

Enhancing the growth rate of local lemon saplings by foliar application with SWE and zinc

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Abstract

This study was conducted in the lath house of the research station at University of Kufa, to evaluate the efficiency of foliar spraying with seaweed extract and zinc and its interaction at different concentrations on vegetative growth of local lemon (*Citrus limon* Burm) saplings. Seaweed extract (SWE) was used as foliar spray at concentrations of (0, 5, 10) ml L⁻¹ and zinc spray at concentrations of 0, 1.5, 3 mg L⁻¹. The interaction of foliar SWE and zinc had a significant positive effect on all studied saplings traits, as the interaction treatment of 10 ml L⁻¹ SWE and 3 mg L⁻¹ zinc was significantly superior in sapling height 32.60 cm, number of branches 6.70 branch seedling⁻¹, number of leaves 96.83 leaf sapling⁻¹, leaf content of total chlorophyll 126.65 mg 100g⁻¹ FW, sapling shoot and root dry weight to 57.60 g and 34.60 g respectively, sapling's content of macro-elements especially percentage of nitrogen 1.57%, phosphorus 0.41% and Potassium 2.44%, which were significantly different from most of the individual, interacted and control treatments. Findings of this study showed the possibility of producing vigor and large lemon sapling using combination of SWE and Zinc fertilizer at recommended levels.

Keywords. Bio-stimulants, Citrus, Lemon, foliar application, Zinc

Introduction

Citrus trees are widely cultivated in Iraq, particularly in the central and southern regions. Citrus is an important fruit tree in terms of nutrition, economy, medicine, aesthetics, and the environment (17). Lemon (*Citrus limon* Burm) is native to northeastern India and southwestern China (16). The number of lemon trees planted in Iraq is estimated at approximately 291,487, and Iraq's production of lemon fruits is estimated at 5,178 tons, while the average yield per tree is 18.4 kg (12). Citrus fruits are among the most important cultivated fruits worldwide, as they are the richest source of vitamin C. However, the quality of citrus production is declining

due to micronutrient deficiencies caused by alkaline pH, low organic matter, and the calcareous nature of the soil (28). The local lemon is economically important, as it is a highly sought-after variety in Iraq due to its good-quality, small, juicy fruits, thin skin, and lower acidity than other global cultivars (8). For budded citrus trees to grow and develop optimally, they must be supplied with nutrients, which are the driving forces behind vital activities. They are involved in important metabolic processes in the plant. A deficiency of these nutrients causes physiological imbalances, which negatively impact the growth of the scion and the future productivity

of the bedded saplings (10). Organic production has been widely encouraged after identifying the problems caused by conventional products, in addition to the increased economic returns that organic agriculture offers (24). Seaweed extract is a natural, low-cost source of organic matter and minerals. It contains macronutrients (such as P, K, Ca, and Mg), micronutrients (such as copper, iron, manganese, and zinc), some growth regulators (such as auxins, cytokinins, gibberellins, and polyamines), proteins, vitamins, sugars, sterols, polyphenols, antioxidants, pigments, and antimicrobial agents (4, 11, 22, 26). In addition to the importance of zinc in the growth of fruit trees, it is involved in regulating protein and carbohydrate metabolism. There are several ways to mitigate zinc deficiency, the most important of which is foliar zinc application to improve citrus fruit growth, yield, and quality (27, 28)7). Zinc is important in the formation of the amino acid tryptophan, the precursor for the synthesis of indole acetic acid (IAA), an important plant growth hormone. Therefore, a deficiency of this element results in stunted plants with low apical dominance in severely

deficient plants (19). Therefore, this study aimed to evaluate the effect of spraying with seaweed extract and zinc on the growth of local limon saplings.

Materials and Methods

Experiment location and procedure

The experiment was conducted at the Agricultural Research Station at the University of Kufa during the 2024 growing season to study the effect of spraying seaweed extract and zinc on the growth and nutritional content of local lemon (*Citrus limon* Burm) saplings under 50% shade conditions. One hundred and sixty-four saplings, as homogeneous as possible, were selected from the Karbala Research Station from 9-month-old local lemon saplings grown in 3.5 kg plastic bags. On September 1, 2024, the saplings were transferred to 10 kg plastic pots (3:1 soil: peat moss). All treatments were equally maintained, including manual irrigation, weed removal, and fertilization. Samples were taken from the growing medium for soil analysis and physical and chemical properties (Table 1 .(

