RESEARCH ARTICLE Agricultural Science Digest, Volume 46 Issue 3: 446-451 (June 2026)

Effect of Foliar Application Extract Seaweed and Citric Acid on the Vegetative Growth Characteristics of Young Fig (*Ficus carica* L.) Trees

Raad Ahmed Medan[1], Walid F.A. Mosa[2]

10.18805/ag.DF-840

ABSTRACT

Background: Providing vigorously growing trees with well-developed root and shoot systems at the early stages in the orchard is essential for the widespread cultivation of fruit trees in general and figs in particular, as poor nutrition and slow growth naturally delay the entry of trees into the fruiting stage.

Methods: Therefore, this study aimed to investigate the effect of spraying with seaweed extract (Kelpak) at 0, 2, 4 and 6 mL^{-1} and citric acid at 0, 500, 1000 mg L^{-1} on some vegetative growth traits of young fig trees of the local CV. Khalou Baziani. A factorial experiment was applied using a randomized complete block design (RCBD) with three replicates.

Result: Spraying with Kelpak at 6 ml L^{-1} significantly increased the studied vegetative traits (increase in main stem diameter, branch length and diameter, leaf area and relative chlorophyll content), which were recorded as (2.550 mm, 65.833 cm, 1.421 mm, 131.156 cm^2, 43.104 CCI), while the 4 ml L^{-1} concentration was superior in leaf dry matter percentage at 19.977%. Citric acid at 1000 mg L^{-1} was superior in increasing branch length and diameter, leaf area, relative chlorophyll content and leaf dry matter percentage, which reached (59.584 cm, 21.30 mm, 114.60 cm^2, 42.215 CCI, 19.019%). A significant effect was observed due to the interaction between Kelpak and citric acid, where the treatment of 6 ml L^{-1} Kelpak combined with 1000 mg L^{-1} citric acid was significantly superior to the control in most studied traits.

Key words: Citric acid, Fig trees, Kelpak, Seaweed extract.

INTRODUCTION

Fig (*Ficus carica* L.) is a fruit of subtropical regions. Its trees have a short dormancy period and low chilling requirements, ranging from 100 to 300 chilling hours depending on the cultivar. Fig trees can tolerate high temperatures up to around 50°C; however, they produce good-quality fruit at average temperatures close to 37°C and the fruit skin dries out if the temperature exceeds 40°C. Ancient Arabs considered figs the “king of fruits” and it is mentioned in the Holy Qur’an (“By the fig and the olive and Mount Sinai”) as well as in the Prophetic Hadiths (Al-Dajwa, 1997; Shamsuddin *et al*., 2020). Figs are consumed fresh, dried, or as juice and they are also used in the production of alcoholic beverages and for various medicinal purposes. Nutritionally, figs rank highly among fruits. Every 100 g of fresh fig fruit contains 78% water, 1.3% protein, 0.3% fat, 17% carbohydrates, 2% fiber, 48 mg carotene, 50 mg vitamin B and 1 mg vitamin C. They also contain essential mineral salts, including calcium (54 mg), phosphorus (22 mg), potassium (250 mg), zinc (0.4 mg) and iron (0.6 mg) (Medan and Mosa, 2025). The use of marine extracts, including Kelpak, has attracted the attention of researchers worldwide in modern agriculture to meet the increasing population demands, as they are considered important and effective factors in enhancing nutrient availability to plants. It has been observed that liquid fertilizers derived from marine extracts outperform chemical fertilizers due to their high content of macro- and micronutrients, organic matter, fatty acids, vitamins and natural growth regulators, which enhance vegetative growth, improve productivity and reduce chemical fertilizer costs (Kocira *et al.,* 2018*)*. Kelpak is a natural liquid marine extract obtained from the seaweed *Ecklonia maxima*, a dominant alga along the western coast of South Africa, belonging to the family Lessoniaceae (Robertson-Andersson *et al*., 2006; Mohammad, 2010). Citric acid is considered an antioxidant and may behave similarly to auxins in promoting cell division and enlargement. It is also safe from a health perspective and is widely used

[1]Department of Horticulture and Landscape Design, College of Agriculture in Kirkuk, University of Kirkuk, Iraq.

[2]Plant Production Department (Horticulture-Pomology), Faculty of Agriculture, Saba Basha, Alexandria University, Alexandria 21531, Egypt.

