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Effect of foliar spraying of seaweed extract and with iron and zinc chelated on the growth and nutritional status of Nemaguard peach rootstock seedlings

Amal M. Rakha, Abou Rayya M. S., Nabila E. Kaseem, Thanaa Sh. M. Mahmoud and Ramadan A. Eisa

Horticultural Crops Technology Department, National Research Centre, 33 EL-Buhouth St., Dokki, Cairo 12622, Egypt.

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ABSTRACT

An investigation of the effect of foliar spraying with seaweed extract and some micronutrients (Iron and Zinc-chelated) on the growth and nutritional status of two-year-old Nemagaurd peach rootstock seedlings compared to the control treatment (spray with water only). The study was conducted at the National Research Centre Nursery, Egypt, during two growing seasons of 2022 and 2023. The seedlings were sprayed with three levels 0, 5, and 10 ml/L of seaweed *Spirulina platensis* extract and three levels 0, 25, and 50 mg/L of Fe plus Zn chelated. The experiment consisted of 9 treatments applied using a randomized complete block design (RCBD) with five replications. Three times, foliar spraying was applied: on 2, 16, and 30 th July. In comparison to the control, the results showed that foliar spraying seaweed extract and some micronutrients (iron and zinc chelated) increased all characteristics of vegetative growth significantly, including seedling height, seedling diameter, number of branches/seedlings, number of leaves/seedlings, leaf area (cm^2), total chlorophylls, and fresh and dry weight of leaves. It also increased significantly the total carbohydrates and mineral content of leaves (N, K, P, Fe, Mg, Mn, Cu, and Zn). The study found that the application of seaweed extract and some micronutrients (iron and zinc-chelated) to Nemagaurd peach rootstock seedlings greatly enhanced their vegetative development and nutritional status. For the majority of the traits under study, the combination of seaweed extract at 10 ml/L plus some micronutrients (iron and zinc chelated) at 50 mg/L significantly enhanced their vegetative development and nutritional status compared to the control treatment and other treatments.

Keywords: Peach, Nemaguard, seaweed extract, foliar spraying, iron, zinc, mineral contents, vegetative growth.

1. Introduction

The peach (*Prunus persica* L. Batsch), a member of the "Rosaceae" family, is considered a tasty and healthful summer fruit in most temperate regions of the world. Because of its importance in dietetics, it is one of the most significant stone fruits. In addition to its various applications, fruit is frequently consumed as fresh fruit, juice, and jams because it is an excellent source of protein, carbs, and vitamins, particularly A, B, and C, as well as minerals like potassium, iron, and phosphorus (Alwan, 2017). In terms of Arab peach production, Egypt is ranked third by FAOSTAT (2017). Egypt has 35649 feddans of peach cultivation, and 259522 tons of peach fruits are produced there year (Ministry of Agriculture statistics, Egypt, 2022).

Nemaguard peach rootstock is frequently used for grafting peach varieties, but in calcareous soils it confers susceptibility to iron deficiency. Chlorotic trees grafted on Nemaguard regreen in one or two weeks when Fe (III)-chelates are applied to calcareous soils. This clearly indicates that the rootstock is able to reduce and absorb these soluble iron forms. The high concentration of bicarbonate in calcareous

Corresponding Author: Amal M. Rakha, Horticultural Crops Technology Department, National Research Centre, 33 EL-Buhouth St., Dokki, Cairo 12622, Egypt.
E-mail: aaaam_am@yahoo.com

soils has been identified as one of the most important factors inducing iron chlorosis (Boxma, 1972; Chaney, 1984; Mengel *et al*., 1984).

According to Babu and Yadav (2005) and Ioannis *et al*. (2004), producing fruits of high quality requires a sufficient amount of micronutrients. Zinc (Zn) is a micronutrient that is relevant to enzymatic systems that are required for protein synthesis, seed development, and plant maturity rate (Swietlik, 1999, 2002), among other vital mineral nutrients of plants. Indole acetic acid's precursor, tryptophan, requires it for production. Furthermore, according to Alloway (2008), it is crucial for plant metabolism of starch. Many biological processes, including photosynthesis, nucleic acid metabolism, and the production of proteins and carbohydrates, are known to be impacted by zinc (Zn), which is widely known to function as an enzyme cofactor (Marschner, 1995). Zinc (Zn) insufficiency is more common in alkaline and calcareous soils than nitrogen (N) and phosphorus (P) deficiencies (Rashid and Ryan, 2004). The total iron content in most soils is between 100 and 100,000 mg/kg, but the amounts that are available to plants may be insufficient. This is particularly the case in calcareous soils, which are influenced by several factors, including high pH, $CaCO_3$ content, ion imbalance, and poor physical characteristics, such as high or low soil temperature, high humidity, poor soil aeration, low organic matter content, and compaction, which can lead to iron deficiency (Köseoğlu, 1995; Başar, 2000; Lucena, 2000; Jim, and Stein, 2011). Thus, a deficiency of this element reduced net photosynthesis, which caused a huge reduction in fruit yield (Hashemimajd and Jamaati-e-Somarin, 2011).

Research has shown that the foliar spraying of iron and zinc significantly impacts the vegetative parameters and chemical analysis of various plants. Research conducted on lemon transplants demonstrated that spraying with chelated iron and zinc led to notable increases in stem diameter, leaf thickness, and total leaf area (Ajboory and Al-Douri, 2023). Similarly, a study on maize plants (Deswal and Pandurangam, 2018) revealed that foliar applications of iron and zinc resulted in enhanced plant height, leaf area, and total dry matter per plant, along with improvements in biochemical traits like chlorophyll content and sugar levels. Furthermore, Mohamed *et al*. (2016) indicated that foliar spraying of faba bean plants with $FeSO_4$ and $ZnSO_4$ significantly boosted parameters such as soluble sugars and soluble proteins, along with improvements in biochemical traits like chlorophyll content and sugar levels.

In recent years, seaweed extract has been utilized in organic and sustainable agriculture; its use has become increasingly popular (de Sousa *et al*. 2019). Numerous studies have demonstrated their positive impacts, particularly on the products' yields, both quantitative and qualitative. (Drygaś *et al*. 2021). According to Mughunth *et al*. (2024), seaweeds are biostimulants that have been utilized to improve agricultural soils. In addition, seaweeds are now very important in organic and sustainable agriculture because they contain macronutrients like calcium, phosphorus, and potassium; micronutrients like manganese, zinc, copper, and molybdenum; and growth regulators like auxins, cytokinins, and gibberellins, which enhance the growth of plants (Ismail and Fayed, 2021; Chundurwar *et al.,* 2022).