Table1. physical and chemical properties of the soil used in the study

Properties	Unit	Value
Soil reaction rate	pH	7.6
Electrical conductivity EC	dS m ⁻¹	7.2
Nitrogen N	mg L ⁻¹	30.9
Phosphorus P	mg L ⁻¹	12.3
Potassium K	mg L ⁻¹	14.7
CaCO ₃	%	12.9
Organic matter	%	2.2
Soil texture	Sandy-clay loam	

The 162 lemon saplings were selected, as homogeneous as possible in growth and age, and divided into 9 treatments with three replicates (3x3x3), 27 experimental units each contains 6 saplings. Spray treatments were carried out at six sprays (three applications during spring and three in the fall). The first

spray was carried out on September 15, 2024, and the second and third sprays were carried out 30 days intervals. The fourth spray was carried out on March 15, 2025, followed by the fifth and sixth sprays in the same autumn. The plants were watered abundantly the day before treatment application. Space was left between treatments, and a cork barrier was used to prevent spray from dispersing between

treatments. The treatments included foliar feeding with seaweed extract, Interplant, Weifang, China (Table 2) at three levels (0, 5, 10 ml L⁻¹), sprayed on the leaves until completely wet. Zinc Sulphate Heptahydrate

contains Zinc as Zn 21% and Sulphur 10%, was the second factor used at concentrations of (0, 1.5, and 3) mg L⁻¹, sprayed on the foliage until completely wet

Table2. Constituents of the commercial SWE used in this study

Constituents	algal polysaccharides	Amino acids	EDTA-Ca
Amount/value	≥20 g L ⁻¹	≥100 g L ⁻¹	≥30 g L ⁻¹

Study measurements

The vegetative and root growth indicators included the average increase in sapling height (average difference between before treatment and at the end of the experiment), number of branches (branch sapling-1) and the average increase in leaves number (leaf sapling-1). The fresh and dry weights of the shoot and root system (g) were also calculated.

For chemical characteristics, the chlorophyll content in the leaves (mg 100 g⁻¹ FW) was estimated in five randomly selected fully developed leaves from each experimental unit. The acetone method was used, and the absorbance of the filtrate was determined at

two wavelengths, 645 and 663 nm, using a spectrophotometer, according to the amount of pigment in mg 100 g⁻¹ FW (23). The leaf content of nutrients was determined in samples of fully developed leaves (fourth and fifth) from each branch of each sapling. The nitrogen content in the leaves (%) was determined using the Kjeldahl Apparatus and the acid titration method. The phosphorus content in the leaves (%) was also determined using the ammonium molybdate and ascorbic acid methods (20) using a UV-visible spectrophotometer at a wavelength of 620 nm. The percentage of potassium (%) in the digested samples was determined using a flame photometer (21.)

Experiment design and data analysis

The experimental treatments were distributed in a two-factorial experiment (SWE and Zinc) applied using a completely randomized block design (CRBD) with three replications. The data were analyzed using GenStat 12th (29) software where the ANOVA tables were performed, and the means were compared based on the least significant difference (LSD) at the probability level of 0.05 (15.)

Results and Discussion

Vegetative growth parameters

The results (Table 3) show that the average increase in seedling height and number of branches differed significantly according to the treatments. The spraying treatment with seaweed extracts at 10 ml L⁻¹ showed the highest rate of increase in seedling height 25.84 cm and number of branches of 5.66 branch sapling-1, with a significant difference

from the control treatment, which recorded an increase not exceeding 11.45 cm and 4.13 branch sapling⁻¹, respectively. Zinc spraying also showed a significant effect on seedling height and diameter, especially when spraying with 3 mg L⁻¹, which recorded an increase in plant height of 22.28 cm and No. of branches of 5.81 branch sapling⁻¹ compared to significantly lower values in the control. The

interaction effect was significant, especially when using 10 ml L⁻¹ SWE and 3 mg L⁻¹ zinc, which recorded the highest increase in plant height to 32.60 cm and No. of branches to 6.70 branch sapling⁻¹. Similarly, the same treatment recorded the highest average number of leaves, 96.83 leaf plant⁻¹ with a significant difference from all interaction and individual treatments.