Corresponding Author: Raad Ahmed Medan; Walid F.A. Mosa, Department of Horticulture and Landscape Design, College of Agriculture in Kirkuk, University of Kirkuk, Iraq; Plant Production Department (Horticulture-Pomology), Faculty of Agriculture, Saba Basha, Alexandria University, Alexandria 21531, Egypt.
Email: Raad132@uokirkuk.edu.iq; walidmosa@alexu.edu.eg

How to cite this article: Medan, R.A. and Mosa, W.F.A. (2026). Effect of Foliar Application Extract Seaweed and Citric Acid on the Vegetative Growth Characteristics of Young Fig (*Ficus carica* L.) Trees. *Agricultural Science Digest*. **46(3):** 446-451. doi: 10.18805/ag.DF-840.

Submitted: 07-01-2026 **Accepted:** 23-02-2026 **Online:** 09-03-2026

in modern agriculture and horticulture as a non-conventional approach to regulating various physiological processes in plants (Ibrahim and Ali, 2021; Medan *et al*., 2021). It plays an important role in enhancing the biosynthesis of natural hormones, photosynthesis and nutrient absorption (Abdelmoniem *et al*., 2019). Many researchers have highlighted the importance of using seaweed extracts (Kelpak) and citric acid to enhance and increase vegetative and root growth in various fruit plants. In a study, Al-Hujaymi (2013) found that foliar spraying of nectarine peach seedlings (Nectared 6) with Kelpak at concentrations of 0, 2 and 4 ml L^{-1} significantly increased vegetative growth traits, with the 4 ml L^{-1} concentration showing superiority in plant height, branch length, total leaf chlorophyll content, dry weight percentage of the vegetative parts and leaf area. Similarly, Mohamed and Kalaf (2019) reported that spraying young mulberry trees with Kelpak at 2 ml L^{-1}, in addition to the control treatment (0 ml L^{-1}), resulted in a significant increase in plant height, total leaf chlorophyll content and leaf dry weight compared to the control. Furthermore, Al-Aa'reji and Perot (2017) demonstrated that foliar application of citric acid at concentrations of 0, 500, 1000 and 1500 mg L^{-1} on apricot trees (Royal cultivar) significantly improved all studied traits compared to the control, with the 1000 mg L^{-1} treatment giving the highest results. Likewise, Deeb *et al*. (2023) confirmed that spraying Valencia orange trees with antioxidants (citric acid) at concentrations of 0 and 1 g L^{-1} showed that the 1 g L^{-1} concentration was superior in leaf chlorophyll content and branch length increase compared to the control.

MATERIALS AND METHODS

Plant sampling

The study was conducted in the deciduous fruit orchard at the Agricultural Research and Experiment Station, College of Agriculture, University of Kirkuk, Iraq, located at latitude 35.39° and longitude 44.34°, at an altitude of 350/ m above sea level, during the 2025 growing season from 1/2 to 1/9. The experiment was carried out on young fig trees of the local variety (*Khalou Bazian*), two years old, planted at a spacing of 4 × 4 m and irrigated using a drip irrigation system. The trees were uniform in growth and all cultural practices (soil hoeing, removal of surrounding weeds and pest control as needed) were performed during the study period. The trees were sprayed with citric acid in two applications, the first on 1/4 and the second one month later, at 0, 500, 1000 mg L^{-1} in the early morning. On the following day (2/4), the trees were sprayed with seaweed extract (Kelpak) in two applications, one month apart, at 0, 2, 4, 6 ml L^{-1}. The surfactant Enforce (produced by Agre, Turkey) was used at 0.01% during spraying to reduce the surface tension of water on the leaves. A factorial experiment was designed using a randomized complete block design (RCBD) with three replicates, with two trees considered as one experimental unit, resulting in a total of 72 trees used in the experiment. Data were statistically analyzed using the Analysis of Variance (ANOVA) table with SAS software (2001, Version 9.0) for agricultural experiments. Means were compared using duncan's multiple range test at a 0.05 probability level, according to Roger *et al*. (2003).

Studied traits

Increase in main stem diameter (mm)

The stem diameter was measured at 5 cm above the soil surface using an electronic caliper at the beginning of the experiment (1/2/2025) and at the end of the experiment (1/9/2025). The difference between the two measurements represents the increase in main stem diameter.

Increase in branch length (cm)

Three main branches were selected for each experimental unit and their lengths were measured using a metric ruler. The difference between the initial and final measurements represents the increase in branch length.

Increase in branch diameter (mm)

Three main branches were selected for each experimental unit and their diameters were measured using an electronic caliper. The difference between the two measurements represents the increase in branch diameter.

