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Response of Ibrahimi Apple trees to Boron, Nano-iron injection and application of seaweed extract.

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ABSTRACT

We conducted the experiment in the town of Al-Bu-dhiyab, west of Ramadi on Location Gps 33.491956.43.260994*during* 2024's spring season on 5-year-old Ibrahimi apple trees, to study the effects of injecting micro-Nano elements and adding seaweed extract on vegetative growth, chemical properties, and yield. The experiment included three levels of injection: (0 - injection with distilled water only, B10+Fe20, and B20+(Fe40 mg L^{-1})) and the addition of seaweed extract at four concentrations: (0 - injection using just pure water from distillation, 3, 6, as well as 9 ml L^{-1}). Treatments were applied in three batches on March 16, with a 20-day interval between each treatment. The following characteristics were studied: The content of chlorophyll a and b in leaves, Content of leaves in boron and iron, Percentage of remaining fruits, Fruit fall percentage, Fruit firmness, and The percentage of total soluble solids in the fruits T.S.S.

The findings indicated that the injectable therapy (B20+ (Fe40 mg L^{-1}) resulted in a substantial enhancement of most examined features. Likewise, the incorporation of seaweed extract (9 ml L^{-1}) resulted in an extensive improvement for the examined attributes. The interaction between the study components revealed that the injectable therapy at the concentration of B20+(Fe40) and the addition of seaweed extracted with a level of 9 ml L^{-1} performed in most evaluated features.

***Keywords*:** Apple, Injection, Nanotechnology, Seaweed extract.

INTRODUCTION

An Apple fruit (*Malus domestica* Borkh) a member of the Rosaceae group, which is thought that its native habitat is the temperate region of Southeast Asia, it expanded across Europe as well as elsewhere [1]. Apple fruits are among the richest in pectin, which helps lower cholesterol and prevents its accumulation in human blood vessels, thus reducing blood pressure and alleviating symptoms of joint diseases that affect the elderly [2].

Although the plant receives enough nutrients and soil amendments, there are significant losses in fertilizer application, particularly in extensive agricultural regions, leading researchers to explore other techniques of fertilizer delivery [3]. The efficacy of any method employed for injecting tree trunks must satisfy four criteria: the system must be rapid and efficient, the injector's diameter should be minimal to reduce harm to the tree, the quantity of fertilizers injected per hole must be predetermined, and the hole should be situated low on the tree. Moreover, trunk injection for fertilizing trees offers distinct benefits, including the absence of environmental pollution, enhanced efficiency, reduced costs, and no limitations on tree height, facilitating quicker and more uniform fertilizer distribution throughout the tree via transpiration [4]. Nanotechnology, or nanoscience, concentrates on the examination of material processing at the atomic scale (10^{-9} meters), since nanomaterials display features that diverge from those of their conventional dimensions, reaching 100 nanometers [5].

Nanotechnology, a pioneering force in contemporary agriculture, is expected to emerge as a significant catalyst in the near future by advancing applications designed to improve fertilizer efficacy and address nutritional shortages. Nano fertilizers are regarded as the optimal solution because of their contribution to environmental sustainability [6]. Iron is essential for plant functions, serving as a catalyst for enzymes in respiration and electron transport; it is also a crucial element of chloroplasts and several enzymes [7]. Boron facilitates pollination and fertilization by promoting the growth of the pollen tube and its penetration into the ovule. Its substantial presence in the stigma and styles is crucial for fertilization, since it governs water absorption. Low boron levels result in increased water absorption by the pollen tube, perhaps causing it to rupture prior to reaching the ovule and complete fertilization [8]. Boron is crucial for the synthesis and transport of carbohydrates from leaves to fruits, forming complexes comprising diverse cell wall constituents such as cellulose, hemicellulose, pectin, as well as lignin, which are diminished in the tissues of cells affected by deficiency [9].

