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Increasing the Absorption of Some Mineral Elements and the Quality of Apple Fruits by Foliar Spraying with Boron and Ascorbic Acid

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Abstract

A study was conducted in a 5-donum apple orchard, planted with 20-year-old Delicious Starking apple trees. The trees were spaced at a distance of 5x5 meters and were grafted onto seedling rootstocks (Borkh domestica Malus).

The aim of the study was to investigate the effect of foliar spraying with boron and ascorbic acid on chlorophyll content, certain mineral elements, and fruit quality of the Delicious Starking apple variety, as well as to determine the compound that achieves the best results. The experiment was designed using a completely randomized design, consisting of four treatments and five replications per treatment, with one tree per replication. The treatments included: T0 (control): spraying with water only, T1: spraying with 170 ppm boron concentration, T2: spraying with 5.0 g/L ascorbic acid concentration, and T3: simultaneous spraying with 170 ppm boron concentration and 5.0 g/L ascorbic acid concentration.

Results showed that foliar spraying with 170 ppm boron concentration and 5.0 g/L ascorbic acid concentration, either individually or in combination, enhanced the studied traits. The treatment combining boron and ascorbic acid provided the best results, as it significantly increased the chlorophyll content (2.60mg/g) compared to the control, as well as the potassium (0.56%), Phosphorus (0.22%), nitrogen (2.09%), and boron (19.4 ppm) levels. Additionally, it resulted in higher fruit weight and volume (172.9 g and 185.8 cm3, respectively) compared to the control (143.8 g and 155.6 cm3, respectively), and increased the total soluble solids and total sugars (13.51% and 16.15%, respectively). compared to the control (11.38% and 13.51%, respectively). In conclusion, foliar spraying with 170 ppm boron concentration and 5.0 g/L ascorbic acid concentration proved to be effective in improving the chlorophyll content, mineral elements, and fruit quality of the Delicious Starking apple variety. These findings highlight the potential of using these treatments as a means to enhance apple orchard management and maximize fruit quality

Keywords: *Boron - Ascorbic acid - Foliar spraying - Chlorophyll content - Mineral elements.*

Introduction

The Apple tree, which is classified as a species of the genus Malus, belongs to the family Rosaceae, specifically the suborder Pomoideae, within the order Rosales. Apples are considered one of the oldest, most ancient and most valuable types of fruit [1]. They are

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widely grown in temperate and cool temperate regions due to their ability to adapt to a wide range of environmental conditions. From a nutritional perspective, apples have a high nutritional value because they are rich in carbohydrates, including polysaccharides, dextrin, starch, hemicellulose, cellulose, pectin, proteins, and minerals, such as calcium. Apples are used fresh and in various food industries such as the production of jelly, diapers, sweets, and juice. The versatility of apple trees to adapt to diverse environmental conditions has led to their widespread cultivation, especially in temperate regions [2].

Apple cultivation spans a wide range of latitudes (25-65 degrees north of the equator) and includes a variety of fruit shapes, colors, flavours, shipping capacities and long-term storage potential. Furthermore, apple cultivars vary in time to fruit ripening, with some cultivars ripening within 70 days of full bloom while others require longer. Apple varieties also differ in their cold requirements for breaking winter dormancy. Some varieties require significant chilling hours, while others have moderate or low chilling hour requirements [3].

Apple cultivation is concentrated in mountainous areas with altitudes exceeding 900 meters above sea level. These trees prefer temperate climates where the average temperature during the growing season exceeds 26°C.

In the recent period, agricultural scientists have turned to the issue of foliar spraying with boron acid and ascorbic acid on apple trees. They noted that this practice aims to improve the content of chlorophyll and mineral elements and the quality of the fruit, specifically a very hard variety where boron is a non-metallic element.