Average leaf area (cm^2)

The average leaf area was calculated according to Dvornic (1965). Ten previously weighed leaf samples were cut into squares of known area, weighed and the total leaf area was calculated using the following equation:

$$\text{Leaf area } (cm^2) = \frac{\text{Average weight of whole leaf (g)} \times \text{Area of cut disk } (cm^2)}{\text{Average weight of cut disk (g)}}$$

Table 1: Effect of Kelpak and citric acid spraying on the increase in stem diameter (mm) of young fig trees, local variety (*Khalou Bazian*).

Citric acid	C0 (0 mg L^{-1})	Kelpak C500 (500 mg L^{-1})	1000 C (1000 mg L^{-1})	Average
K0 (0 ml L^{-1})	2.036b	2.10b	2.410ab	2.182b
K2 (2 ml L^{-1})	2.216ab	2.270ab	2.266ab	2.251b
K4 (4 ml L^{-1})	2.473ab	2.260ab	2.280ab	2.337ab
K6 (6 ml L^{-1})	2.340ab	2.640a	2.670a	2.550a
Average	2.266a	2.317a	2.406a	

Means sharing the same letters, whether individually or in combination, are not significantly different according to Duncan's multiple range test at a 0.05 probability level.

Statistical analysis

The results were statistically analyzed by using One-Way ANOVA in a randomized complete block design (RCBD). Duncan's test was used at 0.05 to compare between the means of the treatments (Snedecor and Cochran, 1990) by using CoHort Software (Pacific Grove, CA, USA).

RESULTS AND DISCUSSION

Stem diameter (mm)

The results shown in Table 1 indicate that foliar spraying with seaweed extract significantly increased the rate of stem diameter growth. The K6 concentration showed the highest increase at 2.550/ mm and did not differ significantly from the K4 concentration compared to the control, while the K0 concentration produced the lowest increase at 2.182/ mm. The results in the same table indicate that all concen-trations of citric acid did not have a significant effect on the increase in stem diameter compared to the control treatment. The results of the interaction between Kelpak and citric acid showed a significant effect on the rate of stem diameter increase. The combined treatments K6 C1000 and K6 C500 gave the highest increases. At 2.670 and 2.640 mm, respectively, while the interaction K0 C0 produced the lowest increase at 2.036 mm.

Branch length (cm)

The results presented in Table 2 show a significant difference among the experimental treatments in branch length increase. The Kelpak treatment K6 outperformed all other treatments, reaching 65.833 cm compared to the control, while the K2 treatment produced the lowest increase at 47.614 cm. The results in the same table indicate a significant effect of citric acid spraying on branch length, with the C1000 concentration being superior and giving the highest increase at 59.584 cm compared to the control. In contrast, the C0 concentration resulted in the lowest branch length at 54.121 cm. The results of the interaction between Kelpak and citric acid showed a significant effect on branch length increase. The combined treatment K6 C1000 gave the highest value at 68.300 cm, while the lowest value was recorded for K0 C0 at 42.150 cm.

Branch diameter (mm)

The data presented in Table 3 show that foliar spraying with Kelpak had a significant effect on increasing branch diameter. The K6 and K4 concentrations were superior, reaching 1.421 and 1.357/ mm, respectively, while the K0 concentration produced the lowest increase at 0.966/ mm. The results in the same table indicate a significant effect of citric acid spraying on branch diameter. The C1000 concentration was superior, giving the largest branch diameter at 1.302 mm compared to the control, whereas the C0 concentration produced the smallest diameter at 1.125 mm. The results of the interaction between Kelpak and citric acid showed a significant effect on branch diameter increase. The combined treatment K6/ C1000 gave the highest value at 1.473 mm, while the lowest value was recorded for K0 C0 at 0.833 mm.

Leaf area (cm^2)

The results presented in Table 4 show that leaf area significantly increased with foliar spraying of Kelpak. The K6 concentration produced the largest leaf area at 131.156 cm^2 compared to the control, while the K0 concentration gave the smallest leaf area at 93.717 cm^2. The results also indicate a significant effect of citric acid spraying on leaf area, with the C1000 concentration producing the largest leaf area at 114.600 cm^2 compared to the control, whereas the C500 concentration resulted in the smallest leaf area

Table 2: Effect of Kelpak and citric acid spraying on branch length increase (cm) of young fig trees, local variety (*Khalou Bazian*).

