Effect of Foliar Application of Seaweed Extract and Chelated Iron on Some Chemical and Fruit Characteristics of (*Ziziphus mauritiana Lam. Cv. Tufahi Trees*)

Faiza Khadim Dawood AL-Rumaydh
Faiza-khadim@utq.edu.iq

University of ThiQar----College ofAgriculture&Marshes

Abstract
The present investigation was carried out in year 2025 in a private jujube (*Ziziphus mauritiana Lam. Cv. Tufahi Trees*) orchard in Al-Khamisat region of Dhi Qar Governorate. Twenty seven trees were selected and the trees were homogeneous in shape and size. The trees were treated as experimental units to test the effect of foliar application of various concentrations of seaweed extract and chelated iron on some chemical and fruit quality parameters. The seaweed extract and the second agent were applied at three concentrations: 0, 2, and 4 mL L^{-1} for the seaweed extract, and 0, 250, and 500 mL L^{-1} for the second agent, respectively. The results of the analyses were as follows :Spraying with seaweed extract at 4 mL L^{-1} significantly improved fruit physical traits, recording the highest values for fruit length (3.52 cm), diameter (3.16 cm), volume (5.41 cm^3), and weight (10.07 g). Additionally, this treatment enhanced total soluble solids (TSS: 10.57%), vitamin C (188.14 mg/100g FW), leaf chlorophyll content (5.74 mg/100g FW), and dry matter (21.56 g) .Similarly, foliar application of chelated iron at 500 mg L^{-1} significantly increased leaf chlorophyll (7.31 mg/100g FW) and fruit dry matter (22.90 g), as well as physical characteristics (length: 3.77 cm, diameter: 3.30 cm, volume: 5.41 cm^3, and weight: 11.05 g), TSS (11.37%), and vitamin C content (184.98 mg/100g FW). The interaction treatment between 4 mL L^{-1} seaweed extract and 500 mg L^{-1} chelated iron exhibited a significant synergistic effect, resulting in the highest overall improvement across all evaluated characteristics.
Keywords: Ziziphus mauritiana, Jujube, Foliar application, Chelated iron, Seaweed extract, Fruit quality.

Introduction

The jujube tree *(Ziziphus mauritiana Lam. Cv. Tufahi Trees*) is a member of the Rhamnaceae family, consisting of 600+ species and 58 genera. This consists of trees, shrubs and climbing plants, and occasionally herbs, the genus Zizyphus contains about 100 species of fruit trees that grow in the tropical and subtropical regions of the Northern Hemisphere and in warm temperate regions worldwide. The jujube tree is hardy, resistant to high temperatures and tolerant of harsh environmental conditions and widely planted in arid and semi-arid areas (2, 25) It is thought that this jujube tree originated from the Indian sub-continent to northern China, South America, Sudan, tropical regions and North Africa. It is grown in Iraq especially in the central and southern areas (5). The Basra region of Iraq is the best known for the (Tufahi) variety and is one of the most important and common varieties of jujube in the region, due to its economic profitability, large size, special taste and nutritional value (27). The fruits are spherical, semi-spherical or elliptical with yellow color at maturity, mottled with green (27). Jujube tree fruit is rich in sugars, proteins, vitamins (C and A), fiber, minerals,

ISSN 2072-3857

fats, amino and organic acids, which make it a nutritious fruit. Each 100 grams of pulp contains 20.9 calories. Fruits are used effectively in treating digestive and liver diseases. It has economic importance in many industries because of its wood and is also used as a fuel, windbreak or ornamental tree due to the beauty of its leaves and bark which has many medicinal uses (20). Foliar application enhances the efficiency of fertilizer utilization and consequently promotes plant growth and development, which may ultimately be reflected in fruit production. In the present study, seaweed extract was used as an organic fertilizer supplement to conventional chemical fertilizers. Foliar application of seaweed extracts has been reported to improve plant tolerance to various environmental stresses, including soil salinity and drought, and to enhance resistance to pest and fungal attacks (19). These beneficial effects may be attributed to the high content of nutrients, vitamins, antioxidants, and naturally occurring plant hormones present in seaweed extracts.