Boron is an essential micronutrient for plants, including apple trees. It plays a crucial role in cell wall formation, carbohydrate metabolism, and pollination and fertilization processes. Boron deficiency can lead to poor fruit set, reduced fruit size, and increased susceptibility to certain diseases. Applying boron as a foliar spray to apple trees can help alleviate boron deficiency and improve fruit quality [4].

Foliar application allows direct absorption by the leaves, ensuring effective absorption and utilization by the tree. Boron sprays are typically used during critical growth stages, such as bud break and flowering. Ascorbic acid, known as vitamin C, is another beneficial compound for apple trees.

It is involved in many physiological processes and has been shown to improve fruit quality traits. Ascorbic acid acts as an antioxidant, which helps reduce oxidative stress and enhance the shelf life of harvested fruits. It also plays a role in flavor development and color retention in apples [5].

1.1. Research problem:

Farmers face challenges in apple production because of problems such as flowers, low fruit contract rates, and the fall of fruits prematurely [6].

1.2. Research objective :

The primary objective of this study is to analyze the effect of boron and ascorbic acid spraying on apple trees, with a special focus on their effect on leaf content, chlorophyll levels, some mineral elements, and fruit quality.

1.3. Literary studies

Many researchers concluded that foliar spraying once, twice, or three times with a boric acid solution at a concentration of 1 g/l, along with ground fertilization at the recommended dose, led to an increase in the productivity of apple trees. Increased fruit size and increased boron content in leaves [6].

Other researchers have also pointed out that foliar fertilization can be used to improve tree productivity because it is effective and cost-effective. They stressed the necessity of applying foliar fertilization to increase growth and production rates and reduce food competition. Foliar spraying of nutrients directly onto leaves and fruits is the most effective and quick way to provide trees with the necessary nutrients [7].

Foliar spraying can be considered a production technique to meet the nutritional needs of the trees. Foliar nutrition of apple orchards with N, P, K, Ca, Mg, Zn, and B has resulted in high-quality and high-yield fruit production.

emphasized the importance of boron as one of the essential micronutrients for fruit trees, especially apple and peach trees. Its deficiency results in a decrease in fruit set, which is attributed to the shortened life span of the flower pistil. concluded that foliar spraying with boric acid at concentrations of 750-500-250 ppm, either alone or in combination with iron, zinc, and manganese at a concentration of 500 ppm, increased vegetative growth and fruit size and weight in olives. The foliar application also elevated the content of nitrogen, iron, zinc, manganese, and boron in the leaves, while the phosphorus content was lower compared to the control group. Furthermore, the application of boron fertilization, regardless of the method of application, enhances flower pollination, fruit set, and improves productivity and fruit quality in various temperate fruits. It also improves marketable characteristics of the fruits by reducing the incidence of physiological disorders [8].

It was also found that foliar spraying with boron led to an increase in yield and fruit weight in eggplant, in addition to enhancing the vitality and germination of pollen. It also increased the content of major elements (nitrogen, phosphorus, and potassium) in comparison to the control group. Ascorbic acid, plays a role in promoting photosynthesis by observing a strong correlation between leaf area and ascorbic acid content in apple trees. They confirmed that there was an increase in vegetative growth in Anna apple trees when sprayed with ascorbic acid at a concentration of 250 mg/L. It was also found that spraying Anna apple trees grafted on MM106 rootstock with ascorbic acid at a concentration of 250 mg/L, either alone or in combination with other nutrients, resulted in increased leaf area and length of new growth on the trees [9].

Methodology

The experiment was conducted in Al khaldia village located in Al Ramadi city / AL Anbar governorate . The apple orchard used for the experiment had a total area of 5 dunums (approx. 5,000 square meters). The soil in the field is characterized as clayey, moderately alkaline, high in active lime content, and low in organic matter. Table 1 provides further details. In this context, it is important to note the specific environmental conditions and soil characteristics of the experimental site. The high altitude, coastal location, and moderate rainfall are factors that may have an impact on the growth and development of the apple trees. Additionally, the clayey soil composition, with its alkaline nature and high active lime content, along with the limited organic matter, is relevant in understanding the quality of the soil and its potential influence on the experimental results. By considering these site-specific factors, the research aims to provide comprehensive academic insights into the effects of boron and ascorbic acid spray treatments on apple trees in this particular environment. The findings will contribute to a better understanding of how these treatments can potentially enhance growth, increase production, and improve fruit quality in challenging soil and climatic conditions [11].

