Response of Apple Trees (cv. Ibrahimi) to the Time of Foliar Application with Zinc and Boron

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Abstract: The study was conducted in one of the private orchards in the Saqlawiya area - Fallujah during the 2020 growing season. The foliar spray was used to study the effect of the timing of foliar spraying (three sprays, the first at the beginning of flowering, second at the stage of full flowers blooming, and the third at the stage of petal fall), Presented with symbols (D1, D2 and D3), respectively. The second factor consisted of spraying with boron and zinc with the following concentrations (0,1, and 3 gm. L\(^{-1}\)), mentioned as (S0, S1, S2, S3), respectively. these elements were used singly or in the form of a mixture with the same concentrations. This study aims to study the effect of the two factors on the growth and setting of apple trees, cv. Ibrahimi. Therefore, (36) five-year-old apple trees with homogeneous vegetative growth were selected as much as possible. The results revealed that foliar application with boron and zinc for the Ibrahimi apple trees improved the quality of the fruits and their vegetative and flowering traits. The results revealed that spraying with micronutrients at the stage of petal fall had a significant effect on flower traits and yield especially the media culture (M3) which presented the best results for the traits. The results revealed that spraying with micronutrients at the stage of petal fall had a significant effect on flower traits and yield especially the time (D3) which presented the best results for the traits (leaf area, Rate of increase in the length of the branches, Rate of increase in branch diameters, Fruits set Percentage, Percentage of fallen fruits and Percentage of remaining fruits, which reached (24.25cm\(^2\), 56.77cm, 0.42cm, 26.65%, 45.25%, 54.75%), respectively. On the other hand, spraying with micronutrients achieved significant effect, especially (S3), that gave the highest values for the traits (Rate of increase in branch diameters, Fruits set Percentage, Percentage of fallen fruits and Percentage of remaining fruits), which were (37.50 cm, 0.42%, 26.65%, and 46.71 gm L\(^{-1}\)).

1. Introduction
The apple (Malus domestica Borh) is a fruit tree belonging to the Rosaceae family, one of the most popular and widely distributed deciduous fruits in the world [1]. Its cultivation has spread in Europe and Asia since ancient times and has been known since 4000 BC [2]. Its spread and distribution in the regions of the world helped the genetic diversity that allowed its species to adapt in the warm and cold regions. There are apple orchards in Siberia and northern China, where the temperature in winter reaches (-40 C), as well as in the tropical highlands of Colombia and Indonesia, and it grows in those tropical areas and trees give two yields in one year [3].
The number of trees planted in Iraq is estimated at about 732,877 apple trees, which produce about 16,050 tons, and the average production per tree is about 21.17 kg, most of which are planted in the northern and central regions of Iraq [4]. Where it leads the world market as one of the most popular and widespread fruits, and this is helped by the possibility of storing fruits for a long time compared to other fruits [5]. The fruits of apples are of high nutritional and medical value, as they contain carbohydrates, fructose and protein, in addition to containing amino acids, the most important of which are lysine and arginine, as well as fats, and a high percentage of organic materials, the most important of which are malic acid and citric acid. As for vitamins A, B, C, and D [6]; [7]. Also, apples are considered one of the most fruits rich in pectin, as some medical studies have shown that this substance lowers cholesterol and prevents its accumulation in the blood vessels of humans and thus works to reduce blood pressure and reduce symptoms of joint disease that affects the elderly [8].

The cultivation of apples has developed in recent years, as the Ministry of Agriculture in Iraq has introduced new local varieties, including the Ibrahimi variety, to spread its cultivation in the Iraqi country according to special programs. Assigning horticultural and forestry stations in the governorates to produce and preserve seedlings, study this variety and conduct scientific experiments on it. The density of flowering is high, but the percentage of fruit set compared to flowering is low, so this study was proposed to increase the percentage of fruit set. The time of flower opening varies according to the varieties and climatic conditions in the region, as well as according to the need of the varieties for the hours of cold needed to break the bud phase. The date of the flowering inflorescence varies on the tree and the branch, and the date of the flower opening varies within the same inflorescence. In general, the opening date is long or shortened according to the mentioned factors, from days to weeks, which requires attention and choosing an appropriate date for spraying nutritional solutions that affect the fruit set and the growth of fruits [8].