Seaweed extracts also contribute to plant growth by supplying essential nutrients and bioactive compounds that may enhance physiological and metabolic processes. They have been reported to promote chlorophyll synthesis, cellular respiration, cell division, and cell elongation, thereby enhancing photosynthetic activity and overall plant growth (26). Micronutrients are required in relatively small quantities compared with macronutrients; however, their deficiencies can adversely affect plant growth and development. Iron (Fe) is an essential micronutrient that plays a critical role in chlorophyll biosynthesis and oxidation–reduction reactions. It is also involved in maintaining chlorophyll integrity and in the synthesis of chlorophyll-associated compounds and cytochromes, which are essential components of photosynthetic and respiratory processes.

Iron deficiency is commonly characterized by a reduction in chlorophyll concentration and alterations in chloroplast structure, resulting in interveinal chlorosis, particularly in young leaves. This symptom is partly associated with the relatively limited mobility of iron within plant tissues and may subsequently become more pronounced along the leaf veins (15). The application of chelated iron can help alleviate iron deficiency because chelating agents maintain iron in a soluble and plant-available form, thereby reducing the formation of insoluble precipitates and facilitating its uptake by plant tissues (23). Chelated compounds consist of organic ligands that bind mineral ions, thereby maintaining the nutrient in a stable and soluble form without substantially altering its availability and mobility. This property facilitates the efficient uptake and utilization of essential mineral nutrients by plants (17).

Restructuring the study objectives as follows:

-To determine the effect of foliar spraying with chelated iron on improving key fruit and chemical characteristics of jujube trees (Ziziphus spina-christi)

-To examine the impact of seaweed extract applications on the chemical and fruit quality traits of Ziziphus spina-christi

-To evaluate the interactive effects of combined treatments (seaweed extract and chelated iron) on the vegetative and reproductive characteristics of jujube trees

Materials and Methods:

Experimental Location

The study was conducted in the Al-Khamisat area, an agricultural region located approximately 8 km from the center of Dhi Qar Governorate, Iraq, during the 2024–2025 agricultural season. The study aimed to evaluate the effects of the applied treatments on selected vegetative growth and fruit characteristics.

Twenty-seven healthy and uniformly

ISSN 2072-3857

vigorous trees were selected for the experiment. The selected trees were approximately seven years old and were characterized by relatively uniform vegetative growth and developmental status. All trees were grown in alluvial clay soil. Throughout the experimental period, the orchard was subjected to standard maintenance practices, including regular irrigation, pruning, pest and disease management, and manual and mechanical weed control, as required.

Before initiating the experiment, representative soil samples were collected randomly from different locations within the orchard to assess the physicochemical properties of the soil. Soil samples were collected from a depth of 0–60 cm at the beginning of the agricultural season. The collected samples were thoroughly mixed and prepared for laboratory analysis. The results of the preliminary soil analysis conducted before the commencement of the experiment were as follows:

Table (1): To identify some chemical and physical properties of the soil

Unit	**Value**	
	7.8	PH
$DS.m^{-1}$	3.26	EC
Trait		
%	45.33	Sand
%	25.33	Clay
%	29.11	Silt
Soil texture: Sandy Clay Loam		
mg kg-1	24.77	**Nitrogen**
mg kg-1	7.94	Phosphorus
$mg\ kg^{-1}$	142.01	**Potassium**

Two factors were investigated in the experiment. The first factor was the foliar application of liquid seaweed extract at three concentrations: 0 mg L^{-1} (T1), 2 mg L^{-1} (T2), and 4 mg L^{-1} (T3). The seaweed extract was applied as a foliar spray in three applications at 20-day intervals, on March 10, April 1, and April 20.

The second factor was foliar application of chelated iron at three concentrations: 0 mg L^{-1} (F1), 250 mg L^{-1} (F2), and 500 mg L^{-1} (F3). The chelated iron treatments were applied as foliar sprays on March 15, April 5, and April 25. Thus, each treatment was applied three times during the experimental period according to the specified application schedule.

Studyed Characteristics:

1. Total Chlorophyll Content in Leaves (mg g^{-1} Fresh Weight)

The total chlorophyll content of the leaves was determined according to the method described by Goodwin (1976). The results were expressed as

ISSN 2072-3857

milligrams of total chlorophyll per gram of fresh leaf weight (mg g^{-1} FW).

2. Dry Matter Content (g)
Ten fully ripened fruits were randomly selected from each experimental unit and weighed as fresh samples. The dry matter content was subsequently determined according to the method described in Reference (16).

3. Fruit Length (cm)
Ten fruits were randomly selected from each experimental unit, and fruit length was measured using a Vernier caliper. The measurements were recorded in centimeters (cm).