Seaweed extracts are organic inputs used in agricultural production, with about 15 million tons employed yearly in the sector. They pose no threat to health among people, animals, or natural surroundings. They enhance and control plant development, hence influencing the chemistry and biological properties of plants. They also include major and minor elements, amino acids, auxins, cytokinins, and polysaccharides. They also modulate osmosis at elevated concentrations and enhance plant resilience to salt, drought, and adverse environmental circumstances [10]. They enhance nutrient absorption efficiency, mitigate load exchange phenomena, and promote photosynthesis and respiration processes. Furthermore, they possess antioxidant properties due to the presence of tocopherol, beta-carotene, niacin, thiamine, and ascorbic acid, which augment enzyme activity [11]. The research seeks to determine the ideal concentrations of boron and nano-iron injections, together with the effects of seaweed extract and their interactions on the vegetative and chemical properties and yield of apple plants.

Materials and Methods

Location of the Experiment

The research was carried out within a private apple orchard in the city of Al-Bu-dhiyab situated 8 km west from Ramadi on location Gps33.491956.43.260994 . The trees were grafted onto quince rootstock and were 5 years old, with uniform growth size as much as possible. The experiment was carried out from March 16, 2024, to July 1, 2024.

Execution of the Experiment

Five-year-old apple trees with uniform vegetative growth size were selected, planted in a spacing of (3×4) m for the purpose of conducting the experiment. Orchard maintenance operations, including irrigation, weeding, and fertilization, were performed uniformly across the trees. Soil analysis was conducted to determine soil chemicals as well as physiological property that showed in Table (1).

Four main branches were selected from the circumference of the trunk, and each branch was marked with tape for the purpose of taking measurements of the traits that will be studied.

Table 1. Chemicals as well as physiological features of the Orchard Soil

Attributes	Values	Measurement units
Electrical conductivity EC	1.41	Deci-siemens m^{-1}
Total dissolved solids TDS	704	mg l^{-1}
pH	7.2	-------
Soil separators		
Clay	227.5	gm kg^{-1}
Gilt	402.5	gm kg^{-1}
Sand	370	gm kg^{-1}
Tissue	Mixture	
Nitrogen	0.29	Mg L^{-1}
Phosphorus	0.8	Mg L^{-1}
Attributes	Values	Measurement units
Potassium	1.32	millimole l^{-1}
Calcium	10.6	millimole l^{-1}
Magnesium	3.41	millimole l^{-1}
Sodium	1.54	millimole l^{-1}
Bicarbonate	1.72	millimole l^{-1}
Carbonates	Nil	
Organic matter	1.7	gm kg^{-1}
Gypsum	11.8	gm kg^{-1}
Lime	240	gm kg^{-1}
Exchange Capacity CEC	21	Centimol. Shipment.kg^{-1}

Treatments and experimental design

The experiment was performed on 36 apple trees that exhibited maximal homogeneity in vegetative development. The experiment used two factors:

The first factor

This factor involved injecting tree trunks with elements of boron B [12] and iron Fe [13] nanoparticles at three different concentrations.

1. Injection with distilled water only, denoted as (N0).

2. Injection with Boron presented as orthoboric acid, H_3BO_3 with levels 10 mg L^{-1} and injection with iron as Fe_2O_3 with levels 20 mg L^{-1}, denoted as (N1).
3. Injection with Boron presented as orthoboric acid H_3BO_3 with level 20 mg L^{-1} and injection with iron as Fe_2O_3 with levels 40 mg L^{-1}, denoted as (N2).

The second factor

This factor involved the addition of seaweed extract to apple trees at four different concentrations [14].

1. Adding water only, denoted as (A0).
2. Adding seaweed extract with levels of 3 mL L^{-1}, denoted as (A1).
3. Adding seaweed extract with levels 6 mL L^{-1}, denoted as (A2).
4. Adding seaweed extract with levels 9 mL L^{-1}, denoted as (A3**).**

Transaction Dates

The injection of nano-scale micronutrients and the incorporation of ground seaweed extract was carried out on the same day and at the times listed below.