Table (1) Soil analysis results in the search site

Mechanical analysis % Sand % Celt Clay%			N ppm	P ppm	K ppm	organic matter %	effective calculations%	calcium calcium carbonate%	EC MilliMus / cm	pH	Depth / cm
18	29	53	4	20	233	2	25	61	0.68	7.45	30-0
19	28	53	3	11	157	1.33	26	70	0.66	7.42	60-30

2.1. Material:

The "Delicious Starking" apple trees, which are 20 years old, are planted at a spacing of 5 x 5 meters. These trees are grafted onto the rootstock of Borkh domestica Malus and are interplanted with trees of the “Delicious Golden” variety for cross-pollination. The "Delicious Starking" variety of apple is of American origin. It is characterized by its medium to large-sized tree, vigorous growth, and requirement for moderate to high chilling hours. Chilling hours refer to the cumulative amount of time that the tree experiences cold temperatures during its dormant period.

The "Delicious Starking" tree requires a substantial number of chilling hours to effectively break dormancy and initiate the next growth cycle. Regarding fruit maturity, the “Delicious Starking” variety ripens from the second half of September to the first half of October. The fruits of this variety are suitable for transportation and storage, making them commercially viable options. (Source: Mazhar and Al-Halabi, 2010) In terms of spraying materials used, boron acid (17% B) was applied as a source of boron, and pure ascorbic acid was used. In summary, the 20-year-old “Delicious Starking” apple trees are planted at specific spacing and grafted onto Borkh domestica Malus rootstock. They are interplanted with “Delicious Golden” trees for cross-pollination [12].

The "Delicious Starking" variety, originating from the United States, is characterized by its medium to large-sized tree with vigorous growth and moderate to high chilling hour requirements. The fruits mature from late September to early October and are suitable for transportation and storage. Boron acid and pure ascorbic acid were used in the spraying process.

The agricultural service operations have been unified across all experimental trees. A fall pruning was conducted in October, and urea fertilizer was applied in February at a rate of 1 kg per tree. The trees were also pruned in February, and weed and pest control measures were implemented throughout the growth season. The experiment included the following treatments [13]:

1. T0: Control - spraying with water only.

2. T1: Spraying with boron at a concentration of 170 ppm (1 gram of boric acid).

3. T2: Spraying with ascorbic acid at a concentration of 5.0 grams per liter.

4. T3: Spraying with boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 grams per liter.

The experiment was conducted using a completely randomized design, consisting of 4 treatments and 5 replicates for each treatment, with one tree per replicate. Therefore, the total number of trees in the experiment was 4 × 5 × 1 = 20 trees. The spraying was done at the following timings:

1. At the bud opening stage.

2. After three weeks from the first stage (beginning of flowering).

3. After three weeks from the second stage (pea-sized fruit).

The spraying was carried out using a backpack sprayer with a capacity of 20 liters, at a rate of 4 liters per tree, in the early morning.

2.2. The studied traits:

Estimation of total leaf chlorophyll content (mg/g):

The content of chlorophyll in the leaves was estimated using a spectrophotometer according to Tretiakov's equation (1990):

$Ch = 6.4D663 + 18.8D644$

where Ch represents the total chlorophyll content in milligrams per liter, and D is the optical density values of the pigment extract at the indicated wavelengths.

The chlorophyll content was then calculated as the content of chlorophyll in the leaves (mg/g) using the following equation:

$A = (C \times V) / (P \times 1000)$

where A is the concentration of chlorophyll in milligrams per gram, C is the chlorophyll concentration in milligrams per liter, V is the volume of the pigment extract in milliliters, and P is the weight of the plant tissue in grams [14].