4. Fruit Diameter (cm)
Ten fruits were randomly selected from each experimental unit, and fruit diameter was measured using a Vernier caliper. The measurements were recorded in centimeters (cm).

5. Fruit Weight (g)
Ten fruits were randomly selected from each experimental unit and weighed individually using a precision balance. The mean fresh weight of the fruit was calculated by dividing the total weight of the sampled fruits by the number of fruits examined. The average fruit weight was calculated using the following equation: Average fruit weight (g $fruit^{-1}$) = Total weight of fruits (g) / Total number of fruits

6. Fruit Volume (cm^3)
Fruit volume was determined using the water-displacement method. A graduated cylinder was filled with a known volume of water, and the initial water level was recorded. The fruits were then carefully immersed in the cylinder, and the increase in water volume was recorded as the volume of water displaced by the fruits. The mean fruit volume was calculated according to the following equation: Average fruit volume (cm^3 $fruit^{-1}$) = Volume of displaced water (cm^3) / Number of fruits

7. Vitamin C Content (mg 100 g^{-1} Fresh Weight)
The vitamin C content of the fruits was determined according to the method described in Reference (1). The results were expressed as milligrams of vitamin C per 100 g of fresh fruit weight (mg 100 g^{-1} FW).

Experimental Design:
The present study was designed as a Randomized Complete Block Design (RCBD) in a factorial experiment with two factors. The first factor was the application of liquid seaweed extract at three concentrations (0, 2, and 4 mL/L) applied 20 days apart on March 10, April 1, and April 20, representing three application levels (T_1, T_2, and T_3). The second factor was the application of chelated iron at three concentrations (0, 250, and 500 mg/L) on March 15, April 5, and April 25 (F1, F2, and F3). Treatments were replicated three times. The results were statistically analyzed using the GenStat software package. Differences between arithmetic means were compared using the Least Significant Difference (LSD) test at a probability level of 0.05. The interaction between the factors of the study was significant.

Results and Discussion:
1-Chlorophyll content of leaves (mg/100g FW).
As revealed in the table 4, spray with seaweed extract had a significant effect. The results were significantly better in treatment (H3) with 5.743 mg/100 g (fresh weight) as compared to treatment (2 ml/L) with 5.174 mg/100 g (fresh weight). The control treatment (H1) had the lowest average concentration of 4.568 mg/100 g (fresh weight). Treatment with chelated iron

ISSN 2072-3857

at a concentration of 500 mg/L also had the highest average concentration of 7.309 mg/100 g (fresh weight). Also, the interaction between the factors of the study was significant, showing as the highest factor the treatment of H3F3 with an average concentration of 7.727 mg/100 g (fresh weight). The superiority of the 500 mg treatment to the control (distilled water) which recorded the lowest average of 2.350 mg per 100 g fresh weight is due to the indirect effect of iron on the formation of the chlorophyll molecule as it participates in a series of compounds which resulted in chlorophyll increase in leaves as described. The results obtained are similar to that of (18) in the case of pomegranate trees.

Table (2) Effect of seaweed extract and chelated iron and their interactions on chlorophyll concentration of jujube trees (cv. Tuffahi)

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
3.074	3.740	3.133	2.350	**F1**
5.102	5.763	5.190	4.353	**F2**
7.309	7.727	7.200	7.000	**F3**
	5.743	5.174	4.568	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
0.2811		0.1623	0.1623	

Dry Matter (g):

The result of seaweed extract spraying on Sidr tree (Tuffahi variety) is presented in Table (5) which indicates that the dry matter of fruits produced by the trees treated with seaweed extract has significantly increased. The treatment with the concentration of 4ml/L recorded the highest value of 21.561g while the control treatment recorded the lowest value of 19.191g. Similarly, it was observed from Table (5) that the highest value was observed at 500 mg/L of chelated iron spray whereas the lowest average value was recorded with the control treatment (without chelated iron spray) as 17.607 g. Moreover, the interaction between the two study factors was significantly different due to the highest average of 24.007 g for the treatment that used 4 ml/L of seaweed extract and 500 mg/L of chelated iron.