• The first appointment was on March 16, 2024
• The second appointment will be on April 6, 2024
• The third appointment will be on April 26, 2024

Design of experiments the experiment included the injection of nanoelements at three concentrations and the addition of seaweed extract at four concentrations, using a two-factor design grounded on randomized complete block design (R.C.B.D.) done by three trials, each representing one tree per treatment, overall quantity for trees is 36 (3×4×3). Duncan's test is used for comparing the arithmetic indicate a great level of 0.05 [15].

Studied characteristics:

1. The content of chlorophyll a and b in leaves is measured in mg g^{-1} fresh weight.

On 12/6/2024, 16 whole leaves were taken from the middle of the new branches from different directions of the tree, and chlorophyll was estimated according to the method of Bajracharya [16]. The leaf samples were washed with distilled water to remove dirt and impurities, thoroughly dried, and cut into small pieces to facilitate the extraction process. Then, 0.2 grams of each sample were taken, and extraction was performed using 10 ml of acetone (80% concentration). After the extraction process was completed, the extract was collected, and the absorbance of the sample was measured using a spectrophotometer at wavelengths of 663 and 645 nanometers. The amount of chlorophyll (mg L^{-1}) was then estimated using the following equations:

Chlorophyll a = 9.78 (A663) – 5.00 (A645)
Chlorophyll b = 21.4 (A645) – 4.65 (A663)

2. Content of leaves in boron and iron (mg L^{-1})

After a quantity of dried and ground leaves was collected, the boron content of the leaves was measured according to Bingham [17]. For iron, it was measured using the method of Olsen and Sommers [18] with a spectrophotometer.

3. Percentage of remaining fruits (%)

The remaining fruits were calculated on the same selected branches that were chosen at the beginning of the season before harvesting the yield. The following equation is applied:

$$Percentage\ of\ remaining\ fruits\ = \frac{Number\ of\ fruits\ remaining\ at\ harvest}{The\ number\ of\ fruits\ produced\ before\ snowfall} \times 100$$

4. Fruit fall percentage (%)

The percentage of fruit fall was calculated after the end of the wave of newly set fruits fall and the wave of June fall. According to the following equation:

$$Fruit\ fall\ percentage\ = 100 - percentage\ of\ remaining\ fruits\ (\%)$$

5. Fruit firmness (kg cm^{-2})

We used a fruit pressure tester (5/16 plunger head) to measure the hardness of the fruit. We took five fruits for each experimental unit and extracted the average.

6. The percentage of total soluble solids in the fruits T.S.S (%)

The percentage of total soluble solids in the fruits was measured with a Hand Refractometer. The fruits were cut into slices and placed in an electric blender for 2-3 minutes, after which the juice was filtered using cotton cloth. The device readings were taken, and the average for each experimental unit was calculated [19].

Results and Discussion

1. **Chlorophyll A content of leaves (mg** 100g^{-1} fresh weight)
2. The results in Table (2) indicate that the chlorophyll A content in the leaves was significantly influenced by the injection of micronutrients, with the treatment N2 recording the highest value of 69.00 mg per 100 g^{-1} of fresh weight, compared to the treatment N0, which recorded the lowest value of 49.58 mg per 100 g^{-1} of fresh weight.

From the results presented in the same table, we find that the addition of seaweed extract significantly affected the chlorophyll A content in the leaves of apple trees, with the treatment A3 recording the highest value of 64.22 mg per 100 g^{-1} of fresh weight, compared to the treatment A0, which recorded the lowest value of 58.67 mg per 100 g^{-1} of fresh weight.

The interaction between the two study factors had a significant effect on the chlorophyll A content in the leaves, with the treatment N2A3 recording the highest value of 70.67 mg per 100 g^{-1} of fresh weight, compared to the treatment N0A1, which recorded the lowest value of 46.33 mg per 100 g^{-1} of fresh weight.