Boron is one of the essential micro-nutrients for plants. It has many functions, the most important of which is facilitating the movement of sugars, cell wall structure, carbohydrate metabolism and respiration. It plays an important role in improving the fertilization of flowers and fruits [9]. It also has a great role in important vital activities, and among the activities it performs is facilitating the movement and transmission of photosynthesis products from the leaves to the active areas of the plant. It has a role in the germination of pollen grains and the growth of the pollen tube [10]. Boron fertilization increases the incidence of flower pollination, the rate of fruit set, increases the productivity and quality of many fruits of temperate regions, and improves the marketing characteristics of fruits by reducing the incidence of physiological disorders [11].

On the other hand, zinc is one of the essential micro-nutrients needed for plant growth and development [12]. It participates in the formation of starch and the activation of the enzyme starch synthetase and also has a role in helping to elongate the stem of the plant and stimulating the action of the growth regulator Auxin [13], it is important in plants, such as encouraging the formation of auxin, a growth hormone that controls cell division, leaf growth, and fruit development. It regulates starch formation, and the great importance of zinc is due to the need of leaf cells for it in order to form the green pigment (chlorophyll) in the leaves [14], which leaves need in the manufacture of sugars through the process of photosynthesis and thus transfer to the fruits, which increases the proportion of sugars in the fruits. [15] indicated in his experiment on citrus trees, foliar spray was used with boron at a concentration of 0.04% and zinc at a concentration of 0.1%, as the microelements were sprayed at a rate of two sprays, the first was 45 days before flowering, and the second spray was two days after full flowering, spraying reduced the percentage of fallen fruits and increased the amount of fruits set. [16] found that spraying apple trees (Starking Delicious) with zinc (5gm L\(^{-1}\)) and boron (1 gm L\(^{-1}\)) on apple trees, where the interaction between boron
and zinc for the two seasons of the study showed a significant superiority by giving the highest percentage of fruit set, increasing the weight and size of the fruit and the amount of yield. [17] stated during his study on apple trees (Williams Pride) that foliar spraying with zinc sulfate at a concentration of 0.3%, led to an increase in the concentration of NPK and zinc in the leaves. [18] confirmed that foliar spraying on Sidr trees (Zizyphus mauritiana) with zinc sulfate at a concentration of 0.6%, led to an increase in the length of the fruit, the width of the fruit, the size and weight of the fruit, and thus the increase in the amount of yield. Therefore, this study aims to:

1. Study the effect of the date of spraying boron and zinc on the characteristics of vegetative growth, as well as the fruit set, growth and specifications of the fruits of the Ibrahimi apple.
2. Know the effect of spraying with zinc and boron, singly or together, during the flowering period on the fruit set and growth of the fruits of the Ibrahimi apple.

2. Materials and Methods

The research was carried out in one of the private apple orchards belonging to a farmer in the Saqlawiya district - Fallujah, to study the effect of spraying with zinc and boron on the holding and growth of the fruits of the Ibrahimi variety, at the age of five years and planted on distance (4×5 m). The soil of the orchard was analyzed to identify some traits physical and chemical soil experiment field. Thirty-six, 5-year-old apple trees (cv. Ibrahimi) of homogeneous vegetative growth were selected as much as possible to conduct the research. A two factor experiment was used. The first factor included the spraying date, symbolized by D1, D2, D3, Foliar spraying applications were carried out for the treatments by three sprays, the First at the beginning of flowering (8/3) and the second at the stage of full blooming of flowers (16/3) and the third at the stage of falling petals (24/3) the second factor was spraying with zinc and boron with three concentrations (0,1,3 gm L⁻¹) symbolizing S0, S1, S2, S3, respectively. The experiment was carried out according to the RCBD randomized complete block design. The data was analyzed using the statistical program Genestat, and the arithmetic means were compared using the L.S.D test, at the probability level of 0.05. [19].