Table (3) Effect of spraying with seaweed extract and chelated iron and their interactions on dry matter Gham for fruits, jujube variety, apple

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
17.607	18.943	17.787	16.090	**F1**
20.787	21.733	21.257	19.370	**F2**

ISSN 2072-3857

22.903	24.007	22.590	22.113	**F3**
	21.561	20.544	19.191	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
0.3284		0.1896	0.1896	

Estimation of Total Soluble Solids (TSS)

The results showed in Table (4) clearly indicated that the treatment with concentration of 4 g, has significant advantage with the highest average value of 10.570 g, while the treatment without addition (spraying with distilled water) had the lowest average value of 9.596 %. The chelated iron treatment was also significant with the treatment with iron concentration of 500mg/l having the highest values of 11.372%, and the control treatment the lowest average of 8.736%. Likewise, the interaction between the two study agents (seaweed extract and chelated iron) was significantly different with the highest value of 12.010 g obtained from treatment with 4 ml/L + 500 mg/L, and the lowest value of 7.963 g from the H1F1 (control) treatment.

Table (4) Effect of spraying with seaweed extract and chelated iron and their interactions on TSS in jujube trees, apple variety

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
8.736	9.170	9.073	7.963	**F1**
10.232	10.530	10.303	9.863	**F2**
11.372	12.010	11.147	10.960	**F3**
	10.570	10.174	9.596	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
0.4339		0.2505	0.2505	

Fruit Length (cm)

As shown in Table 5, foliar application of seaweed extract and chelated iron, as well as their interaction, had a significant effect on fruit length of jujube trees (Tuffahi cultivar). Regarding the effect of seaweed extract, the highest mean fruit length was recorded with the application of 4 mL L^{-1}, reaching 3.5211 cm, followed by the 2 mL L^{-1} treatment, which recorded 3.4572 cm. In contrast, the untreated control recorded the lowest mean fruit length, at 3.2644 cm.

Regarding the effect of chelated iron, the highest mean fruit length was recorded at 500 mg L^{-1}, reaching 3.7667 cm, whereas the lowest mean value was observed in the untreated control treatment, in which the trees were sprayed with distilled water only, with a value of 3.0444 cm.

The interaction between seaweed extract and chelated iron also significantly affected fruit length. The

ISSN 2072-3857

highest mean fruit length was recorded for the H3F3 treatment combination (4 mL L^{-1} seaweed extract + 500 mg L^{-1} chelated iron), with a value of 3.8800 cm, whereas the lowest value was recorded for the H1F1 control treatment (0 mL L^{-1} seaweed extract + 0 mg L^{-1} chelated iron), with a value of 2.9133 cm.

.**Table (5) Effect of spraying with seaweed extract and chelated iron, and their interactions, on the fruit length of Jujube trees (Tuffahi variety)**

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
3.0444	3.1633	3.0567	2.9133	**F1**
3.3611	3.5200	3.3333	3.2300	**F2**
3.7667	3.8800	3.7700	3.6500	**F3**
	3.5211	3.3867	3.2644	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
0.05819		0.03359	0.03359	

Fruit Diameter (cm)

Table (6) illustrates the very significant effect that occurred when spraying with seaweed extract, chelated iron and their interaction on the fruit diameter of Jujube trees (Tuffahi cv. variety). The highest average diameter (3.157 cm) was obtained for the 4 ml/L treatment whilst the lowest average was obtained for the control treatment (2.778 cm). The 500 mg/L treatment had the highest averages of 3.300, 3.068, and 2.564 cm for chelated iron spraying, respectively, while the 250 mg/L treatment had the second highest averages of 3.185, 3.005, and 2.513 cm, respectively, and the control treatment had the lowest averages of 3.300, 3.068, and 2.564 cm, respectively. The H3F3 and control (H1F1) is the highest (3.640 cm) and the lowest (2.133 cm) average diameter respectively.

Table (6) Effect of spraying with seaweed extract and chelated iron and their interactions on the fruit diameter of jujube trees, apple variety

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
2.564	2.877	2.683	2.133	**F1**
3.068	3.133	3.070	3.000	**F2**
3.300	3.460	3.240	3.200	**F3**
	3.157	2.998	2.778	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
0.1181		0.0682	0.0682	

ISSN 2072-3857

Fruit weight (g)

As shown in Table (8), spraying with seaweed extract significantly affected fruit weight. Treatment H3 (4 mL L^{-1}) recorded the highest average fruit weight (10.071 g), followed by treatment H2 (2 mL L^{-1}) with 9.566 g, whereas the control treatment (H1) recorded the lowest value (8.810 g).