2.3. Estimation of mineral content in the papers:

From each shop, a single leaf was collected, starting from the fourth leaf to the sixth leaf from the top of the young modern plants, i.e., complete leaves showing recent vegetable and physiological activity, taken on July 15th for each season. The leaves were washed with ordinary water and then with distilled water to remove any dust and pesticide residues. After drying, they were placed in perforated paper bags and placed in an electric oven at a temperature of 70°C for three days. After that, they were manually ground, and 4.0 g of the ground sample was taken and digested using concentrated sulfuric acid (H_2SO_4) and concentrated perchloric acid ($HClO_4$) in a 4:1 ratio, respectively, to estimate the nitrogen, phosphorus, and potassium contents, as mentioned by Johnson and Ullrich in 1959. The extracted samples were stored in special containers for further use in estimating the following nutritional elements, using the mentioned methods by Bhargava and Raghupathi in 1999 [15]:

- Nitrogen: Using a micro-Kjeldahl apparatus.
- Phosphorus: By the colorimetric method, measuring light absorption at a wavelength of 882 nanometers using an Apel Spectrophotometer.
- Potassium: Using a flame photometer.
- Boron: Using a spectrophotometer.

2.4. Physical specifications of the fruits:

Fifty fruits were taken from each treatment (ten fruits from each tree), distributed in the four directions of the canopy. The following measurements were carried out: - Fruit weight (g):

- The average fruit weight was calculated by dividing the total weight of the fruits by the number of fruits per tree.
- Fruit volume: The average fruit volume (cm3) was calculated based on water displacement.

2.5. Chemical specifications of the fruits:

The fruits were analyzed after harvest in the Special Laboratory. Random samples were taken from the fruits of each tree, distributed in all directions of the tree. The following measurements were recorded [16]:

- Total soluble solids (TSS) percentage:

This was measured by placing a drop of juice on a handheld refractometer and recording the device's reading.

- Total sugar percentage:

This was determined using the standardization method [17].

- Statistical analysis:

The results were analyzed statistically using the statistical software GenStat (version 1.12 Release) and performing one-way analysis of variance (ANOVA) to determine the differences between treatments. The significance was tested by calculating the least significant difference (LSD) value at a significance level of 5% using the Duncan's test.

Results:

3.1. Estimation of total chlorophyll content (mg/g) in leaves:

The foliar spraying with boron and ascorbic acid positively affected the total chlorophyll content in the leaves. Treatments with foliar spraying of boron (T1) at a concentration of 170 ppm (2.08mg/g) and spraying with ascorbic acid (T2) at a concentration of 5.0 g/L (2.54mg/g) showed superior results. The combination of foliar spraying with boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L (T3) also resulted in a higher chlorophyll content (2.08mg/g) compared to the control treatment (T0) (1.86 mg/g), which had the lowest value. The statistical analysis, using one-way ANOVA with Duncan's test at a significance level of 5%, was performed to determine the significance of the differences between the treatments.

3.2. Estimation of leaf content of some mineral elements:

Nitrogen (N) %:

The results in Table 2 indicate that foliar spraying with the studied compounds improved the leaf nitrogen content. Treatment T2 with foliar spraying of ascorbic acid at a concentration of 5.0 g/L (2.23%) and treatment T3 with the combination of foliar spraying of boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L (2.09%) showed higher nitrogen content compared to the control treatment T0 (1.15%). However, no significant difference was observed between treatment T1 with foliar spraying of boron at a concentration of 170 ppm (58.1%) and the control treatment T0, as well as between T1 and the combined treatment T3.

Phosphorus (P) %:

Treatment T2 with foliar spraying of ascorbic acid at a concentration of 5.0 g/L (23.0%) and treatment T3 with the combination of foliar spraying of boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L (22.0%) showed higher phosphorus content compared to the control treatment T0 (15.0%). There was no significant difference between treatment T1 with foliar spraying of boron at a concentration of 170 ppm (15.0%) and the control treatment T0.