Table 2. Effect of0 injection of micro-nanometallic elements and addition of seaweed extract on the content of chlorophyll A in leaves (mg 100 g^{-1} fresh weight)

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	47.33g	46.33g	51.00f	53.67e	49.58c
N1 (10+20mg L^{-1})	62.33d	64.67c	66.00c	68.33b	65.33b
N2 (20+40mg L^{-1})	66.33c	69.67ab	69.33ab	70.67a	69.00a
Rate A	58.67d	60.22c	62.11b	64.22a	

Table (3) demonstrates that the administration of micronutrient components in apple trees significantly influenced the chlorophyll B concentration in the leaves. Treatment N2 exhibited the maximum concentration of 40.00 mg per 100g-1 of fresh weight, which was not statistically different from treatment N1 at 38.08 mg per 100g-1 of fresh weight, but treatment N0 had the lowest concentration at 28.08 mg per 100g-1 of fresh weight. The incorporation of seaweed extract did not have any notable impact on the chlorophyll B concentration in the leaves. The interplay between the two study variables significantly influenced the chlorophyll B concentration in the leaves of treatment N2A1, which exhibited the highest measurement of 41.33 mg per 100 g-1 of fresh weight, showing no significant difference from treatment N2A2, which attained 40.67 mg per 100 g-1 of fresh weight, whereas treatment N0A1 recorded the lowest concentration at 25.67 mg per 100 g-1 of fresh weight.

Table 3. The effect of injection with micronutrient elements and the addition of seaweed extract on the chlorophyll B content of the leaves (mg per 100g^{-1} of fresh weight)

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	27.67cd	25.67d	28.00cd	31.00c	28.08b
N1 (10+20mg L^{-1})	36.00b	38.67ab	38.00ab	39.67ab	38.08a
N2 (20+40mg L^{-1})	39.00ab	41.33a	40.67a	39.00ab	40.00a
Rate A	34.22a	35.22a	35.56a	36.56a	

Boron content of leaves (mg kg^{-1} dry matter)

The findings in Table (4) demonstrate that the administration of micronutrients significantly influenced the boron concentration in apple tree foliage. Treatment N2 exhibited the greatest value of 35.92 mg kg^{-1} of dry matter, while treatment N0 had the lowest value of 25.25 mg kg^{-1} of dry matter.

Adding seaweed extracts had a big impact on the boron content of the leaves. Treatment A3 had the highest value, measuring 32.56 mg kg^{-3} of dry matter, compared to treatment A0, which had the lowest value, measuring 28.67 mg kg^{-3} of dry matter.

The findings in Table (4) demonstrate that the administration of micronutrients significantly influenced the boron concentration in apple tree foliage. Treatment N2 exhibited the greatest value of 35.92 mg kg^{-1} of dry matter, while treatment N0 had the lowest value of 25.25 mg kg^{-1} of dry matter.

Table 4. Effect of injection with micronutrients and the addition of seaweed extract on the boron content of leaves (mg kg^{-1} of dry matter)

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	23.67h	24.67gh	26.00fg	26.67efg	25.25c
N1 (10+20mg L^{-1})	27.67ef	28.67e	31.00d	33.67c	30.25b

N2 (20+40mg L^{-1})	34.67bc	35.33abc	36.33ab	37.33a	35.92a
Rate A	28.67c	29.56c	31.11b	32.56a	

The iron content of leaves is measured in mg kg^{-1} dry matter.

The findings shown in Table 5 demonstrate that the incorporation of micronutrients had a significant impact on the quantity of iron present in the leaves of apple plants. The iron concentration of treatment N2 was the greatest, measuring 129.00 mg kg^{-1} of dry matter, while the iron content of treatment N0 was only 118.58 mg kg^{-1} of treated material.

Treatment A3 attained the maximum value of 127.11 mg kg^{-1} of dry matter, which was significantly higher than treatment A0, which reached 121.56 mg kg^{-1} of dry matter. This indicates that adding seaweed extract had a considerable impact on the iron concentration in the leaves. The boron content in the leaves changed a lot when the two study factors interacted with each other. Treatment N2A3 had the highest value, at 130.33 mg kg^{-1} of dry matter, while treatment N0A0 had the lowest value, at 113.33 mg kg^{-1} of dry matter.