Seaweeds are abundant in proteins, oligosaccharides, enzymes, vitamins, and different secondary metabolites that help plants resist disease by controlling their molecular, physiological, and biochemical processes (Agarwal *et al.,* 2021; Elhan and Ahmad, 2022). Studies have demonstrated that seaweed extracts contain essential nutrients, amino acids, and bioactive components that enhance plant growth and development (Al-Khuzaey and Al-Asadi, 2019; Abbas *et al.,* 2020; Hamouda *et al.,* 2022; Hamdan and El-Hamdani, 2022). Applying seaweed extract has resulted in increased leaf area, fresh and dry weights, and improved nutrient content such as nitrogen, phosphorus, and potassium in seedlings (Ayat *et al*. 2019). Additionally, seaweed extract application has been linked to enhanced physiological traits, cytological characteristics, and plant molecular analyses, indicating a comprehensive positive impact on plant health and productivity (Hamouda *et al*. 2022). The benefits of foliar fertilization include low rates of treatment, consistent fertilizer material distribution, and prompt nutrient response (Umer *et al*., 1999). Micronutrients applied through foliage can have an efficiency of 10–20 times higher than those applied through soil (Zaman and Schumann, 2006). Overall, foliar spraying of seaweed extract is a sustainable and effective method to promote seedlings' growth and chemical composition, making it a valuable alternative to traditional chemical fertilizers (Abbas *et al*. 2020). Therefore, the current study aims to investigate the effect of foliar spraying of seaweed extract with iron and zinc chelated on vegetative parameters and nutritional status of Nemaguard seedlings.

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2. Materials and Methods

An experiment was conducted in 5 kg plastic culture pots on two-year-old Nemagaurd peach seedlings during the years 2022-2023 at National Research Centre Nursery in Egypt to study the effect of foliar spraying with seaweed extract and some micronutrients (iron and zinc chelated) on the growth and nutritional status of the seedlings. The seedlings were sprayed with three levels 0, 5, and 10 ml/L of seaweed *Spirulina platensis* extract and three levels 0, 25, and 50 mg/L of Fe plus Zn chelated. The experiment consisted of 9 treatments applied using a randomized complete block design (RCBD) with five replications as follows: control, T1: seaweed extract at 5 ml/L, T2: seaweed extract at 10 ml/L, T3: iron and zinc chelated at 25 mg/L, T4: iron and zinc chelated at 50 mg/L, T5: seaweed extract at 5 ml/L with iron, zinc chelated at 25 mg/L, T6: seaweed extract at 5 ml/L with iron, zinc chelated at 50 mg/L; T7: seaweed extract at 10 ml/L with iron, zinc chelated at 25 mg/L; T8: seaweed extract at 10 ml/L with iron, zinc chelated at 50 mg/L. Table 1 shows the physical and chemical analysis of agricultural soil. The seedlings were sprayed three sprays per season, two weeks between each spray and the next, and the spraying dates were the first spray on 2nd July, the second spray on 16th July, and the third spray on 30th July. The studied traits were recorded two months after the last spray from both seasons.

Table 1: Some chemical and physical properties of soil before treatment

Sand (g/100g)	Silt (g/100g)	Clay (g/100g)	Texture		OM (%)	EC dSm^{1}	pH	HCO^{-3}	CO^{-3}
66.8	14	19.2	Sandy loam		1.02	0.24	7.81	1.24	-
Cl^- (ppm)	**Na^+ (ppm)**	**N (%)**	**P (%)**	**K (%)**	**Mg (%)**	**Fe (ppm)**	**Mn (ppm)**	**Cu (ppm)**	**Zn (ppm)**
53.19	16	0.15	0.17	0.17	0.51	25	10	0.5	8.89

2.1. Studied traits

Seedling length (cm): The average length of five seedlings per treatment was measured starting from ground level to the main tip using a tape measure.

Seedling diameter (cm): The average diameter of five seedlings for each treatment was measured at a height of 10 cm above the ground using the Vernier calipe technique.

Number of shoots/seedling: The average number of shoots of five seedlings for each treatment was counted.

Number of leaves/seedling: The average number of leaves of five seedlings per treatment was calculated.

Leaf area (cm^2): The average area of twenty-five leaves per treatment was determined using a Cl-202 portable laser leaf area meter.

Total chlorophylls content of leaves (SPAD unit): The average total chlorophyll content of twenty-five leaves for each treatment was determined using the chlorophyll measuring device model SPAD-502 in the field.

Fresh and dry weight of leaves (g): The average of twenty-five leaves for each treatment was weighed to record the fresh weight, then washed with distilled water and dried in the oven at a temperature of 70°C until a constant weight was reached and weighed to record the dry weight.

Total carbohydrate content of leaves (mg/g dry weight): according to Dubois *et al.*, 1956.

Determination of leaf mineral content: According to Evanhuis and Dewaard (1980), 0.5 g of the ground dried material of each sample was digested with H2O2 and H2So4. Earlier leaf samples were ground in a porcelain mortar to prevent contamination with any minerals. A suitable sample was then obtained in order to determine the minerals.

Nitrogen (N%): Using micro Kjeldhal, the N% was determined according to Pregl's (1945) instructions.

Phosphorus (P%): According to Chapman and Pratt (1961), the P% was determined calorimetrically.

Potassium (K%): According to Brown and Lilleland (1976), the K% was determined using flame photometer.

Iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn): The concentrations were measured by atomic absorption according to Jackson (1973) and expressed as ppm on a dry weight basis.

2.2. Statistical analysis

The variance analysis (ANOVA) was utilized to statistically analyze the data acquired from the experiment, which used a randomized block design with five replicates (Snedecor and Cochran, 1990). At a 5% probability level, means were compared using Duncan's Multiple Range Test (Duncan, 1955). With the use of a computer and MSTAT-C, all the data was collected and statistically analyzed.