Potassium (K) %:

The data in Table 2 shows that foliar spraying with the studied compounds increased the leaf potassium content. Treatment T1 with foliar spraying of boron at a concentration of 170 ppm

(56.0%), treatment T2 with foliar spraying of ascorbic acid at a concentration of 5.0 g/L (54.0%), and treatment T3 with the combination of foliar spraying of boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L (56.0%) exhibited higher potassium content compared to the control treatment T0 (43.0%).

Boron:

The treatments with foliar spraying of the studied compounds positively influenced the leaf boron content. Treatment T1 with foliar spraying of boron at a concentration of 170 ppm (39.5ppm) and treatment T3 with the combination of foliar spraying of boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L (44.9 ppm) had higher boron content compared to the other treatments. Treatment T2 with foliar spraying of ascorbic acid at a concentration of 5.0 g/L (29.4 ppm) showed a lower boron content, while the control treatment T0 had the lowest value (19.4 ppm). All treatments outperformed the control treatment. (See Table 2)

Table (2). The effect of foliar spraying with boron and ascorbic acid on the chlorophyll content of leaves and some mineral elements of Delicious Star apple variety

Adjective	Total chlorophyll mg/g	Nitrogen%	Phosphorus %	Potassium %	Boron% PPm
T0	1.86c	1.15b	0.15b	0.43b	19.4c
T1	2.08b	1.58ab	0.15b	0.56a	39.5a
T2	2.54a	2.23a	0.23a	0.54a	29.4b
T3	2.60a	2.09a	0.22a	0.56a	44.9a
LSD	0.221	0.690	0.039	0.087	5.969

Based on the results in Table 2, it is evident that foliar application of boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L, either alone or in combination, outperformed the control treatment in terms of chlorophyll, nitrogen, potassium, and boron content in the leaves. The increase in boron content may be attributed to its role in enhancing the activity and effectiveness of growth hormones, especially cytokinins, which help maintain chlorophyll pigmentation and increase the synthesis of nutrients in the leaves (Kirkby and Mengel, 1982). Additionally, boron may contribute to the increase in certain nutrients, such as potassium and boron, by enhancing the active root mass for absorption, leading to increased potassium uptake and concentration in the leaves [18].

Furthermore, foliar application of boron helped provide additional amounts through multiple sprayings, as the increased boron from foliar application is known to have greater mobility within plants. This is supported by the study of Han et al. (2008), which demonstrated that increased boron from boron foliar spraying enhanced the nutrient dynamics. This finding is also consistent with previous studies on fruit trees, including apple trees, which showed increased boron content in the leaves after boron foliar spraying.

As for ascorbic acid, its contribution to the observed effects may be attributed to its physiological roles in stimulating active growth. Ascorbic acid participates as a cofactor in enzymatic reactions involved in carbohydrate and protein metabolism, as well as respiration and photosynthetic processes [19]. These processes contribute to an increase in nitrogen content and promote protein and nucleic acid synthesis, particularly RNA [20]. Additionally, ascorbic acid influences the photobuilding process and preserves the activity of important plant enzymes involved in growth and photosynthetic processes, as well as maintaining chloroplast integrity due to its antioxidative properties [21].

The results of this study are consistent with the findings of Baradisi (2004), who reported an increase in nitrogen, phosphorus, and potassium content in garlic leaves when treated with ascorbic acid at concentrations ranging from 100 to 200 mg/L.