2.1. Studied characters

2.1.1. Leaf area (cm²)

The samples taken on June 15 for the growing season 2020, and 10 fully-grown leaves were taken from each tree in each replicate, starting from the fifth - eighth leaf below the apical meristem [20]. This was done at the end of the experiment and by dividing the total by 10, we get the average one leaf area. The leaf area was extracted by measuring the maximum length of the leaf and the maximum width of the leaf as follows:

\[
\text{Leaf area} = \frac{2}{3} \times \text{Length} \times \text{width} \ [21]
\]

After calculating the average area of one leaf and calculating the number of leaves on each tree, the leaf area was obtained according to the following equation:

Leaf area of a tree = number of leaves per tree x average leaf area (cm).

2.1.2. The rate of increase in the length of the branches (cm)

Four branches were assigned to each experimental unit, and their lengths were measured at the beginning of the experiment (1/March) for the 2020 growing season, where the second measurement was taken on (1/September) for the 2020 growing season for the same branches and the difference between the two readings, which represents the increase in the length of the branch, was extracted.

2.1.3 Rate of increase in branch diameters (cm)

The diameter of the stem was measured using the Vernier at a distance of 10 cm at the beginning of the experiment (1/March) for the 2020 growing season, where the second measurement was
taken (1/September) for the 2020 growing season, where the difference between the two readings that represented the increase was extracted.

2.1.4. Fruit set Percentage

Four branches were randomly selected from the four sides of each tree, counting the number of total flowers on each tree, and then the number of flowers on the four marked branches in the second week of April was calculated, and the percentage of the fruit set was calculated from the following equation:

\[
\text{Fruit set (\%)} = \frac{\text{N. of Fruit after Fruit set}}{\text{Total number of flowers}} \times 100 \quad [8]
\]

2.1.5. Percentage of fallen fruits

Four branches distributed randomly on the four sides of the tree were chosen, where the number of fruit in the month of April 22/4/2020 was counted, then the number of remaining fruits was recounted at the beginning of the harvest date, then the percentage of fallen fruits was estimated according to the following equation:

\[
\text{Percentage of fallen fruits \%} = \frac{\text{No. of fallen fruits}}{\text{Total fruit number}} \times 100
\]

2.1.6. Percentage of remaining fruits

Calculated by calculating the number of fruits remaining on trees at harvest, on marked branches for each tree (within a replicate) and for each treatment.

\[
\text{Percentage of remaining fruits \%} = \frac{\text{No. of remaining fruits}}{\text{Total no. of fruits}} \times 100
\]

3. Results and Discussion

3.1. Single leaf area (cm\(^2\))

The results shown in Table (1) showed that the rate of increase in leaf area was significantly affected by the foliar spray treatments with boron and zinc and the interaction between them. Where the third date represented by D3 achieved the highest percentage of leaf area (22.65 cm\(^2\)), which did not differ significantly from D2 (22.44 cm\(^2\)), while the first date D1 recorded the lowest leaf area of 19.33 cm\(^2\). Whereas, the effect of spraying levels with boron and zinc, they had a significant effect on the leaf area, where the level of spray S2 recorded the highest leaf area of 23.63 cm\(^2\) (sprayed with zinc at a concentration of 3 gm L\(^{-1}\)), which did not differ significantly from the level of spray S1 (23.06 cm\(^2\)), while the control treatment S0 recorded less leaf area of one leaf (16.33 cm\(^2\)). The interaction between spraying time and spraying levels of boron and zinc showed a significant effect on leaf area. Where the D3S3 interaction treatment achieved the maximum value of the leaf area 24.25 cm\(^2\) (the date of the third spray + the interaction treatment was sprayed with boron at a concentration of 1 gm L\(^{-1}\) + sprayed with zinc at a concentration of 3 gm L\(^{-1}\)), which did not differ significantly from the level of spray S1 (23.06 cm\(^2\)), while the control treatment S0 recorded less leaf area of one leaf (16.33 cm\(^2\)).

