



Article

Sustainability via Folic Acid and Organic Silicon Application on Mineral and Carbohydrate Content of Sorani and Nabali Olive Transplants

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Abstract: Good nutrition for fruit Transplant, including olives, depends on the amount of mineral elements present in the soil or added in the form of foliar fertilizers to these Transplant, this experiment aimed to know the response of Transplant of two olive cultivars (Sorani and Nabali) to foliar spraying with two concentrations of folic acid (0 and 100 g L⁻¹) and three concentrations of organic silicon (0, 5 and 10 mg L⁻¹) and their effect on the growth and mineral content of the Transplant. The results showed that foliar spraying with folic acid at a concentration of 100 g L⁻¹ and silicon at a concentration of 10 mg L⁻¹ gave the highest significant values in the leaf content of mineral elements (nitrogen, phosphorus, potassium, zinc and iron in addition to carbohydrates) and significantly exceeded the comparison treatment, while there was no effect of the two study cultivars on all of these traits. It also became clear that all interactions between the factors, especially between the high concentrations, gave the highest values of these traits, especially when the triple interaction between the treatment (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon for the Sorani variety).

Key words: Sustainability in Agriculture, Folic Acid, Silicon, Transplant, Olive, cultivars.

1. Introduction

Olive (*Olea europaea* L.) is cultivated in many parts of the world, especially those located within the Mediterranean basin. Therefore, there are many olive cultivars, some of which are used for oil extraction, while others are used for pickling purposes. There are also dual-purpose cultivars used for both oil and pickling⁴. The cultivars may differ or be similar depending on the region in which they are grown. There are also phenotypic, physiological, and genetic differences between the cultivars. The phenotypic difference is in the size of the root and vegetative systems, the nature of growth and spread of each, as well as the difference in the shape, size, and color of the fruits and leaves. Physiological differences also occur through the difference in the speed of the vital and physiological processes of

these cultivars, such as the ability of the root system to absorb water and mineral elements, and other physiological processes². Olive Transplant in nurseries are characterized by their slow growth compared to other fruit seedlings, so they need a long period of time until they are ready for planting in the permanent orchard and reaching the fruiting stage, which leads to an increase in their production and service costs. Therefore, attention must be paid to fertilizing them by using different types of fertilizers (chemical, organic, biological, etc.) in order to stimulate their growth and improve their mineral content (Shayal alalam and Alalaf, 2020 and Agha, 2024).

Vitamins are among the most important vital compounds that affect the growth of fruit seedlings when used as a spray on the vegetative system, as they help regulate many factors affecting the course of physiological processes within plants. They also serve as a cofactor in the formation of enzymes, and they work to increase growth through their effect on increasing the amount of plant hormones that affect cell elongation and division, in addition to their role as an initiator of the Thiamine pyrophosphate compound, which the plant needs in the metabolism of carbohydrates and amino acids) Aly *et al.*, 2022 And Baqir *et al.*, 2024).

Silicon is considered a beneficial element for plants, due to its role in improving the photosynthesis process by increasing the biosynthesis of chlorophyll pigment and delaying leaf aging. It also works to enhance water use efficiency, interact with other physiological processes such as nutrient absorption, and increase the rigidity of cell walls, which leads to mechanical support for the aerial parts of the plant. In addition, it plays a role in increasing the absorption of sufficient quantities of water and nutrients, thus increasing the leaf nutrient content, which is reflected in accelerating the photosynthesis process and increasing the manufactured carbohydrates, thus improving growth (Martos-Garcia *et al.*, 2025 And Schaller *et al.*, 2025).

Given the importance of the studied factors (varieties, spraying with vitamins and silicon), the experiment aimed to determine the response of olive seedlings of two varieties (Sorani and Nabali) to fertilizer treatments and their effect on the growth and mineral content of the seedlings.

2. Materials and Methods

2.1. Experimental Site and Period

The experiment was carried out in the Lath house of the Horticulture and Landscape Design Department at the College of Agriculture and Forestry, University of Mosul, during the 2024 season.

2.2. Plant Material

Two-year-old olive Transplant were selected, with a height of (40-50 cm) and a main stem diameter of about (6 mm).

2.3. Experimental Setup

They were planted in plastic bags with a capacity of (6 kg) containing river soil. The experiment included the following factors:

Factor 1: two olive cultivars (Sorani and Nabali).

Factor 2: Foliar spraying with two concentrations of folic acid (0 and 100 g L⁻¹).

Factor 3: Foliar spraying with three concentrations of organic silicon (0, 5, and 10 mg L⁻¹)

2.4. Fertilizer Application

Fertilizer treatments were applied to the vegetative system three times during the growing season on April, May, and June.