3. Results

3.1. Vegetative parameters of Nemaguard peach rootstock seedlings

3.1.1. Seedling length (cm)

In the first season, the foliar spraying with seaweed extraction at 5 and 10 ml/L caused a significant increase in the seedling length of Nemaguard seedlings, valued at 68.70 and 72.90 cm, respectively, compared to the control (Table 2). Comparison to the control, spraying with iron and zinc chelated at 25 and 50 mg/L increased significantly the seedling length of Nemaguard seedlings to 51.90 and 60.00 cm, respectively. The enhancement of seedling length in Nemaguard seedlings was significantly higher in combination with seaweed extraction at 10 ml/L and iron and zinc chelated at 50 mg/L of each value of 92.40 cm compared to the control. In the second season, the same trend was observed in all treatments as described in the first season, with an increase in the seedling length in comparison to those in the first season results. The foliar spraying with seaweed extraction at 5 and 10 ml/L caused a significant increase in the seedling length of Nemaguard seedlings valued at 81.00 and 87.75 cm, respectively, and 64.80 and 76.32 cm when using iron and zinc chelated at 25 and 50 mg/L, respectively, and 93.60 cm when using a combination of seaweed extraction at 10 ml/L with iron and zinc chelated at 50 mg/L of each compared to the control.

3.1.2. Seedling diameter (cm)

In the first season, the seedling diameter was increased significantly when foliar spraying with seaweed extraction at 5 and 10 ml/L of Nemaguard seedlings valued 0.54 and 0.54 cm, respectively, compared to the control (Table 2). On the other hand, seedling diameter of Nemaguard seedlings did not increase significantly when spraying iron and zinc chelated at 25 and 50 mg/L compared to the control. Foliar spraying with a combination of seaweed extract at 5 ml/L with iron and zinc chelated at 50 mg/L and seaweed extract at 10 ml/L with iron and zinc chelated at 50 mg/L caused a highly significant increase in seedling diameter of Nemaguard seedlings valued at 0.66 cm compared by control. In the second season, the foliar spraying with T1, T2, T3, and T4 caused an increase in seedling diameter but did not differ significantly compared to the control Moreover, the combination with seaweed extract at 10 ml/L with iron and zinc chelated at 50 mg/L resulted in an increase in the diameter of Nemaguard seedlings valued at 0.59 cm compared to the control.

3.1.3. Number of shoots /seedling

The application of foliar spraying with seaweed extract at 10 ml/L treatments caused a significant increase in the number of shoots/seedlings in the first season, valued at 9.98 and 10.35 in the first and second seasons, respectively, compared to the control (Table 2). The control treatment produced the fewest number of shoots per seedling throughout the course of the two seasons .

Table 2: Effect of foliar application of seaweed extraction, iron, and zinc chelated on length, diameter, No. of shoots/seedling, No. of leaves/seedling, leaf area of Nemaguard peach rootstock seedlings

Treatments	Vegetative parameters				
	Seedling length (cm)	Seedling diameter (cm)	No. of shoots/seedling	No. of leaves/seedling	Leaf area (cm^2)
			1st season		
Control	46.20i	0.42c	2.70f	33.60h	9.63e
T1: Seaweed extract at 5 ml/L	68.70f	0.54b	7.80bc	59.70c	12.11d
T2: Seaweed extract at 10 ml/L	72.90h	0.54b	9.98a	62.10c	12.57d
T3: Iron and zinc chelated at 25 mg/L	51.90h	0.42c	6.30e	38.10g	9.83e
T4: Iron and zinc chelated at 50 mg/L	60.00g	0.51bc	8.10b	41.40f	9.92e
T5: Seaweed extract at 5 ml/L with iron, zinc chelated at 25 mg/L	76.20d	0.57ab	6.30e	48.90e	15.34c
T6: Seaweed extract at 5 ml/L with iron, zinc chelated at 50 mg/L	89.10b	0.66a	6.60de	81.60b	16.64b
T7: Seaweed extract at 10 ml/L with iron, zinc chelated at 25 mg/L	82.80c	0.60ab	6.60de	51.90d	15.59c
T8: Seaweed extract at 10 ml/L with iron, zinc chelated at 50 mg/L	92.40a	0.66a	7.18cd	87.00a	17.92a
			2nd season		
Control	62.55f	0.36c	4.20f	30.60g	9.62e
T1: Seaweed extract at 5 ml/L	81.00d	0.41bc	9.00b	46.80f	10.43d
T2: Seaweed extract at 10 ml/L	87.75c	0.45bc	10.35a	48.15e	13.15c
T3: Iron and zinc chelated at 25 mg/L	64.80f	0.36c	4.95e	36.60f	12.77c
T4: Iron and zinc chelated at 50 mg/L	76.32e	0.41bc	4.95e	38.70f	12.89c
T5: Seaweed extract at 5 ml/L with iron, zinc chelated at 25 mg/L	90.90b	0.47b	5.85d	52.80d	14.94b
T6: Seaweed extract at 5 ml/L with iron, zinc chelated at 50 mg/L	93.15ab	0.50ab	6.30cd	87.75b	16.79a
T7: Seaweed extract at 10 ml/L with iron, zinc chelated at 25 mg/L	93.15ab	0.50ab	5.85d	62.55c	16.64a
T8: Seaweed extract at 10 ml/L with iron, zinc chelated at 50 mg/L	93.60a	0.59a	6.46c	93.60a	17.30a

a, b, c, d and e means at the same column with different superscript are significantly ($P<0.05$) different.

3.1.4. Number of leaves/seedling

Table (2) illustrates all foliar spraying treatments caused a significant increase in the number of leaves/seedlings compared to the control. The highest increase in leaves/seedling was recorded for treatment seaweed extract at 10 ml/L with iron and zinc chelated at 50 mg/L valued at 87.00 compared to the control in the first season. In the second season, the same trend was observed. The highest increase in leaves/seedling was recorded, valued at 93.60 compared to the control.