Similarly, chelated iron spraying had a significant effect on the same trait. The concentration of 500 mg L^{-1} (F3) recorded the highest value (13.254 g), followed by 250 mg L^{-1} (F2) with 12.224 g, while the control treatment recorded the lowest value (9.331 g).

Furthermore, the interaction between the two studied factors was statistically significant. The combination treatment of 4 mL L^{-1} seaweed extract and 500 mg L^{-1} chelated iron (H3F3) yielded the highest fruit weight (11.049 g), whereas the control treatment (H1F1) recorded the lowest value (7.862 g). The positive effect of seaweed extract may be attributed to its active components, such as plant hormones, which promote cell division and elongation, as well as enhance photosynthetic activity and nutrient translocation to the fruits, leading to increased fruit weight. These results are in agreement with the findings of (22), as well as previous studies [2, 9] on mango and date palm trees, respectively.

Table (7) Effect of spraying with seaweed extract and chelated iron and their interactions on fruit weight of jujube trees (Tuffahi cultivar)

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
7.862	8.413	8.140	7.033	**F1**
9.536	10.250	9.573	8.783	**F2**
11.049	11.550	10.983	10.613	**F3**
	10.071	9.566	8.810	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
0.1709		0.0987	0.0987	

Fruit Size (cm^3)

From table (8) it is evident that spraying with seaweed extract was significant as treatment (H3) at 4 ml/L had the highest average fruit size of 5.413 cm^3 while treatment at 2 ml/L had 5.056 cm^3. The lowest value was observed for the control treatment (H1) which was 4.826 cm^3. Spraying with chelated iron was also significant for the same trait, with spraying at a concentration of 500 mg/L giving the highest value of 6.056 cm^3 followed by spraying with a concentration of 250 mg/L, compared to the lowest value obtained in the control treatment (spraying with distilled water) of 4.212 cm^3. The effect of the interaction between the two factors of the study

ISSN 2072-3857

was also significant. Seaweed extract (H3F3) at 4ml/L with iron at 500mg/L recorded the highest values at 6.273cm³ compared to (H1F1) which recorded the lowest values at 3.953cm³.The larger fruits lead after seaweed extract application is thought to be due to roles of components of the extract in cell division, cell elongation and elasticity of cell walls. This results in the increase of cell wall voids and deposition of cellulosic materials through chemical reactions inside the cell wall structure which removes the cell wall pressure. The water and nutrients enter this way, enlarging the size of cells by increasing their size and the diameter of cell walls; and as a result, the size of fruit increases (4). This finding is in agreement with the work done by Hormzi, (2010).

Table (8) Effect of spraying with seaweed extract and chelated iron and their interactions on fruit size in jujube trees, Apple variety

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
4.212	4.460	4.223	3.953	**F1**
5.027	5.507	4.907	4.667	**F2**
6.056	6.273	6.037	5.857	**F3**
	5.413	5.056	4.826	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
0.1861		0.1074	0.1074	

Vitamin C Assessment

The effects of seaweed extract and chelated iron, as well as their interaction, on the vitamin C content of jujube fruits (Tuffahi cultivar) are presented in Table (9) The results showed that seaweed extract significantly affected the vitamin C content of the fruits. The application of seaweed extract at 4 mL L^{-1} resulted in the highest vitamin C content, reaching 175.30 mg 100 g^{-1} fresh weight, whereas the untreated control (H1) recorded the lowest value of 168.30 mg 100 g^{-1} fresh weight.

Chelated iron also significantly affected the vitamin C content of jujube fruits. The application of chelated iron at 500 mg L^{-1} resulted in the highest vitamin C content, with a value of 184.98 mg 100 g^{-1} fresh weight, while the untreated control recorded the lowest value of 160.69 mg 100 g^{-1} fresh weight.

Regarding the interaction between seaweed extract and chelated iron, the highest vitamin C content was recorded for the combined treatment of 4 mL L^{-1} seaweed extract + 500 mg L^{-1} chelated iron. The lowest value was recorded for the treatment without the addition of seaweed extract and chelated iron (H1F1), with a vitamin C content of 158.32 mg 100 g^{-1} fresh weight. In contrast, the highest interaction value was 188.14 mg 100 g^{-1} fresh weight. These results indicate that the combined application of seaweed extract and chelated iron

ISSN 2072-3857

may have produced a complementary effect in enhancing vitamin C accumulation in jujube fruits

Table (9) shows the effect of spraying with seaweed extract and chelated iron and their interactions on vitamin C in jujube trees (Tuffahi variety).