| Treatment | S0 | S1 | S2 | S3 | D average |
|-----------|----|----|----|----|-----------|
| D1        | 15.04 | 20.16 | 21.42 | 20.68 | 19.33     |
| D2        | 16.81 | 24.77 | 24.53 | 23.61 | 22.43     |

Table 1. Effect of spraying time with zinc and boron on leaf area (cm\(^2\)) of Ibrahimi apple
This result is due to the increase in leaf area when sprayed with microelements, perhaps due to the role of zinc in the manufacture of tryptophan, which generates growth hormones, especially auxin (IAA), and this leads to an increase in cell division in physiologically active areas such as the apical meristem and leaves, consequently, new cells are formed, which positively reflects on the formation of new leaves and an increase in their area, zinc also plays a role in increasing cell division in physiologically active areas such as apical meristem and leaves, and thus positively reflected on the shape of the leaf and increasing its area. In addition to the role of boron in stimulating cell division and stimulating growth processes in the plant, as well as its direct role as an essential component of cell walls, and this is essential for building new cells and tissues essential during the vegetative growth of the plant, including the process of leaf expansion and increase in its area, or it may return to the role of boron in stimulating and activating the enzyme (Nitrate reductase), which works to synthesis nitrogen in the leaves. Zinc encourages the formation of growth compounds inside the plant (auxins) and prevents their disintegration and helps in the process of water absorption and thus prevents the process of stunting in the plant [22]. These results are consistent with the results of the study reached by [23] about spraying with zinc at a concentration of 0.6% on pomegranate trees, and with the results of [23] on olive trees using boron spray with a concentration of 0.6% and zinc at 0.6%. It agrees with [25]. During his experiment on apples trees, they were sprayed at the full flowering stage with boron at a concentration of 17.5% and zinc 12%.

3.2. The rate of increase in the length of the branches (cm)

The results shown in Table (3) show that there is a significant increase in the rate of increase in branch lengths when the zinc and boron spraying treatments are interacting. The third date D3 achieved the highest rate of increase in stem length (37.40 cm), while this percentage decreased in the first date D1 to 25.22 cm, and the levels of zinc and boron spray showed a significant effect on the rate of increase in branch lengths in this trait. The spraying treatment S3 achieved the highest value of 37.50 cm, while this percentage decreased for the control treatment S0 (19.48 cm). The interaction between the spray rate and the zinc and boron spray treatments had a significant effect in this trait. The interaction D3S3 treatment achieved the highest value of 56.77 cm compared to the lowest value of the D2S0 treatment (18.07 cm).

| Treatment | Levels of Zinc and Boron | D average |
|-----------|-------------------------|----------|
|           | S0 | S1 | S2 | S3 |         |
| D1        | 19.87 | 19.07 | 39.60 | 22.37 | 25.22 |
| D2        | 18.07 | 37.53 | 19.73 | 33.37 | 27.17 |
| D3        | 21.60 | 27.50 | 43.73 | 56.77 | 37.40 |
| Average S | 19.84 | 28.03 | 34.36 | 37.50 |        |
The reason for the increase in the length of branches may be due to the role of zinc in the construction of the amino acid Tryptophane, which is the basic material for building the natural hormone (IAA) necessary in the expansion and elongation of plant cells [26]; [27], or it may be due to the expansion of the leaf area, which may lead to more effective photosynthesis and food processing, and then increase the food stock, which leads to increased cell division and elongation [28]. Zinc encouraged the formation of growth compounds inside the plant and prevents their disintegration and helps in the process of water absorption and thus prevents the process of stunting inside the plant [22], it may be due to the role of the micro-elements boron and zinc in improving growth parameters and the effectiveness of photosynthesis and respiration. These results are similar to what. [24] found on olive trees cv. Frontoio and [29] that spraying Anna apple trees.