Citric acid	C0 (0 mg L^{-1})	Kelpak C500 (500 mg L^{-1})	C 1000 (1000 mg L^{-1})	Average
K0 (0 ml L^{-1})	42.150d	46.153d	56.103c	48.884c
K2 (2 ml L^{-1})	47.210d	46.833d	48.800d	47.614c
K4 (4 ml L^{-1})	58.333c	60.473bc	65.133ab	61.313b
K6 (6 ml L^{-1})	64.800ab	64.400ab	68.300a	65.833a
Average	54.121b	54.465b	59.584a	

Means sharing the same letters, whether individually or in combination, are not significantly different according to Duncan's multiple range test at a 0.05 probability level.

Table 3: Effect of Kelpak and citric acid spraying on branch diameter increase (mm) of young fig trees, local variety (Khalou Bazian).

Citric acid	C0 (0 mg L^{-1})	Kelpak C500 (500 mg L^{-1})	1000 C (1000 mg L^{-1})	Average
K0 (0 ml L^{-1})	0.833e	0.933e	1.133d	0.966c
K2 (2 ml L^{-1})	0.870e	1.206cd	1.263bcd	1.113b
K4 (4 ml L^{-1})	1.393ab	1.340abc	1.340abc	1.357a
K6 (6 ml L^{-1})	1.406ab	1.383ab	1.473a	1.421a
Average	1.125c	1.215b	1.302a	

Means sharing the same letters, whether individually or in combination, are not significantly different according to Duncan's multiple range test at a 0.05 probability level.

at 104.846 cm^2. Regarding the interaction between Kelpak and citric acid concentrations, a significant increase in leaf area was observed. The combined treatments K4 C0 and K4 C1000 produced the highest leaf areas at 137.083 and 135.667 cm^2, respectively, while the lowest value was recorded for K0 C0 at 90.667 cm^2.

Relative chlorophyll content in leaves (CCI)

The statistical analysis presented in Table (5) shows that foliar spraying with Kelpak had a significant effect on total leaf chlorophyll content. The K6 concentration produced the highest value at 43.104 CCI compared to the control, while the K2 concentration gave the lowest value at 39.246 CCI. Spraying with citric acid also significantly increased total leaf chlorophyll content. The C1000 concentration produced the highest chlorophyll content at 42.215 CCI compared to the control, whereas the C500 concentration resulted in the lowest content at 39.988 CCI. The interaction between Kelpak and citric acid concentrations significantly affected leaf chlorophyll content. The combined treatment K6 C1000 gave the highest value at 45.013 CCI compared to the control, while the lowest value was recorded for K0 C0 at 38.130 CCI.

Leaf dry matter percentage (%)

The results shown in Table 6 indicate a significant difference among the experimental treatments in leaf dry matter percentage. The Kelpak concentration K4 was superior to all other treatments, producing 19.977%, while the K2 concentration gave the lowest value at 17.511%. Regarding the effect of citric acid spraying, the results in the same table indicate a significant difference. The C1000 concentration produced the highest leaf dry matter percentage at 19.019%, which did not differ significantly from the control, whereas the C500 concentration resulted in the lowest value at 17.916%. The results also show a significant effect of the interaction between Kelpak and citric acid concentrations. The combined treatments K4 C0 and K4 C1000 produced the highest leaf dry matter percentages at 21.000% and 20.800%, respectively, while the lowest value was recorded for K0 C0 at 17.033%.

The significant increase in vegetative growth traits (Table 1, 2, 3, 4, 5 and 6) may be attributed to the effect of the seaweed extract Kelpak, which naturally contains several macro- and micronutrients as well as plant hormones, particularly auxins and cytokinins. These compounds promote cell division, elongation and tissue growth (Hamzah

Table 4: Effect of Kelpak and citric acid spraying on leaf area (cm^2) of young fig trees, local variety (*Khalou Bazian*).

Citric acid	C0 (0 mg L^{-1})	Kelpak C500 (500 mg L^{-1})	C1000 (1000 mg L^{-1})	Average
K0 (0 ml L^{-1})	90.667f	95.083ef	95.400ef	93.717d
K2 (2 ml L^{-1})	91.900f	94.083ef	117.000bc	100.994c
K4 (4 ml L^{-1})	137.083a	120.717b	135.667a	107.194b
K6 (6 ml L^{-1})	101.750ed	109.500cd	110.333cd	131.156a
Average	105.350b	104.846b	114.600a	

Means sharing the same letters, whether individually or in combination, are not significantly different according to Duncan's multiple range test at a 0.05 probability level.

