight of 21.97 g, whereas the control treatment gave the lowest fruit weight of 13.43 g. A spraying treatment with 100 mg L^{-1} of boron and 200 mg L^{-1} of ascorbic acid produced the greatest fruit weight of 26.83 g, as shown in the table, while the control treatment produced the lowest fruit weight of 12.84 g. These interaction treatments differ significantly from one another.

Table 7. Effect of spraying with boron and ascorbic acid and their interaction on the fruit weight of chili pepper plants (g)

Boron concentration (mg L^{-1})	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	12.84 e	13.26 e	17.85 c	14.65 C
50	13.55 e	16.00 d	21.28 b	16.94 B
100	13.89 e	16.27 d	26.83 a	19.00 A
Means of Ascorbic acid	13.43 C	15.18 B	21.97 A	

Plant Yield (g $plant^{-1}$)

Table 8 shows that with a boron spraying treatment at 100 mg L^{-1}, the plant yield was 1492.5 g, which is the most statistically superior treatment while the control treatment gave 838.80 g. The spraying treatment with ascorbic acid at 100 mg L^{-1} was superior to the control treatment, according to the same data, since it produced the maximum plant yield (1745.7 g) compared to 652.71 g (the control treatment).

Table results reveal that interaction treatments differ significantly; the control treatment produced the lowest yield per plant 497.32 g, while the spraying treatment with boron and ascorbic acid at 100 mg L^{-1} and 200 mg L^{-1} produced the highest yield 2430.4 g.

Table 8. Effect of spraying with boron and ascorbic acid and their interaction on the plant yield the of chili pepper plants (gm plant^{-1})

Boron concentration (mg L^{-1})	Ascorbic acid concentration (mg L^{-1})			Means of Boron
	0	100	200	
0	497.32 f	807.98 d	1211.1 c	838.80 C
50	652.84 e	1129.6 c	1595.5 b	1126.0 B
100	805.92 d	1239.6 c	2430.4 a	1492.5 A
Means of Ascorbic acid	652.71 C	1058.2 B	1745.7 A	

One possible explanation for plants producing more fruits is that boron improves their nutritional status by boosting vegetative growth. This study found that boron affected photosynthesis, which in turn increased nutrient accumulation in the plant. As a result, the plant produced more flowers, which improved the fruit set and ultimately increased fruit yield. This, in turn, led to an increase in the dissolution and absorption of most nutrients from the rhizosphere. Furthermore, ascorbic acid prevents the oxidation of chlorophyll. In its role as an antioxidant. In addition, one well-known growth stimulant is ascorbic acid, which has a wide range of effects on plant physiology and biochemistry. These include increasing plant biomass, leaf pigments, and photosynthesis efficiency, all of which have a positive effect on fruit yield (Olalekan, 2017).

Conclusions

The study found that the main stem diameter, plant height, branch, leaves and fruit number, fruit weight, and plant yield were all best increased by an interaction treatment consisting of spraying boron at 100 mgL^{-1} and ascorbic acid at 200 mg L^{-1}. As compared to the control group, it reached a height of 22.47 and 74.38 cm, 5,000 branches, 170.76 leaves, 90.46 fruits, 26.38 g, and 2430.4 respectively.

Conflicts of Interest

Regarding the publication of this manuscript, the authors declare that there are no conflicts of interest.

Acknowledgments

Thank you to Mr. Al-Farouk Omar and Mr. Mohamed Hassan for helping us in this study, starting with caring for the yield and continuously monitoring the stages of plant growth and ending with conducting the required analyses.

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