3.1.5. Leaf area (cm^2)

The results of Table (2) shown that the leaf area was increased significantly in the first season when foliar spraying with seaweed extract at 5 ml/L with iron, zinc chelated at 50 mg/L valued 16.64 cm^2, and seaweed extract at 10 ml/L with iron, zinc chelated at 50 mg/L valued 17.92 cm^2 compared to the control. On the other hand, treatments of iron and zinc chelated at 25 mg/L valued 9.83 cm^2 and iron and zinc chelated at 50 mg/L valued 9.92 cm^2 did not cause a significant increase in leaf area. All combination treatments caused a significant increase in leaf area; the highest increase in leaf area was observed in seaweed extract at 10 ml/L with iron, zinc chelated at 50 mg/L valued at 17.92 cm^2, followed by seaweed extract at 5 ml/L with iron, zinc chelated at 50 mg/L valued at 16.64 cm^2 compared to the control. On the other hand, in the second season, treatments of T2, T3, and T4 did not cause a significant increase in leaf area. All combination treatments caused a significant increase in leaf area; the highest increase in leaf area when foliar spraying with observed in seaweed extract at 10 ml/L with iron and zinc chelated at 50 mg/L valued at 17.30 cm^2, followed by 16.79 cm^2 for T6 and 16.64 cm^2 for T7 compared to the control.

3.1.6. Total chlorophylls content of leaves (SPAD unit):

Table (3) illustrates that during the first study season, whether treatments alone or combined positively affected the leaf chlorophyll content of leaves in Nemaguard seedlings, the combination treatments had a higher effect on the leaf chlorophyll content of leaves than the single ones. The significant increase in leaf chlorophyll content of leaves was recorded for T1, 19.80 for T2, 21.99 for T3, 18.00, and T4, 18.78 compared to the control, 14.79. The combined treatment had the highest significant effect on leaf chlorophyll content of leaves in T8 (26.88), followed by T6 (25.23), T7 (24.18), and T5 (23.58) compared to the control. The same trend was recorded in the second season; the significant increase in leaf chlorophyll content of leaves was recorded at 17.01 for T1, 20.03 for T2, 15.26 for T3, and 16.79 for T4 compared to the control. The combined treatment had the highest significant effect on leaf chlorophyll content of leaves in T8 (25.74), followed by T6 (25.34), T7 (24.26), and T5 (22.59) compared to the control, 14.45**.**

3.1.7. Fresh weight of leaves (g)

In table 3, the fresh weight of leaves increased significantly in all treatments. In the first season, the fresh weight of leaves increased significantly, valued at 3.98 g for T1, 4.16 g for T2, 3.02 g for T3, and 3.78 g for T4 compared to the control, 2.75 g. The combined treatment had the highest significant effect on leaf chlorophyll in T8 (5.74 g), followed by T7 (5.62 g), T6 (5.58 g), and T5 (4.73 g) compared to the control. The same trend was recorded in the second season; the significant increase in leaf chlorophyll was recorded at valued 3.80 g for T1, 4.20 g for T2, 4.32 g for T3, and 4.02 g for T4 compared to the control. The combined treatment had the highest significant effect on leaf chlorophyll in T5 (4.88 g), followed by T6 (4.82 g), T8 (4.78 g), and T7 (4.75 g) compared to the control.

3.1.8. Dry weight of leaves (g)

The dry weight of leaves was increased significantly in all treatments (Table 3). In the first season, the dry weight of leaves increased substantially, valued at 2.03 g for T1, 2.52 g for T2, 1.65 g for T3, and 2.12 g for T4 compared to the control, 1.34 g. The combined treatment had the highest significant effect on leaf chlorophyll in T8 (2.97 g), followed by T6 (2.80 g), T7 (2.70 g), and T5 (2.70 g) compared to the control. The same trend was recorded in the second season; the significant increase in dry weight of leaves was recorded at 2.32 g for T1, 2.43 g for T2, 2.73 g for T3, and 2.78 g for T4 compared to the control, 2.07 g. The combined treatment had the highest significant effect on dry weight of leaves in T8 (2.64 g), followed by T5 (2.51 g), T6 (2.45 g), and T7 (2.43 g) compared to the control.

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Table 3: Effect of foliar application of seaweed extraction, iron and zinc chelated on total chlorophyll, fresh and dry weight of leaves (g) of Nemaguard peach rootstock seedlings

Treatments	Vegetative parameters		
	Total chlorophyll of leaves	**Fresh weight of leaves (g)**	**Dry weight of leaves (g)**
	1st season		
Control	14.79g	2.75f	1.34f
T1: Seaweed extract at 5 ml/L	19.80e	3.98cd	2.03d
T2: Seaweed extract at 10 ml/L	21.99d	4.16c	2.52c
T3: Iron and zinc at 25 mg/L	18.00f	3.02e	1.65e
T4: Iron and zinc at 50 mg/L	18.78ef	3.78d	2.12d
T5: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	23.58c	4.73b	2.70bc
T6: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	25.23b	5.58a	2.80ab
T7: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	24.18bc	5.62a	2.70bc
T8: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	26.88a	5.74a	2.97a
	2nd season		
Control	14.45f	3.71e	2.07d
T1: Seaweed extract at 5 ml/L	17.01e	3.80de	2.32c
T2: Seaweed extract at 10 ml/L	20.03d	4.20bc	2.43c
T3: Iron and zinc at 25 mg/L	15.26f	4.32b	2.73a
T4: Iron and zinc at 50 mg/L	16.79e	4.02cd	2.78a
T5: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	22.59c	4.88a	2.51bc
T6: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	25.34ab	4.82a	2.45bc
T7: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	24.26b	4.75a	2.43c
T8: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	25.74a	4.78a	2.64ab

a, b, c, d and e means at the same column with different superscript are significantly ($P<0.05$) different.

3.2. Nutritional status of Nemaguard peach rootstock seedlings

3.2.1. Total carbohydrate content of leaves (mg/g dry weight)

In Table 4, total carbohydrate content increased significantly in all treatments. In the first season, the total carbohydrate content increased substantially, valued at 2.95 mg/g for T1, 3.02 mg/g for T2, 2.90 mg/g for T3, and 2.94 mg/g for T4 compared to the control. The combined treatment had the highest significant effect on total carbohydrate content in T8 (3.16 mg/g), followed by T6 (3.14 mg/g), T7 (3.11 mg/g), and T5 (3.09 mg/g) compared to the control. The same trend was recorded in the second season; the significant increase in the percentage of total carbohydrate content was recorded at 2.73 mg/g for T1, 2.75 mg/g for T2, 2.67 mg/g for T3, and 2.69 mg/g for T4 compared to the control group. The combined treatment had the highest significant effect on total carbohydrate content in T8 (2.97 mg/g), followed by T6 (2.95 mg/g), T7 (2.92 mg/g), and T5 (2.89 mg/g) compared to the control.