Chelated Iron average	**seaweed extract**			**Chelated Iron**
	H3	**H2**	**H1**	
160.69	162.41	161.33	158.32	**F1**
170.62	175.36	171.64	164.86	**F2**
184.98	188.14	185.08	181.72	**F3**
	175.30	172.68	168.30	**seaweed extract average**
Interaction		**seaweed extract**	**Chelated Iron**	**LSD $_{0.05}$**
2.111		1.219	1.219	

Discussion

Weed competition can adversely affect the availability and uptake of nutrients by fruit trees; therefore, foliar application provides an effective means of supplying nutrients directly to the leaves, particularly when soil application is less efficient under certain soil conditions (Abu Dhahi & Al-Younes, 1988). The improvement in total chlorophyll content observed following seaweed extract application may be attributed to the biologically active compounds and mineral nutrients present in seaweed extracts, which can support chlorophyll stability and reduce its degradation. Seaweed extracts also contain plant growth-promoting substances, particularly auxins and cytokinins, which may enhance nutrient uptake, assimilate transport, and overall plant metabolic activity. These effects could explain the observed improvement in vegetative growth and fruit development and are consistent with the findings reported in date palms (9).

The increase in fruit dry matter following seaweed extract application may be associated with enhanced photosynthetic activity and the stimulatory effects of naturally occurring growth regulators on nutrient assimilation and carbohydrate metabolism. Increased photosynthetic efficiency can enhance the production of photoassimilates, which are subsequently translocated from source leaves to developing fruits and utilized in the synthesis and accumulation of carbohydrates and other structural and storage compounds. Consequently, the accumulation of dry matter in the fruit may increase.

The higher total soluble solids content observed in fruits treated with seaweed extract may likewise be related to enhanced photosynthetic activity and the subsequent translocation of photoassimilates to developing fruits. The accumulation of soluble sugars,

ISSN 2072-3857

organic acids, and mineral nutrients during fruit development contributes directly to the increase in total soluble solids and supports the metabolic processes associated with fruit maturation (4). Furthermore, the mineral constituents of seaweed extracts, particularly potassium, may contribute to improved fruit development through their roles in enzyme activation, carbohydrate metabolism, and the synthesis of amino acids and proteins. These physiological effects may account for the increases observed in fruit length, diameter, weight, and volume.

The increase in vitamin C content may be associated with enhanced photosynthetic activity and carbohydrate availability resulting from improved vegetative growth. Carbohydrates and their metabolic intermediates provide substrates for the biosynthetic pathway leading to ascorbic acid accumulation during fruit development. Therefore, the enhanced nutritional status and metabolic activity induced by seaweed extract application may have contributed to greater accumulation of ascorbic acid in the fruits. The combined application of seaweed extract and chelated iron may have produced a synergistic effect by improving photosynthetic efficiency, nutrient assimilation, and metabolic activity, thereby enhancing the accumulation of organic compounds, including ascorbic acid.

Iron is an essential micronutrient involved in several fundamental physiological and biochemical processes in plants. It functions as a component or cofactor of numerous enzymes and electron-transfer proteins involved in photosynthesis and respiration and is therefore essential for maintaining efficient cellular metabolism and chloroplast function. The application of chelated iron may improve iron availability and uptake, particularly under soil conditions where iron availability is limited. The resulting improvement in iron nutrition can enhance photosynthetic activity, vegetative growth, and leaf development. The present findings are consistent with those reported by Khalaf (18) in pomegranate and Al-Mawsili (8) in peach trees. The superior performance of the 500 mg L^{-1} chelated iron treatment may be attributed to the greater availability of iron for essential metabolic processes. Iron is required for the functioning of several enzymes and electron-transfer components, including catalase and cytochrome-containing systems, and contributes to chloroplast development and photosynthetic electron transport. Improved iron nutrition may consequently enhance photosynthetic efficiency and the production of photoassimilates, which are translocated from leaves to developing fruits. This may increase the accumulation of carbohydrates and soluble solids in the fruit. Similar responses have been reported by Faisal et al. (13).