3.3. Rate of increase in branch diameters (cm)

The results of presented in Table (4) show that the zinc and boron spraying treatments had a significant effect on increasing the average branch diameters, as the third date D3 achieved the highest value of 0.37 cm compared to the lowest value at the second date D2 (0.30 cm).

| Treatment | Levels of Zinc and Boron | D average |
|-----------|---------------------------|-----------|
|           | S0 | S1 | S2 | S3 |          |
| D1        | 0.27 | 0.29 | 0.32 | 0.45 | 0.33 |
| D2        | 0.21 | 0.29 | 0.32 | 0.38 | 0.30 |
| D3        | 0.35 | 0.32 | 0.38 | 0.43 | 0.37 |
| Average S | 0.27 | 0.30 | 0.34 | 0.42 |       |

The levels of spraying with boron and zinc had a significant effect on the rate of increase in branch diameters, where treatment S3 gave the highest value in increasing the rate of branch diameters (0.42 cm branch diameter) , compared to the lowest value in treatment S0 and S1 (0.27 cm and 0.30 cm) respectively. On the other hand, the interaction between spraying time and spraying levels of zinc and boron had no significant effect on increasing the rate of branch diameters. The reason for the increase in the rate of branch diameters is due to the fact that zinc plays a key role in the construction of endogenous auxin IAA, which is probably reflected in the increase in stem diameter [30]; [31]. Or it may be due to the expansion of the leaf area, which may lead to more effective photosynthesis and food processing, and then increase the food stock, which leads to an increase in cell division and elongation [28]. These results are consistent with the results of [29] when spraying Anna cultivar apple trees.
3.4. Percent of fruit set

The results shown in Table (5) show that the zinc and boron spraying treatments had a significant effect on the fruit set percentage. The highest value at the third date (D3) which gave 24.39%, compared to the lowest value at the first date D1 (19.87%). As for the effect of spraying levels, the spraying treatment significantly affected the percentage of fruit set represented by S3 and gave the highest value (26.65%), compared to the lowest percentage of the control treatment S0 (15.82%). It is also noted from the results of the same table that the interaction between spraying time and spraying levels of zinc and boron did not significantly affect the percentage of fruit set.

The increase in the proportion of knots may be due to the significant superiority of the role of boron in the processes of pollination and fertilization and its encouraging role in the growth of the pollen tube and its penetration into the nuclei, and the increase in the concentration of boron in pollen grains, and this shows the role of boron in raising the proportion of fruit set in apple trees [32]; [33]. As for the reason for the increase in the percentage of fruit set in the trees treated with zinc, it may be due to the fact that its deficiency leads to a weakening of the trees’ ability to form fruit buds as well as fruits, and it affects the process of protein formation and the formation of pollen grains [34]. These results are in line with the findings of [35] on apple trees and the results of [16] on apple trees, the results of [36] on lemon trees, [18] on Sidr trees, and the results of [37] on Apricot trees.

Table 4. Effect of spraying time with zinc and boron on Percent of fruit set (%) of Ibrahimi apple

| Treatment | Levels of Zinc and Boron | D average |
|-----------|-------------------------|-----------|
|           | S0         | S1         | S2         | S3         |
| D1        | 13.76      | 18.23      | 22.60      | 24.90      | 19.87      |
| D2        | 17.77      | 22.87      | 20.22      | 26.69      | 21.89      |
| D3        | 15.91      | 27.13      | 26.15      | 28.37      | 24.39      |
| Average S | 15.82      | 22.74      | 22.99      | 26.65      |             |
| LSD 0.5%  | D          | S          | D×S        |
|           | 2.693      | 3.110      | N.S        |

3.5. Percentage of fallen fruits

Spraying treatments with boron and zinc and timing of spray significantly affected the percentage of fallen fruits and the interaction between them. The results shown in Table (5) showed that the date of spraying with boron and zinc significantly reduced the percentage of fallen fruits. The average percentage of fallen fruits decreased at the date of the third spraying D3, which gave the lowest value of 49.88%, compared to the first date, which reached the highest value of 59.46%. The levels of spraying with boron and zinc had a significant effect in reducing the percentage of fallen fruits, as it reached the highest value of the percentage of fallen fruits for the control treatment (66.52%), while this value decreased at the level of spraying S3 (spraying with boron at a concentration of 1 gm liter\(^{-1}\) + spraying with zinc at a concentration of 3 gm liter\(^{-1}\)), to 49.88%.