3.2.2. Nitrogen (%)

The results in the Table 4 illustrated that the percentage of nitrogen in the first season significantly increased, valued at 0.59% for T1, 0.65% for T2, 0.52% for T3, and 0.55% for T4 compared to the control. The combined treatment had the highest significant effect on nitrogen in T8 by 0.87%, followed by 0.85% in T6, 0.81% in T7, and 0.77% in T5 compared to the control. The same trend was recorded in the second season: a significant increase in the percentage of nitrogen valued at 0.61% for T1, 0.67% for T2, 0.53% for T3, and 0.56% for T4 compared to the control. The combined treatment had the highest significant effect on nitrogen in T8 by 0.92%, followed by 0.88% in T6, 0.84% in T7, and 0.79% in T5 compared to the control.

3.2.3. Phosphorus (%)

In Table 4, the percentage of phosphorus in the first season did not significantly increase in treatments from T1 to T4 compared to the control. The combined treatment had the highest significant effect on phosphorus in T6 valued at 0.434%, followed by 0.430% in T8, 0.425% in T7, and 0.420% in T5 compared to the control. In the second season, the percentage of phosphorus increased significantly by 0.380% for T2 but did not differ significantly in T1, T3, and T4 compared to the control. The combined treatment had the highest significant effect on phosphorus in T8 by 0.405%, followed by 0.403% in T6, 0.398% in T7, and 0.394% in T5 compared to the control.

3.2.4. Potassium (%)

The results shown in Table 4 show that the percentage of potassium in the first season significantly increased, valued at 1.74% for T1 and 1.75% for T2 compared to the control. The percentage of potassium increased but did not reach a significant level in T3 and T4 compared to the control. The combined treatment had the highest significant effect on potassium in T8 by 2.50%, followed by 2.48% in T6, 2.27% in T7, and 2.26% in T5 compared to the control. The percentage of potassium had the same trend in the second season; it significantly increased by 1.78% for T1, 1.67% for T2, 1.58% for T3, and 1.60% for T4 compared to the control. The combined treatment had the highest significant effect on potassium in T8 by 2.54%, followed by 2.53% in T6, 2.27% in T7, and 2.12% in T5 compared to the control.

3.2.5. Iron (ppm)

In Table 5, in the first season, the iron concentration significantly increased in all treatments, valued at 62.01 ppm for T1, 62.04 ppm for T2, 63.24 ppm for T3, and 61.74 ppm for T4, compared to the control. The highest content of iron was recorded for T3 in the single treatments than the control. Compared to the control, the combined treatment had the highest significant effect on iron content in T6 (71.87 ppm), followed by T8 (67.01 ppm), T5 (66.58 ppm), and T7 (65.04 ppm) compared to the control. The highest content of iron was recorded for T6 than the control. In the second season, the iron content had the same trend; it significantly increased by 62.47 ppm for T1, 62.47 ppm for T2, 62.49 ppm for T3, and 63.00 ppm for T4 compared to the control. The combined treatment had the highest significant effect on iron in T8 by 72.04 ppm, followed by 67.01 ppm in T6, 66.80 ppm in T7, and 65.46 ppm in T5 compared to the control.

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Table 4: Effect of foliar application of seaweed extraction, iron and zinc chelated on total carbohydrate, nitrogen, phosphorus and potassium of Nemaguard peach rootstock seedlings

Treatments	Nutritional status			
	Total carbohydrate (mg/g dry weight)	**N (%)**	**P (%)**	**K (%)**
		1st season		
Control	2.53g	0.49i	0.383c	1.58d
T1: Seaweed extract at 5 ml/L	2.95e	0.59f	0.393c	1.74c
T2: Seaweed extract at 10 ml/L	3.02d	0.65e	0.408bc	1.75c
T3: Iron and zinc at 25 mg/L	2.90f	0.52h	0.389c	1.72cd
T4: Iron and zinc at 50 mg/L	2.94e	0.55g	0.383c	1.66cd
T5: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	3.09c	0.77d	0.420ab	2.26b
T6: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	3.14ab	0.85b	0.434a	2.48a
T7: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	3.11bc	0.81c	0.425ab	2.27b
T8: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	3.16a	0.87a	0.430ab	2.50a
		2nd season		
Control	2.21f	0.50i	0.341d	1.44f
T1: Seaweed extract at 5 ml/L	2.73d	0.61f	0.367a-d	1.78d
T2: Seaweed extract at 10 ml/L	2.75d	0.67e	0.380a-c	1.67de
T3: Iron and zinc at 25 mg/L	2.67e	0.53h	0.363b-d	1.58e
T4: Iron and zinc at 50 mg/L	2.69e	0.56g	0.356cd	1.60e
T5: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	2.89c	0.79d	0.394a-c	2.12c
T6: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	2.95a	0.88b	0.403a	2.53a
T7: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	2.92b	0.84c	0.398ab	2.27b
T8: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	2.97a	0.92a	0.405a	2.54a

a, b, c, d and e means at the same column with different superscript are significantly ($P<0.05$) different.

Table 5: Effect of foliar application of seaweed extraction, iron and zinc chelated on Iron, Manganese, Copper and Zinc of Nemaguard peach rootstock seedlings

Treatments	Nutritional status			
	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
	1st season			
Control	59.35g	43.31g	11.19g	23.39e
T1: Seaweed extract at 5 ml/L	62.01f	46.98d	11.48g	23.40e
T2: Seaweed extract at 10 ml/L	62.04f	47.40c	11.90f	23.71e
T3: Iron and zinc at 25 mg/L	63.24d	44.12f	12.66e	24.69d
T4: Iron and zinc at 50 mg/L	61.74C	45.84e	13.48d	24.79d
T5: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	66.58c	61.19b	15.36c	31.59c
T6: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	71.87a	62.98a	16.10a	33.71a
T7: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	65.04B	62.84a	15.79b	32.79b
T8: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	67.01A	63.11a	16.31a	33.80a
	2nd season			
Control	59.45f	41.99h	10.57g	21.71f
T1: Seaweed extract at 5 ml/L	62.47e	45.22e	10.89f	21.73f
T2: Seaweed extract at 10 ml/L	62.49e	45.93d	10.99f	22.98e
T3: Iron and zinc at 25 mg/L	62.49e	42.98g	11.50e	23.29e
T4: Iron and zinc at 50 mg/L	63.00d	43.62f	12.58d	24.31d
T5: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	65.46c	58.99c	14.57c	31.09c
T6: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	67.01b	60.63ab	14.97b	32.41b
T7: Seaweed extract at 5 ml/L with iron, zinc at 25 mg/L	66.80b	60.53b	14.58c	32.25b
T8: Seaweed extract at 10 ml/L with iron, zinc at 50 mg/L	72.04a	60.98a	16.17a	32.89a

a, b, c, d and e means at the same column with different superscript are significantly ($P<0.05$) different.