Table 5. Effect of injection with micronutrients and the addition of seaweed extract on the iron content in the leaves (mg kg^{-1} of dry matter)

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	113.33g	117.33f	120.67e	123.00de	118.58c
N1 (10+20mg L^{-1})	122.67de	124.00cd	126.33bc	128.00ab	125.25b
N2 (20+40mg L^{-1})	128.67ab	128.33ab	128.67ab	130.33a	129.00a
Rate A	121.56c	123.22c	125.22b	127.11a	

Percentage of Remaining Fruits (%)

Treatment N2 recorded the highest percentage of remaining fruits at 58.76%, compared to treatment N0, which recorded the lowest percentage at 43.69%. The results from Table (6) indicate that the injection of micro nanoparticles had a significant effect on the percentage of remaining fruits on apple trees. Treatment N2 recorded the highest percentage of remaining fruits.

In addition, the incorporation of seaweed extract had a substantial impact on the proportion of fruits that were still present. Treatment A3 recorded the maximum percentage, which was 55.00%, in comparison to treatment A0, which recorded the lowest percentage, which was 47.46%. Regarding the different levels of interaction between the study factors, treatment N2A3 demonstrated a significant effect with the highest percentage of 63.14%, compared to treatment N0A0, which recorded the lowest percentage at 39.91.

Table 6. Effect of Injection of Micro nanoparticles and Addition of Seaweed Extract on the Percentage of Remaining Fruits (%)

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	39.91h	42.34gh	45.46fg	47.06f	43.69c
N1 (10+20mg L^{-1})	48.99ef	53.04d	52.31de	54.79cd	52.28b
N2 (20+40mg L^{-1})	53.46d	57.65bc	60.80ab	63.14a	58.76a
Rate A	47.46c	51.01b	52.85b	55.00a	

Percentage of Fruit Drop (%)

Taking into consideration the information that is provided in Table 7, we can see that the injection of micronutrients has a clear and substantial impact on the proportion of fruit that falls off apple trees. The drop percentage for treatment N2 was the lowest, coming in at 41.24%, while the drop percentage for treatment N0 was the greatest, coming in at 56.31%.

Compared to treatment A0, which had the most significant drop percentage at 52.54%, treatment A3 had a substantial impact by recording a drop percentage of 45.00%. This was in contrast to treatment A0, which had the lowest drop percentage at just 45.00%. In addition, the interaction between the two study components had a substantial impact on the percentage of fruit drop. Treatment N2A3 had the lowest percentage of fruit drop, which was 36.86%, in comparison to treatment N0A0, which had the most significant percentage, which was 60.09%.

Table 7. The effect of injecting micronutrients and adding seaweed extract on the percentage of fruit drop (%)

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	60.09h	57.66gh	54.54fg	52.94f	56.31c
N1 (10+20mg L^{-1})	51.01ef	46.96d	47.69de	45.21cd	47.72b
N2 (20+40mg L^{-1})	46.54d	42.35bc	39.22ab	36.86a	41.24a
Rate A	52.54c	48.99b	47.15b	45.00a	

Fruit Firmness (kg cm^{-2})

The results in Table (8) clearly show that the application of a mixture of micronutrients significantly affected the firmness of the fruit from apple trees. The treatment N2 recorded the lowest firmness value of 12.06 kg cm^{-2}, which did not differ significantly from treatment N1 that recorded 12.63 kg cm^{-2}, while treatment N0 recorded the highest firmness level of 13.46 kg cm^{-2}. Despite a decrease in firmness levels with increasing extract concentrations, adding different levels of seaweed extract did not significantly affect fruit firmness. Meanwhile, the interaction had a significant effect, as treatment N2A3 recorded the lowest firmness level of 11.47 kg cm^{-2} compared to treatments N0A1 and N0A0, which recorded the highest firmness level of 13.57 kg cm^{-2}.