The increases in fruit length, diameter, weight, and volume associated with chelated iron application may be related to improved photosynthetic performance and enhanced metabolic activity. Adequate iron nutrition supports enzyme activity, protein synthesis, cellular metabolism, and normal cell division and expansion, all of which are important processes during fruit development. In addition, improved photosynthesis and respiration can increase the supply of

ISSN 2072-3857

assimilates required for fruit growth and biomass accumulation. These findings are in agreement with the results reported by Attallah et al. (12), Badawi et al. (12), and Kadhim (14) in olive trees and are also consistent with observations reported in pomegranate.

The increase in vitamin C content following chelated iron application may be attributed to improved vegetative growth, greater leaf area, and enhanced photosynthetic efficiency, which collectively increase the availability of carbohydrates and metabolic intermediates required for fruit development. During fruit maturation, these carbon substrates contribute to the metabolic pathway leading to ascorbic acid biosynthesis and accumulation. Thus, improved iron nutrition may indirectly enhance vitamin C accumulation by promoting photosynthesis, carbohydrate assimilation, and overall metabolic activity. Furthermore, the combined application of seaweed extract and chelated iron may have exerted complementary effects on plant nutrition and physiological activity, resulting in enhanced accumulation of vitamin C and other nutritionally important compounds in the fruits.

Conclusions

1- Foliar application of seaweed extract and chelated iron significantly improved all studied vegetative and fruit quality traits in jujube trees (cv. Tuffahi).

2- Seaweed extract application at 4 mL L^{-1} was superior in enhancing physical and chemical fruit parameters compared to lower concentrations.

3- Chelated iron spraying at 500 mg L^{-1} recorded the highest overall positive response across all evaluated parameters.

The combined treatment of 4 mL L^{-1} seaweed extract and 500 mg L^{-1} chelated iron (H3F3) yielded the optimum results, demonstrating a synergistic effect on enhancing fruit weight, size, TSS, and ascorbic acid content.

Recommendations

1- Higher concentrations should be applied to find the maximum effect and optimal concentration on vegetative, fruit and chemical characteristics and especially medicinal properties as jujube has secondary compounds.

2- Do the same studies under environmental stress conditions to see how well it can protect plants from environmental stresses.

3- Farmers are recommended to use the seaweed extract and chelated iron effectively, since both of them are important in enhancing the characteristics of plants at minimum cost.

ISSN 2072-3857

References

1. A.O.A.C. 1980 . Asscociation of the Official analytical Chemists, Methods of Analysis. 13th Ed. Washington D.C., U.S.A.
2. Abd El-Motty , E ,Z ; Shahin , M , F ; El-Sheikh , M,H and Abd-El-Migeed , M , M . 2010. Effect of algae extract and yeast application on growth, nutritional status, yield and fruit quality of Keitte mango trees. Agric. Biol. J. N. Am. 1(3): 421-429.
3. Abd EL-Motty , E. Z. ; Shahin , M. F. M. ; EL-Shiekh , M. H. and Abd- EL-Migeed M. (2010 . Effect of algae extract and yeast application on growth,
4. Abu Zaid, Al-Shahat Al-Nasr. 2000. Plant Hormones and Agricultural Applications. Arab House for Publishing and Distribution. Second Edition. Arab Republic of Egypt.
5. Agha, Dhunoun Dawood Abdullah Dawood. 1991. Evergreen Fruit Production. Part 1. Dar Al-Kutub Foundation for Printing and Publishing. Mosul, Iraq.
6. Al-Eidani, Abdul-Redha Akbar Alwan, and Al-Eidani, Taha Yassin. 1992. A morphological study of the genus Zizphus Mill. Basrah Journal of Agricultural Sciences, Volume 5(1): 123-148.
7. Al-Hurmuzi, Saadat Mustafa Muhammad. 2010. A Study of the Effect of Inoculation with Locally Isolated Cynobacteria and Spraying with Seaweed Extracts (Algo 600) on the Growth, Yield, and Chemical Characteristics of Strawberry (Fragaria anaassa L.). Tikrit University Journal of Pure Sciences. 11(3): 40-50.
8. Al-Mawsili, Mudhaffar. 2011. Soil Fertility and Nutrition of Horticultural Plants. Ibn Al-Atheer House for Printing and Publishing. University of Mosul. Iraq.
9. Al-Mubarak, Noor Raad Abdul-Karim Yaqoub. 2014. Effect of spraying with Kelapak seaweed extract and neutral NPK fertilizer on some leaf, fruit, and yield components of the date palm (Phoenix dactylifera L.), Barhi cultivar.
10. Al-Najjar, Latif Haji Hussein and Samir Fouad Ali Tawfiq (1981). Wood Technology. Dar Al-Kutub for Printing and Publishing. University of Mosul. Republic of Iraq.
11. Al-Rawi, Khashaa Mahmoud and Abdul Aziz Khalaf Allah. 2000. Design and Analysis of Agricultural Experiments. College of Agriculture and Forestry, University of Mosul, Iraq.
12. Attaha, A. H. M., Al- Sareh, E. A., and Ibrahim, M. A2006. Yield, annual profit and fruit development of Tufahi jujube cultivar (*Ziziphus mauritiana* Lamk). Basrah J. Agric.Sci.,19(1).21-31 .
13. Faisal, Hassan Abdul-Imam, Qasim Jassim Adhaqa, and Aqeel Hadi Abdul-Wahid. 2017. The Effect of Spraying with Chelated Iron and Salicylic Acid on Some Characteristics of Date Palm (Phoenix dactylifera L.). Kufa