3.2.6. Manganese (ppm)

In the first season, the manganese concentration significantly increased in all treatments, valued at 46.98 ppm for T1, 47.40 ppm for T2, 44.12 ppm for T3, and 45.84 ppm for T4, compared to the control (Table 5). Compared to the control, the combined treatment had the highest significant effect on manganese in T8 (63.11 ppm), followed by T6 (62.98 ppm), T7 (62.84 ppm), and T5 (61.19 ppm). The manganese had the same trend in the second season; it significantly increased valued at 45.22 ppm for T1, 45.93 ppm for T2, 42.98 ppm for T3, and 43.62 ppm for T4 compared to the control. The combined treatment had the highest significant effect on manganese in T8 by 60.98 ppm, followed by 60.63 ppm in T6, 60.53 ppm in T7, and 58.99 ppm in T5 compared to the control.

3.2.7. Copper (ppm)

In the Table 5, the copper concentration significantly increased in all treatments except T1, which did not differ significantly in the first season. The copper concentration increased by 11.48 ppm for T2, 11.90 ppm for T3, and 12.66 ppm for T4 compared to the control. The combined treatment had the highest significant effect on copper in T8 (16.31 ppm), followed by 16.10 ppm in T6, 15.79 ppm in T7, and 15.36 ppm in T5 compared to the control. In the second season, the copper significantly increased in all treatments by 10.89 ppm for T1, 10.99 ppm for T2, 11.50 ppm for T3, and 12.48 ppm for T4 compared to the control. The combined treatment had the highest significant effect on copper in T8 by 16.17 ppm, followed by 14.97 ppm in T6, 14.58 ppm in T7, and 14.57 ppm in T5 compared to the control.

3.2.8. Zinc (ppm)

The zinc concentration did not differ significantly in T1 and T2 compared to the control. On the other hand, the zinc concentration increased by 23.71 ppm in T3 and 24.69 ppm in T4 compared to the control. The combined treatment had the highest significant effect on zinc in T8 (33.80 ppm), followed by 33.71 ppm in T6, 32.79 ppm in T7, and 31.59 ppm in T5 compared to the control. In the second season, the zinc concentration significantly increased in all treatments except T1, which did not differ significantly. The zinc concentration increased by 23.71 ppm for T2, 24.69 ppm for T3, and 24.79 ppm for T4, compared to the control. Compared to the control, the combined treatment had the highest significant effect on zinc in T8 at 33.80 ppm, followed by 33.71 ppm in T6, 32.79 ppm in T7, and 31.59 ppm in T5 compared to the control.

4. Discussion

Since fruit trees are grown in the majority of the recently reclaimed regions, the soil in these locations is typically sandy, low in organic matter, low in nutrients, and less capable of holding water. When nutrients were abundant, leaching losses harmed vegetative development, output, and fruit quality by reducing the amount of nutrients absorbed by plants (Ghabour *et al*. 2018). In order to improve development, productivity, and fruit quality, trees planted in this soil require extra care in cultural practices such as fertilization and foliar spraying with minerals and biofertilizer. Efforts have been made recently to produce new fertilizers in improved forms in an attempt to lessen the difficulties created by old fertilizers, such as soil, water, and air pollution. In recent years, foliar spraying fruit trees with fertilizer has grown increasingly important since bigger amounts of fertilizer applied via the soil are required because some leak down and some become unavailable to the plants due to intricate soil reactions. Applying micronutrients through leaves can be 10–20 times more effective than applying them directly to the soil. However, adverse weather conditions, the incorrect spray mix applied, or the application of the right mix at the incorrect time can all prevent this efficiency from being realized in real-world situations (Zaman and Schumann 2006). The fact that nutrients are applied topically to leaves, which are the sites of metabolism, accounts for their therapeutic effects (Yadav *et al*. 2013). The benefits of foliar micronutrient fertilization are homogeneous fertilizer distribution, low application rates, and prompt nutrient response (Umer *et al*., 1999). Applying micronutrients topically, such as iron, zinc, and boron, appears to be a useful method for both addressing the symptoms of deficiencies and boosting plant productivity. Additionally, it has better drought tolerance and higher resistance to disease and insect pests (Tariq *et al*. 2007).

One application that has begun to be employed in fruit cultivation in recent years is seaweed farming. Seaweed is colored red, brown, and green and may be found in lakes, seas, and oceans. The food, pharmaceutical, cosmetic, and agricultural industries all employ various forms of seaweed. Seaweed can be added to compost or used directly in fruit growth, as well as in conjunction with other materials. It has been noted that applying seaweed using this technique improves the soil's ability to hold water (Dede *et al*., 2011). The structure of seaweed contains micro and macro components, amino acids, vitamins, and growth-stimulating compounds such as IAA, kinetin, zeatin, gibberellins, auxins, and cytokines (Strik *et al*., 2003; Zodape *et al*., 2011). Due to the compounds they contain, it has been discovered that seaweed extracts promote plant yield under specific stress conditions, like salinity, low temperature and drought (Yildirim *et al*., 2008).