Table 8. Effect of injection of micro-nanometallic elements and addition of seaweed extract on fruit hardness (kg cm^{-2})

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	13.57b	13.57b	13.40b	13.30b	13.46b
N1 (10+20mg L^{-1})	13.10b	12.77ab	12.43ab	12.23ab	12.63a
N2 (20+40mg L^{-1})	12.27ab	12.37ab	12.13ab	11.47a	12.06a
Rate A	12.98a	12.90a	12.66a	12.33a	

Total Soluble Solids in the Fruit T.S.S (%)

The micronutrient injection had a significant effect on the total soluble solids (TSS) of apple trees, with treatment N2 having the most significant percentage (13.47%) and treatment N0 having the lowest percentage (12.03%). Table 9 has all of these findings, which may be accessed here. Even though there was an increase in total soluble solids (TSS) with increasing addition concentrations, we did not find any significant influence on the TSS when we added varied quantities of seaweed extract. It was shown that the interaction treatments between the study components had a substantial impact on the total soluble solids (TSS). Treatment N2A3 recorded the most significant percentage, which was 13.57%, while treatment N0A1 recorded the lowest percentage, which was 11.70%.

Table 9. Effect of injection with micronutrients and addition of seaweed extract on the total soluble solids in the fruit T.S.S (%)

Injection of micro-elements N(Fe+B)	Add seaweed extract A				
	A0 (distilled water only)	A1 (3 ml L^{-1})	A2 (6 ml L^{-1})	A3 (9 ml L^{-1})	N rate
N0 (distilled water only)	11.93bc	11.70c	12.10bc	12.37abc	12.03c
N1 (10+20mg L^{-1})	12.50abc	13.13ab	12.63abc	12.70abc	12.74b
N2 (20+40mg L^{-1})	13.27ab	13.50a	13.53a	13.57a	13.47a
Rate A	12.57a	12.78a	12.76a	12.88a	

The data that are reported in Tables 2-9 illustrate the influence that infusing nano-boron and iron has on a variety of vegetative, chemical, and yield characteristics, particularly at doses of 20 mg L^{-1} boron and 40 mg L^{-1} iron throughout the development of the plant. This improved growth may be attributed to the mineral components that are present in the composition of the nutrient solution.

Boron is an essential element that plays a significant part in the creation of cell walls, the division of cells, and the acceleration of photosynthesis. The transfer of sugars from the locations in the leaves where they are produced to the different development and storage places in the plant is a key process that requires it [20]. It is also needed for the enhancement of proteins and carbs. The results presented here agree with those that Kassem et al. [21] and Mohammed [22] investigated in relation to lemon trees and apple trees, respectively. The high proportion of retained fruits and the low percentage of fruit drop may be attributed to the substantial function that boron, which is a component of the nutritional element composition, plays in the processes of pollination and fertilization. It does this by promoting the formation of the pollen tube and its penetration into the ovule, which in turn increases the separation zone and ensures that the fruits remain connected to the branches for the longest possible period of time [23].

It serves a crucial function in fertilization owing to its substantial presence in the stigmas and styles, since it governs water absorption. Low boron levels enhance water absorption by the pollen tube, perhaps leading to its rupture prior to fertilizing the ovum, hence hindering effective fertilization [24].

Boron not only facilitates cell division but also promotes fruit growth, resulting in greater weight; a clear association occurs between the increase in fruit size and the percentage of fruit set, thus enhancing total yields. Elevating boron levels within acceptable limits improves photosynthesis and sugar synthesis essential for developing all tree fruits, while simultaneously diminishing resource rivalry among leaf-produced outputs [25]. This reduces nutrient competition and lowers fruit loss, especially for freshly established fruits. Furthermore, boron is essential for the production and transfer of carbohydrates from the leaves to the fruits, creating complexes with diverse cell wall constituents including cellulose, hemicellulose, pectin, and lignin. These complexes decrease in the tissues of cells lacking boron [26].