ISSN 2072-3857

Journal of Agricultural Sciences 9(2) 1-13.
14. Farhan, Yusra Jabbar. 2015. The Effect of Spraying with Seaweed Extract and Shading on the Growth and Yield of Strawberry Cultiva Festival. Master's Thesis. College of Agriculture, University of Baghdad. Republic of Iraq.
15. Hopkins , W. G. 1999. Introduction to Plant Physiology . John Wiley and Son Inc . p : 512 .
16. Howrtiz, W.W. 1975. Official Methods of Analysis Association of Official Analytical Chemists, Washington, D.C. , U.S.A.
17. Kaboota, Dalia Esmat Shaya. 2005. The effect of spraying with iron, zinc, and nitrogen on the growth of jujube seedlings, Tuffahi cultivar. Master's thesis, College of Agriculture, University of Baghdad, Iraq.
18. Khalaf, Zainab Saad. 2025. A Study of the Effect of Foliar Spraying with Chelated Iron and Dry Yeast Extract on Vegetative Growth, Biochemical, and Anatomical Characteristics of Pomegranate Trees (Punica granatum L.). Master's Thesis. University of Thi-Qar, Iraq.
19. Morales – Payan, J. P., and J. Norrie. 2010. Accelerating the growth of Avocado (Persea Americana) in nursery using a soil applied, commercial extract of the brown alga Ascophyllum nodosum. International Seaweed Symposium, 189.
20. Muhammad, Khawla Hamza. 2011. Effect of spraying with urea and potassium chloride on some physiological and anatomical aspects of the leaves and fruits of the jujube tree (Ziziphus mauritiana Lam. cv. Tufahi), Tufahi cultivar. PhD dissertation. University of Basra, Iraq.
21. Norrie , J; Branson , T. and Keathley , P. E. 2002 . Marine plant extracts impact on grape yield and guality . Acta Horticulturae . 594 : 315 – 319 .
22. Ozaga , T. A. ; and Reinecke D.M.. 2003 . Hormonal interactions in fruit development . J. Growth Reg. , 31 : 1 – 15 .
23. Romheld, V. and H. Marschner, 1986. Plant Physiology Copyright American Society of Plant Physiologist 80 : 175 – 180 .
24. Saleh, Mohammed Mahdi, Jassim Mohammed Khalaf, and Karim Abdullah Hassan. 2020. The effect of spraying with licorice root extract, garlic extract, and seaweed extract (Sea Force) on the vegetative growth characteristics of fig trees (Ficas carica L.), Aswad Diyala cultivar. Kirkuk University Journal of Agricultural Sciences, Volume (11), Issue (3).
25. San, B., and Yildirim, A. N. 2010. Phenolic, alpha-tocopherol, beta-carotene and fatty acid composition of four promising jujube (Ziziphus jujuba Mill) selections. Journal of food composition and analysis, 23(7), 706-710
26. Spinelli, F., Fiori, G., Noferini, M., Sprocatti, M., and Costa, G. (2010). A novel type of

ISSN 2072-3857

seaweed extract as a natural alternative to the use of iron chelates in strawberry production. Scientia horticulturae, 125(3): 263-269.

27. Ta'een, Diaa Ahmed. 2006. The effect of post-harvest calcium chloride treatment on the storage behavior of jujube fruits (Zizphus mauritiana Lam.cv.Tufahi). Basrah Research Journal (Instructions). Issue 32, Part 3, pp. 57-64.

ISSN 2072-3857