4.1. Effect of foliar spraying of seaweed extract and with iron and zinc chelated on vegetative parameters

Ajboory and Al-Douri (2023) investigated the effects of different zinc and iron sources on the growth characteristics of lemon seedlings. The ferrous sulfate led to increased seedling height, while chelated iron enhanced stem diameter, leaf thickness and leaf area. Also, the combination of zinc and ferrous sulfate resulted in the greatest increase in seedling height, and the highest total leaf area was observed with the combined use of iron and zinc. The foliar spray of zinc sulfate, or Zn, has a good impact on the fruit yield, quality, and vegetative and reproductive growth of "Kinnow" mandarin (Razzaq, 2013). The previous findings demonstrated that foliar spraying with chelated iron had a good impact on the majority of vegetative development traits and buckthorn seedling content. El-Hamdani and Al-Ali (2022) demonstrated that spraying 100 mg/L chelated iron was noticeably higher in terms of stem diameter, bait stalk diameter, leaves contents of dry matter, phosphorous, and potassium. It performed noticeably better than nitrogen when sprayed at a concentration of 50 mg/L. With the notable exception of the percentage of dry matter in leaves, the seaweed extract Alga Mix 1.5 g/L spraying produced a significant superiority in all vegetative growth and leaf content characteristics. It also significantly increased the diameter of the original stem, bait stalk diameter, the total protein, potassium, phosphorus, and nitrogen.

Because it facilitates the synthesis of chlorophyll, the absorption of nutrients, and metabolic activities, iron is essential for plant growth. It raises the height of seedlings and the levels of elements, carbohydrates, and chlorophyll in their leaves. Iron also facilitates the synthesis of enzymes and the production of chlorophyll pigment, which promote the growth of plants. In addition to increasing the absorption of nutrients, such as nitrogen and iron, the increased root growth of seedlings at chelated iron levels also causes an increase in the accumulation of nutrients in the leaves.

Fruit trees' production, vegetative growth and fruit quality can all be enhanced by one of the cultivation techniques, such as foliar spraying zinc sulfate and algal extract (Abd El-Motty and Orabi, 2014; Hanafy Ahmed *et al*., 2012; and Abd El-Motty and Shahin, 2010). Zinc sulfate in combination with algal extract applied topically increased total chlorophyll and leaf mineral content. In general, the most effective therapy for improving all examined leaf metrics was 2.0% algal extract combined with 0.4% zinc sulfate (Salama 2015). The study conducted by Desai *et al*. (1991) on sweet orange and Supriya and Bhattacharyya (1993) on citrus limon, respectively, is consistent with the results of zinc treatments found in relation to leaf chlorophyll concentration. The total chlorophyll content of the leaves on lemon and sweet orange trees was found to be increased by zinc foliar spraying. The utilization of chelated zinc fertilizer can be explained by the fact that zinc is involved in the synthesis of tryptophane, an amino acid that serves as the building block for the natural hormone indole acetic acid (IAA), which is essential for the growth and elongation of plant cells. Additionally, zinc is involved in the activation and production of chlorophyll, the synthesis of proteins, and carbohydrates and the efficiency of enzymes (Chichircco and Poma, 2015; Valadkhan *et al*., 2015). Foliar spraying of formulations improves nutrient availability through leaf stomata via gas exchange (Sekhon, 2014). Fertilizer's larger surface area and high absorption increase photosynthesis, metabolic enzyme activation, sugar translocation, protein assimilation, water absorption, and nutrient transport, enhancing plant physiological activities and increasing carbohydrate levels, leaf area, and plant height, as observed in blueberries (Sabir *et al*. 2014), apples (Mohasedat *et al*. 2018), date palm (Roshdy and Refai 2016) , and mango (Abdelaziz *et al*. 2019).

Because seaweed has so many advantages, it is frequently utilized as a biostimulator. Due to its high concentration of organic matter, microelements, vitamins, and fatty acids, as well as its abundance in growth regulators including auxins, cytokinins, and gibberellins, the application of seaweed extract for various crops was crucial (Crouch and Van Staden, 1994). The results of our investigation were in line with those of Al-Abedy and Al-Abbasi (2020); Kareem *et al*. (2022) who discovered that foliar spraying with micronutrients or seaweed extract alone and their interactions increased all the plant growth parameters that were investigated, including plant height, stem diameter, number of branches per plant, leaf area, number of leaves per plant, total chlorophyll content in the leaf, leaf dry matter, carbohydrates, and percentages of N, P, K, and Cu in comparison to plants that were not treated. Chlorophyll content rose when seaweed extract was applied (Whapham *et al*., 1993; Thirumaran *et al*., 2009). Turan and Köse (2004) found that applying seaweed extract to grapevine resulted in an increase in N, P, and K. The current findings about the effects of foliar spaying of algae leaf extracts on vegetative growth, including the number of leaves per shoot, mineral content and leaf area,, are consistent with those of Eman and Abd-Allah (2008), who discovered that the presence of trace elements, amino acids, cytokine, gibberellins and auxin, which enhance vegetative growth and nutritional status, may play a role in the increases in vegetative growth characteristics caused by algae extracts. Additionally, Jensen (2004) demonstrated that algae extract contains a variety of macroelements, including gibberellins, auxins, and cytokinins, as well as numerous microelements, including Co, B, Mo, Zn, and Cu. When sprayed on plants, the algae extract enhanced the ability of the roots to absorb nutrients and grow, as well as the thickness, root growth, and robust vegetative growth of the plants. Furthermore, Eman and Abd-Allah (2008) discovered that algae extract had a beneficial impact on all growth aspects of superior grapevines, including leaf area, shoot length, and number of leaves/shot. In comparison to the control treatment, iron 100 mg/L seaweed extract 1.5 g/L significantly increased the original stem diameter, bait stalk diameter, percentage of dry matter in leaves, phosphorous, and potassium, respectively. Conversely, the interaction (chelated iron 50 mg/L seaweed extract 1.5 g/L) significantly increased the percentage of nitrogen in the leaves (El-Hamdani and Al-Ali 2022). According to Ismail *et al*. (2011), algae spraying increased the chlorophyll content of bitter orange leaves, the results of algal extract treatments regarding leaf chlorophyll content are consistent with those findings.

Hassan *et al*. (2019) found that all treatments involving algae and moringa extract at various spraying dates had a favorable impact on vegetative development, leaf mineral contents, fruit set, yield, and fruit chemical characteristics. For increasing vegetative growth and improving leaf mineral content, fruit set, yield, and oil content, the most effective combination treatments were 0.4% algae extract and 2% moringa leaf extract or 0.4% algae extract and 4% moringa leaf extract. The impact of spraying chelated iron at concentrations of 0, 100, and 200 mg/L and Alga 600 seaweed extract at concentrations of 0, 150, and 300 mg/L, as well as their interactions, on the characteristics of vegetative growth, branch length, branch diameter, and dry weight of leaves were investigated by Abbas *et al*. (2020). A notable improvement in the tree's height and the diameter and length of its branches' dry weight sheets was observed upon lead spraying with iron claw extract marine algae separately, with particular attention to the high concentration of iron and the low extract level.