These findings align with the observations of Kassem et al. [21] about apple trees, Mohammed [22] concerning lemon trees, and the results presented by Harhash et al. [27]. Iron augments chlorophyll production, elevating its content in the foliage. This therefore enhances photosynthetic efficiency and elevates the quantity of carbohydrates synthesized and stored in the leaves, hence augmenting the total soluble solids (TSS) [28]. Iron is crucial for optimizing photosynthesis and facilitating the distribution of carbohydrates throughout the plant [29]. These results are consistent with the findings of Davarpanah et al. [30] in their research on pomegranate trees.

The data that is shown in Tables (2-9) indicates that the integration of seaweed extract had a substantial impact on all growth parameters when the concentration was set at 9 milliliters per liter. As a result of seaweed's large contribution to the production of pigments such as chlorophyll and carotene, as well as its preservation of plasma membranes, seaweed has a favorable influence on the chlorophyll concentration in leaves [31]. This is attributable to the higher efficiency of photosynthesis. It is possible to attribute the superiority of the seaweed extract addition coefficients to the influence of nutrients on photosynthesis, respiration, and cellular metabolism. Nutrients play a significant role in the composition of nucleic acids, which are essential for cell division and the synthesis of proteins, enzymes, and hormones [32]. There are a number of main and minor elements present in the seaweed extract, which have a positive impact on the elemental composition of the leaf [33].

Conclusions:

The research concludes that the tree trunk injection approach was cost-effective and highly efficient in administering nano fertilizers rapidly and addressing deficient instances at various development stages at the concentration of B20+ Fe40mg L^{-1}. Furthermore, incorporating seaweed extract had favorable outcomes across all features, particularly at a concentration of 9 ml L^{-1}.

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استجابة أشجار التفاح الإبراهيمي للبورون وحقن الحديد النانوي وإضافة مستخلص الأعشاب البحرية

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الخلاصة

نفذت التجربة في قرية البوذياب – شمال غرب مدينة الرمادي وعلى موقع *Gps*: 33.491956.43.260994 في الموسم الربيعي 2024 على أشجار التفاح صنف ابراهيمي بعمر 5 سنوات ، لدراسة تأثير الحقن بالعناصر النانوية الصغرى واضافة مستخلص الطحالب البحرية على صفات النمو الخضري والكيميائي والحاصل ، تضمنت التجربة ثلاث مستويات من الحقن (0 الحقن بالماء المقطر فقط ، *B10+Fe20* و *B20+(Fe40* ملغم لتر-1 واضافة مستخلص الطحالب البحرية بأربع مستويات (0 الحقن بالماء المقطر فقط ، 3 ، 6 و 9 مل لتر-1) تمت المعاملة على ثلاث دفعات في السادس عشر اذار وبين معاملة وأخرى 20 يوم . درست الصفات التالية؛ محتوى الأوراق من كلوروفيل *a* و*b*، محتوى الأوراق من البورون والحديد، نسبة الثمار المتبقية، نسبة تساقط الثمار، صلابة الثمرة ونسبة المواد الصلبة الذائبة الكلية في الثمار *T.S.S*.

اظهرت النتائج ان مستوى الحقن *B20+(Fe40* ملغم لتر-1 أدى الى زيادة معنوية في اغلب الصفات المدروسة. اما بالنسبة لعامل اضافة مستخلص الطحالب البحرية (9مل لتر-1) ادى الى زيادة معنوية في اغلب الصفات المدروسة ايضاً. اما مستويات التداخل بين عاملي الدراسة فان عامل الحقن بالتركيز *B20+(Fe40* واضافة مستخلص الطحالب البحرية بالتركيز (9مل لتر-1) قد تفوق في اغلب الصفات المدروسة.

الكلمات مفتاحية: التفاح ، الحقن ، تقنية النانو ، مستخلص الطحالب البحرية.