Table 5: Effect of Kelpak and citric acid spraying on relative chlorophyll content in leaves (CCI) of young fig trees, local variety (*Khalou Bazian*).

Citric acid	C0 (0 mg L^{-1})	Kelpak C500 (500 mg L^{-1})	C1000 (1000 mg L^{-1})	Average
K0 (0 ml L^{-1})	38.130d	38.476d	41.833bc	39.480c
K2 (2 ml L^{-1})	38.766d	38.466d	40.506c	39.246c
K4 (4 ml L^{-1})	41.826bc	40.563c	41.506bc	41.298b
K6 (6 ml L^{-1})	41.853bc	42.446b	45.013a	43.104a
Average	40.144b	39.988b	42.215a	

Means sharing the same letters, whether individually or in combination, are not significantly different according to Duncan's multiple range test at a 0.05 probability level.

Table 6: Effect of Kelpak and citric acid spraying on leaf dry matter percentage (%) of young fig trees, local variety (*Khalou Bazian*).

Citric acid	C0 (0 mg L^{-1})	Kelpak C500 (500 mg L^{-1})	C 1000 (1000 mg L^{-1})	Average
K0 (0 ml L^{-1})	17.033e	17.233de	18.910bc	17.725c
K2 (2 ml L^{-1})	17.300cde	17.500cde	17.733cde	17.511c
K4 (4 ml L^{-1})	21.000a	18.133bcde	20.800a	19.977a
K6 (6 ml L^{-1})	19.500ab	18.800bcd	18.633bcde	18.977b
Average	18.708a	17.916b	19.019a	

Means sharing the same letters, whether individually or in combination, are not significantly different according to Duncan's multiple range test at a 0.05 probability level.

et al., 2022). The increase in plant height resulted in greater leaf area, which enhanced photosynthetic output, consequently increasing branch length, diameter and leaf dry weight as shown in Table 1, 2 and 6 (Sheikho and Taha, 2017; Begum, 2018). These extracts also help balance biochemical and physiological processes at the cellular and tissue levels, stimulating and improving the efficiency of carbon metabolism and thereby enhancing vegetative growth traits (Al-Hadethi and Al-Dulaimi, 2019; Mosa, *et al*., 2022a). The increase in leaf chlorophyll content is attributed to the presence of amino acids in seaweed extracts, particularly alanine and serine, which play an important role in activating photosynthesis and improving its efficiency (Jaff and Medan, 2024). These results are consistent with those of Salman *et al*. (2018) and Al-Saif *et al*. (2023a and b).

Citric acid is an effective compound for improving nutrient availability, enhancing root growth and optimizing soil pH. When used correctly, it can significantly improve plant health and crop productivity by helping plants tolerate stressful conditions such as salinity and drought through enhanced nutrient uptake and stronger root systems. Strong plants are more capable of facing environmental challenges (Abdel-Aziz *et al*., 2005). Citric acid is also a non-enzymatic antioxidant that acts as a scavenger of free radicals generated by plant stress, which can disrupt nutrient metabolism, affect the electron transport chain and increase lipid peroxidation and plasma membrane degradation. It has a similar effect to natural auxins that promote growth within the plant. Additionally, citric acid may stimulate photosynthetic activity and the utilization of its products for growth and development, thereby increasing cell division and expansion through sufficient nutrients from photosynthesis, ultimately enhancing the studied vegetative growth traits (Osama *et al*., 2015). These findings are consistent with those reported by Mohamed (2018) for mango trees and by Mosa *et al*. (2022b) for pear.

CONCLUSION

Based on the results, it can be concluded that foliar spraying with seaweed extract (Kelpak) and citric acid at appropriate concentrations played a significant role in most of the studied vegetative growth traits of young fig trees, local c.v (*Khalou Baziani*). Spraying with Kelpak at 6 ml L^{-1} and citric acid at 1000 mg L^{-1} produced the greatest effect and the most effective response in most of the studied traits, whether applied individually or in combination, under the conditions of the study area. The study recommends using Kelpak seaweed extract and citric acid as an integrated approach to improve the vegetative growth of young fig trees under conditions similar to those of the experiment.

ACKNOWLEDGEMENT

The authors extend their sincere thanks and appreciation to the College of Agriculture at Kirkuk University for their scientific support and for providing the necessary resources to complete this research. Their valuable contributions were essential in achieving the objectives of this study.

Consent for publication

All authors declare their consent for publication.

Author contribution

The manuscript was edited and revised by all authors.

Conflict of interest

The author declares no conflict of interest.

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