Table3. Vegetative response of lemon saplings affected by foliar application with SWE in the presence of foliar zinc at different concentration levels

SWE ml L ⁻¹	Sapling height (cm) increase				No. of branches (Branches. sapling ⁻¹)				No. of leaves (leaves plant ⁻¹)			
	Zn (mg L ⁻¹)			Aver.	Zn (mg L ⁻¹)			Aver.	Zn (mg L ⁻¹)			Aver.
	0	1.5	3		0	1.5	3		0	1.5	3	
0	8.60	11.44	14.33	11.45	3.20	4.30	4.90	4.13	50.60	57.90	60.40	56.3
5	16.10	18.20	19.92	18.00	4.40	5.30	5.84	5.18	68.82	75.20	85.15	76.39
10	20.44	24.50	32.60	25.84	4.80	5.50	6.70	5.66	70.10	88.64	96.83	85.19
Aver.	15.00	18.00	22.28		4.13	5.05	5.81		4.13	5.05	5.81	
L.S.D	SWE/Zn = 3.20				SWE/Zn = 0.0203				SWE/Zn=6.720			
P≤0.05	Interaction=6.60				Interaction=0.0502				Interaction=12.10			

Saplings qualitative parameters

The results showed that the total chlorophyll content in the leaves recorded higher levels in the treatments sprayed with the SWE 10 ml L⁻¹, with an average of 123.36 mg 100g⁻¹ FW compared to 114.91 mg 100g⁻¹ FW of the control. Also, the total chlorophyll content in leaves increased to 123.18 mg 100g⁻¹ FW in the treatment of spraying with zinc 3 mg L⁻¹, compared to 115.36 mg 100g⁻¹ FW in the control. It was noted that the highest value for this parameter (126.65 mg 100g⁻¹ FW) was recorded in the interaction treatment 10 ml L⁻¹ SWE and 3 mg L⁻¹ foliar zinc with a significant difference from all treatments and the control (Table 4). Similarly, spraying 10

ml L⁻¹ SWE or 3 mg L⁻¹ of foliar zinc significantly increased the average shoot and root dry weight compared to the control (Table 4). Overall, the highest value was achieved in the interaction treatment, spraying with 10 ml L⁻¹ seaweed extract in the presence of 3 mg L⁻¹ zinc, which recorded 57.60 g and 34.60 g for the shoot and root dry weight, respectively, significantly outperforming the other treatments and the untreated control, which only resulted in 26.52 g of shoot and 16.50 g of root (Table 4).

Table4. Some growth qualitative parameters of lemon saplings affected by foliar application with SWE in the presence of foliar zinc at different concentration levels

SWE ml L ⁻¹	Leaf chlorophyll (mg 100 gFW ⁻¹)				Shoot DW g				Root DW g			
	Zn (mg L ⁻¹)				Zn (mg L ⁻¹)				Zn (mg L ⁻¹)			
	0	1.5	3	Aver.	0	1.5	3	Aver.	0	1.5	3	Aver.
0	108.70	115.83	120.20	114.91	26.52	29.70	34.75	30.32	16.50	19.80	21.50	19.26
5	118.25	121.10	122.70	120.71	31.60	34.30	42.48	36.72	24.30	27.30	29.90	27.16
10	119.15	124.30	126.65	123.36	37.20	44.5	57.60	46.43	25.20	30.10	34.60	30.00
Aver.	115.36	120.41	123.18		31.77	36.16	44.94		22.00	25.73	28.66	
L.S.D	SWE/Zn =0.482				SWE/Zn =0.842				SWE/Zn =2.10			
P≤0.05	Interaction=0.9495				Interaction=1.683				Interaction=4.20			

Macro-elements content in saplings

Regarding the treatments effect on leaf content of nutrient, it is noted (Table 5) that the leaf content of nitrogen, phosphorus and potassium (%) was always higher in plants treated with SWE at 10 ml L⁻¹ with average of 1.51, 0.38 and 2.41 or those sprayed with foliar zinc 3 mg L⁻¹ with averages of 1.55, 0.39 and 2.4%, respectively, with significant differences from those sprayed at lower levels or the untreated control. The results indicate that the highest values of the macro-elements in the leaves were always in the interaction treatment 10 ml L⁻¹ SWE and 3 mg L⁻¹ foliar zinc, which recorded 1.57%, 0.41% and 2.44% for NPK, respectively, with significant differences compared to all individual, interaction and control treatments, which recorded values of

nitrogen 1.42% phosphorus 0.33% and potassium 2.34%.

SWEs are among the important organic sources used in agricultural production as a fertilizer supplement. They contain major nutrients (N, P, K), as well as micronutrients (Zn, B, Fe), growth-promoting substances, and some amino and organic acids essential for protein synthesis (14). In comparison to similar mineral fertilizers, SWE is an affordable inexpensive source of plant nutrition (3). The marked improvement in seedling growth treated with SWE is often attributed to the extract's content of growth hormones, such as cytokinins and auxins. The extract also contains carbohydrates, proteins, amino acids, and various vitamins .