Studies using various application techniques have shown that seaweed improves fruit quality, production, and vegetative development in the growth of olive, plum, pear, and strawberry fruits (Kaya, 2007; Atasay and Turemis, 2008; Colavita *et al*., 2014; Dundar, 2019). Furthermore, applying seaweed to the leaves of orange, palm, and apple trees reduces the likelihood of losses during harvest (Blunden *et al*., 1992; Basak, 2008). According to reports, seaweed extracts increase fruit set in species of stone and pome fruits (Battacharyya *et al*., 2015). To enhance nutritional status, vegetative growth, yield, and fruit quality, algae extract is being used as a novel biofertilizer. It contains macro and micronutrients, as well as some growth regulators, polyamines, proteins, and vitamins (Abd El-Migeed *et al*., 2004; Abd El-moniem and Abd-allah, 2008; and Spinelli *et al*., 2009). Growing regulators also influence cellular metabolism in treated plants, resulting in increased growth and crop yield (Stirk *et al*., 2003; Ördög *et al*., 2004; and Abd El-Motty *et al*., 2010). These are the main mechanisms through which algae affect cell metabolism.

Seaweed extract significantly enhances vegetative growth in Nemagaurd seedlings, affecting height, branches, leaves, leaf area, chlorophyll percentage, and leaf weight. It contains essential nutrients and amino acids, leading to increased absorption and positive seedling growth, consistent with previous studies (Thanaa *et al*. 2016; Hassan *et al*. 2019; Mosa *et al*. 2023). Seaweed extract boosts dry matter percentage in leaves by containing essential macro- and microelements, plant hormones, and vitamins. This leads to increased leaf area, increased photosynthesis products, and increased dry weight.

Seaweed also enhances organic product activity, increasing carbohydrate accumulation (Spann and Little, 2011; Al-Hadithi *et al*., 2015).
Seaweed fertilizer positively influences soil properties, increasing micro-organism activity, nutrient absorption, and photosynthesis. This leads to increased vegetative growth, increased leaf number, and fresh leaf weight. The properties of iron and zinc particles, along with seaweed extract content, affect solubility, diffusion, and accessibility in plants. This suggests the potential for new balanced fertilizers for crop nutrition (Al-Janabi and Al-Hasnawi 2021).

4.3. Effect of foliar spraying of seaweed extract and with iron and zinc chelated on nutritional status of plants

Plants can meet their iron requirements through foliar fertilization. An investigation into the impact of foliar spray ferrous sulfate on low-chill peach plants with iron shortage was conducted. Records were kept for the number of leaves per shoot, leaf area, chlorophyll content, leaf Fe: Mn ratio, fruit yield, and fruit physicochemical characteristics. The iron: manganese ratio and chlorophyll content of leaves both significantly increased, according to the findings (Kumar *et al*. 2018). The results showed that sulfur application at a level of 750 gm S. tree-1 and foliar spraying of Fe at a concentration of 100 mg Fe/L, either separately or in combination, considerably raised the levels of N, P, K, S, Fe, Mn, and Zn in leaves, particularly in the second season (Al-Aareji and Bani, 2020). Some fruit trees' mineral concentrations improve when foliar spraying of iron is applied. Singh *et al*. (1996) sprayed "Sharbati" peach trees with iron and zinc chelates and sulfates, and they observed a considerable rise in leaf Zn and Fe and a decrease in leaf chlorosis. Iron concentration in leaves of peach trees cvs. "Katerina" and "Fire Blight" increased significantly when $FeSO_4.7H_2O$ (0 and 500 mg/L) was applied topically, as demonstrated by Tsipouridis *et al*. (2006). El-Sheikh *et al*. (2007) discovered that combinations of chelate material at the rate of 0.7 gm Fe/L, 0.3 gm Zn/L, and 0.3 gm Mn/L, or combinations of Zn, Fe sulphate and Mn at 0.5 gm/L of each nutrient, were sprayed once, twice, and three times a year on "Florida Prince and Desert Red" peach plants. The control resulted in an improvement in the leaf mineral content of Zn, Mn, and Fe for both peach trees. The results showed that spraying the plants twice or three times a year was more successful than spraying once a year. A study carried out by Singh and colleagues (2018) demonstrated that foliar spraying of 0.5% ferrous sulfate to Florida Prince peach trees resulted in a considerable increase in the amounts of active iron, total iron, and ferric iron in the leaves.

During this phase of vegetative and fruit growth and maturation, show outward signs of zinc and iron deficiency. These symptoms harm the quality of the fruit and the farming the following year if left untreated. Sprays of zinc and iron have previously been shown to benefit peaches (Singh *et al*. 1986). Grewal *et al*. (1991) reported that the foliar spraying with Zn and Fe caused an increase in total leaf Zn and Fe content and clarified that there is no antagonism between the absorption of zinc and iron visible. Turan and Köse (2004) observed an increase in N, P and K with the application of seaweed extract on grapevine. The uptake of nitrogen by plants was greatly enhanced by iron chelates, according to the results. Furthermore, foliar potassium and magnesium dropped in response to iron chelates, suggesting a remedy for iron shortage (Hasna and Mustapha 2014). Spraying apple zinc foliar throughout the growing season enhanced the Zn content of the sprayed leaves, even if the leaves were only starting to grow at the time of spraying (Orphanos 2000). On mangoes, Kassem and Marzouk (2004) discovered that Zn spraying enhanced the concentrations of K, Ca, Mg, and Zn in the leaves. Additionally, Hasani *et al*. (2012) investigated the effects of manganese sulfate and zinc foliar sprays on pomegranate leaf nutrient concentrations; zinc foliar sprays dramatically enhanced zinc concentrations in the leaves but decreased Mn and P concentrations.

5. Conclusion

Based on these findings, it appears that foliar spraying seaweed extract can enhance the nutritional status and vegetative growth of Nemaguard rootstock seedlings, especially when combined at 10 ml/L with 50 mg/L of zinc plus iron chelates.

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