The interaction between spraying date and spraying levels of boron and zinc had a significant effect in reducing the percentage of fallen fruits. The control treatment D3S0 gave the highest
value of 67.89%, compared to 49.34%, 45.25% and 48.51% for the treatments D2S3, D3S3 and D3S2 respectively.

Table 5. Effect of spraying time with zinc and boron on Percentage of fallen fruits % of Ibrahimi apple

| Treatment | Levels of Zinc and Boron | D average |
|-----------|--------------------------|-----------|
|           | S0          | S1        | S2      | S3      |           |
| D1        | 64.36       | 85.56     | 59.48   | 55.06   | 59.46     |
| D2        | 67.22       | 60.57     | 57.06   | 49.34   | 58.54     |
| D3        | 67.98       | 51.40     | 48.51   | 45.25   | 49.88     |
| Average S | 66.52       | 56.84     | 55.13   | 49.88   |           |

Spraying with boron had a role in reducing the percentage of fallen fruits, and this is due to the increase in the boron element in the branches and leaf area. This increases the net process of photosynthesis and the building of sugars necessary for the growth of all fruits on the tree and reduces the competition between them for materials manufactured in the leaves. Boron also plays an important role in the manufacture and movement of carbohydrates from leaves to fruits and forms complexes with a number of cell wall components such as cellulose, hemicellulose, pectin and lignin, which are reduced in tissues of cells that suffer from a deficiency [38]; [39]. These results are in line with the results of [35] on apple trees, the results of [40] on navel orange trees, and the results of [15] in his experiment on citrus trees.

3.6. Percentage of the remaining fruits

The results shown in Table (6) showed the significant effect of spraying treatments with boron and zinc and timing of spray and the interaction between them on the percentage of the remaining fruits %. Where this value increased at the date of the third spraying D3 (54.75%), while the percentage of the remaining fruits decreased at the date of the first spraying (44.94%). As for the levels of spraying with boron and zinc, they were significantly affected, as the S3 treatment (spraying with boron at a concentration of 1 gm L\(^{-1}\) + spraying with zinc at a concentration of 3 gm L\(^{-1}\)) gave the highest value of 50.12%, compared to the control treatment that gave the lowest value of 33.48%.

Table 6. Effect of spraying time with zinc and boron on percentage of the remaining fruits % of Ibrahimi apple

| Treatment | Levels of Zinc and Boron | D average |
|-----------|--------------------------|-----------|
|           | S0          | S1        | S2      | S3      |           |
| D1        | 35.64       | 41.44     | 40.16   | 44.94   | 40.54     |
| D2        | 32.78       | 39.43     | 42.96   | 50.66   | 41.46     |
| D3        | 32.02       | 84.60     | 51.49   | 54.75   | 46.71     |
| Average S | 33.48       | 43.16     | 44.87   | 50.12   |           |

The interaction between spraying date and spraying levels of zinc and boron had a significant effect
on the percentage of the remaining fruits. The D3S3 interaction treatment gave the highest value of 54.75%, while this value decreased with interaction treatment D3S0 to 32.02%. The foliar spray had an effect in reducing the number of fallen fruits and increasing the percentage of the remaining fruits on the tree. The positive effect of boron and zinc in production and the average number of remaining fruits was also observed [41]. The foliar spray had an effect in reducing the number of fallen fruits and increasing the percentage of fruits remaining on the tree, and it is consistent with the results of [42], which found that spraying with boron on Ajami apple trees reduced the fallen fruits and increased the percentage of fruits remaining on the tree, also these results are consistent with the results of [43] on sweet and orange trees, and [44] on “Khalkhali” olive trees.

4. Conclusions

The use of foliar nutrition with zinc and boron, whether singly or mixed between them, showed an effect on leaf area, branch lengths, branch diameters, fruit set, reducing the percentage of fallen fruits and keeping the highest percentage of the remaining fruits.

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