Table5. Leaf content of Macro-elements (NPK) in lemon saplings affected by foliar application with SWE in the presence of foliar zinc at different concentration levels

Treat.	Leaf nitrogen N (%)				Leaf phosphorus P (%)				Leaf potassium K (%)			
SWE ml L ⁻¹	Zn (mg L ⁻¹)			Aver.	Zn (mg L ⁻¹)			Aver.	Zn (mg L ⁻¹)			Aver.
	0	1.5	3		0	1.5	3		0	1.5	3	
0	1.42	1.49	1.54	1.48	0.33	0.35	0.37	0.35	2.34	2.35	2.38	2.36
5	1.43	1.50	1.55	1.49	0.34	0.36	0.40	0.37	2.36	2.38	2.40	2.38
10	1.44	1.53	1.57	1.51	0.35	0.37	0.41	0.38	2.38	2.40	2.44	2.41
Aver.	1.43	1.50	1.55		0.34	0.36	0.39		2.36	2.37	2.4	
L.S.D	SWE/Zn =0.0038				SWE/Zn=0.00187				SWE/Zn =0.00544			
P≤0.05	Interaction=0.0077				Interaction=0.00384				Interaction=0.00272			

These compounds contribute to increasing the plant's vegetative and root growth potential and play a significant role in enhancing the plant's ability to absorb nutrients, which positively impacts productivity (26). It was found that spraying with the algae extract improved the growth characteristics, speed and number of buds in sour orange (5). The results of the study are consistent with a previous study showed that spraying with seaweed extract (4.5, 3, 1.5, 0 ml L⁻¹) resulted in significant growth improvement of the West Indian Lime *C. aurantifolia* rootstock seedlings, especially when spraying with (4.5 ml L⁻¹) with a significant increase in plant height, stem diameter, number of leaves, leaf area, fresh weight of the vegetative system, fresh and dry weight of the root system, and total chlorophyll content in the leaves (1.)

Studies indicate that 80% of Iraq's soils are calcareous with a high alkalinity and carbonate content (50-500 g kg⁻¹). Most plants suffer from zinc deficiency due to its low availability in the soil (2). Zinc is important in many vital functions, especially chlorophyll formation, photosynthesis, participation in the

synthesis of plant auxin (the plant growth hormone), Carbonic anhydrolase, Alcohol dehydrogenase, Superoxide dismutase, Carboxy peptidase, Aldolase, RNA polymerase, as well as zinc importance in IAA synthesis, water uptake and stabilization of protein (13). Zinc is essential for activation of many special enzymes, such as fructose-1,6 biphosphatase, which is important in the distribution of hexagonal sugars in chloroplasts and cytoplasm, and carbonic anhydrase, which hydrogenates CO₂. In addition, zinc plays a structural role in enzymes such as DNA alcohol dehydrogenase and polymerase (13). The results of the study showed that the growth indicators of lemon seedlings improved significantly after treatment with foliar zinc compared to unsprayed seedlings. Kinnow mandarin *Citrus reticulata* trees growth was remarkably improved when sprayed with foliar zinc sulphate and calcium carbonate, accordingly depends on the concentration used (30).(

Spraying Winter Dawn strawberry seedlings with zinc at concentrations of 2.0 and 4.0% contributed to a significant increase in plant height, number of branches, number of leaves, and leaf area (25). It was also found that

spraying apricot seedlings (*Prunus armeniaca* L.) with chelated zinc in the presence of GA3 had a significant increase in stem length, number of branches, stem diameter, number of leaves, and leaf area (7). The effect of foliar

Conclusion

Findings of this study showed that spraying lemon saplings with SWE at 10 ml. L⁻¹ three times during the growing season resulted in better saplings growth and vigor. Similar findings were also found when using foliar zinc on the saplings especially when used at 3 mg L⁻¹. The best lemon saplings growth and quality were obtained in plant treated with a

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feeding with zinc on the growth and flowering of olive tree Al-Khadiri variety using a concentration of 75 mg L⁻¹ of zinc was also observed, which achieved a significant increase in leaf area (18).

combination of foliar application of SWE at 10 ml. L⁻¹ and Zinc at 3 mg L⁻¹. This interaction treatment resulted in the highest values of all the parameters studied including plant height, number of branches, number of leaves, shoot and root dry weight, leaf content of total chlorophyll and macro-elements NPK (%). This treatment combination can be highly recommended for better growth and production of commercial lemon saplings.

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