3.3. Physical characteristics of the fruits:

Fruit weight (g):

From the data presented in Table 3, it can be observed that the compounds used in foliar spraying had a positive effect. Treatment T3, which involved foliar spraying with boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L together, exhibited the highest fruit weight (172.9 g) among all treatments. This was followed by treatment T1, which involved foliar spraying with boron at a concentration of 170 ppm (160.4 g), and treatment T2, which involved foliar spraying with ascorbic acid at a concentration of 5.0 g/L (157.5 g). There was no significant difference between T1 and T2. The control treatment (T0) had the lowest fruit weight (143.8 g), and all other treatments outperformed it.

Table (3). The effect of foliar spraying with boron and ascorbic acid on the weight and size of fruits

Adjective Transaction	Average weight of fruit / g	Average fruit size / cm^3
T0	143.80 c	155.60 c
T1	160.40 b	173.20 b
T2	157.50 b	170.00 b
T3	172.90 a	185.80 a
LSD	11.22	9.82

Fruit size (cm^3):

The control treatment (T0) had the smallest fruit size (155.60 cm^3), and all other treatments outperformed it. Treatment T3, which involved foliar spraying with boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L together, exhibited the largest fruit size (185.80 cm^3). This was followed by treatment T1, which involved foliar spraying with boron at a concentration of 170 ppm, and treatment T2, which involved foliar spraying with ascorbic acid at a concentration of 5.0 g/L. There was no significant difference between T1 and T2.

From the results presented in Table 3, it can be concluded that the foliar spraying of boron at a concentration of 170 ppm and ascorbic acid at a concentration of 5.0 g/L, either alone or in combination, had a positive impact on the fruit weight and size compared to the control treatment. The increased fruit weight in the boron foliar spraying treatment can be attributed to its role in facilitating the transport of sugars to the fruits, as the movement of sugar molecules with boron is easier and faster than their movement alone. As for the increase in fruit weight and size in the ascorbic acid foliar spraying treatment, it may be due to the auxin-like effect of ascorbic acid in promoting cell division and elongation, positively affecting leaf area [22], resulting in improved fruit growth, weight, and size.

Discussion

Chemical Specifications of Fruits:

Total Soluble Solids (TSS): We infer from the data in Table 4 that foliar spraying with 170 ppm boron (T1) showed a significant increase in total soluble solids (TSS) with a content of 15. 95 %. Treatment T3, which involved foliar spraying with 170 ppm boron and 5.0 g/L ascorbic acid together, resulted in a TSS content of 16.15%. However, no significant differences were observed between treatment T2, which involved foliar spraying with 5.0 g/L ascorbic acid, and the control treatment (T0), as well as between treatment T2 and treatment T1 with 170 ppm boron.

Total Sugar Content (%): Treatment T1, involving foliar spraying with 170 ppm boron, had a total sugar content of 13.52%, while treatment T3, which included foliar spraying with 170 ppm boron and 5.0 g/L ascorbic acid together, showed a sugar content of 13.51%. Treatment T2, with foliar spraying of 5.0 g/L ascorbic acid, resulted in a sugar content of 12.6%%. Similar to the TSS results, no significant differences were observed between treatment T1 with 170 ppm boron and the combined treatment T3, nor between treatment T2 and the control treatment T0.

Conclusions

Based on Table 4, we can conclude that treatment T1 with 170 ppm boron and treatment T2 with 5.0 g/L ascorbic acid individually or in combination outperformed the control treatment T0 in terms of total soluble solids and total sugar content. The combination of foliar spraying with 170 ppm boron and 5.0 g/L ascorbic acid showed the best results in all three studied traits and resulted in the highest fruit weight (172.9 g), fruit volume (185 .8cm^3), and chlorophyll, nitrogen, phosphorus, and potassium content compared to the control treatment (T0), treatment T1 with 170 ppm boron, and treatment T2 with 5.0 g/L ascorbic acid, respectively.

Recommendations:

Foliar spray apple trees with 170 ppm boron and 5.0 g/L ascorbic acid together at a rate of three sprays: the first at bud opening, the second after three weeks, and the third three weeks after the second spray. This treatment can improve some vegetative and fruit traits under conditions similar to the experimental conditions.

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