2.5. Experimental Design

The experiment was designed according to a randomized complete block design (RCBD) with three factors, three replicates, and four Transplant per experimental unit. Therefore, the number of seedlings used in the experiment was (2 x 2 x 3 x 3 x 4 = 144 seedlings).

2.6. Data Collection

The following parameters were measured:

(Nitrogen (N%), Phosphorus (P%), Potassium (K%) Estimation of nutrients in the digestive solution according to the method of estimation followed using the Microkjeldahl device described by (Bhargava and Raghupathi, 1999).

Zinc (Zn) and Iron (Fe) (mg kg^{-1} dry weight) It was estimated using an atomic absorption spectrophotometer according to the method described in Al-Mawsili (2019).

Total carbohydrates in leaves (%) It was measured using the Joslyn (1970).

3. Results and Discussion

N in leaves %: In Table (1) Spraying Transplant with folic acid at a concentration of 100 g L^{-1} led to the highest value for this trait, which significantly exceeded the comparison treatment. The value also increased when spraying with silicon at a concentration of 10 mg L^{-1} , and significantly exceeded the rest of the concentrations. The varieties had no effect on the trait values When interacting between folic acid and organic silicon, we find that the highest concentration of N in the leaves was in the treatment of 100 g L^{-1} folic acid + 10 mg L^{-1} silicon, which was significantly superior to all interactions. As for the interaction between folic acid and cultivars, the treatment of 100 g L^{-1} folic acid for the Sorani cultivar gave the highest significant value for the trait. In the case of interaction between silicon and cultivars, the treatment of 10 mg L^{-1} silicon for the Sorani cultivar recorded the highest significant increase for the trait. As for the triple interaction between factors, it is noted that the highest significant value for the trait was for the treatment (100 g L^{-1} folic acid + 10 mg L^{-1} silicon for the Sorani cultivar).

Table (1). Effect of foliar spraying with folic acid and silicon on the nitrogen concentration in the leaves of olive seedlings cultivars Sorani and Nabali

cultivars	folic acid gm L^{-1}						Av. cultivars	
	0			100				
	silicon (mg l^{-1})							
	0	5	10	0	5	10		
Nabali	1.11 b	1.35 b	1.43 b	1.14 b	1.35 b	1.39 b	a 1.45	
Surani	1.38 b	1.45 b	2.00 a	1.39 b	1.32 b	2.14 a	1.45 a	
Av. folic acid	b1.28			a1.62				
Av. Nano silicon	1.25 b	1.40 b	1.71 a					
Interaction between silicon and folic acid			Interaction between silicon and cultivars			Interaction between folic acid and cultivars		
silicon	folic acid		Nano silicon	Cultivars		folic acid	cultivars	
	0	100		Nabali	Surani		Nabali	Surani
0	1.12 c	1.39bc	0	1.28 b	1.40b	0	1.28 b	1.29 b
5	1.35bc	1.38bc	5	1.67 a	1.23 b	100	a 1.62	1.62 a
10	1.41b	2.07a	10	1.39b	1.74a			

The averages followed by different letters indicate the presence of significant differences between them according to the Duncan multinomial test at the 5% probability level.

P in leaves %: In Table (2), The folic acid treatment at a concentration of 100 g L⁻¹ recorded a significant increase in the values of this trait compared to the control treatment. Spraying at a concentration of 10 mg L⁻¹ of silicon resulted in an increase in the values of the trait, significantly exceeding the control treatment. The cultivars had no significant effect on the values of the trait. In the case of interaction between folic acid and silicon, the treatment of 100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon was significantly superior to most interactions. When interacting between folic acid and varieties, we note that the highest value was recorded by the treatment of 100 g L⁻¹ folic acid for the Sorani variety. In the case of interaction between silicon and varieties, the treatment of 5 mg L⁻¹ silicon gave the Nabali variety. When there was a three-way interaction between the factors, we find that the highest significant value for the trait was the result of the treatment (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon for the Sorani variety).

Table (2). Effect of foliar spraying with folic acid and silicon on the Phosphorus concentration in the leaves of olive seedlings cultivars Sorani and Nabali

cultivars	folic acid						Av. cultivars	
	0			100				
	silicon (mg l ⁻¹)							
	0	5	10	0	5	10		
Nabali	0.107c	0.177 ab	0.168ab	0.148a-c	0.144a-c	0.173ab	0.153 a	
Surani	0.142bc	0.148a-c	0.177ab	0.154ab	0.156ab	0.189 a	0.160 a	
Av. folic acid	0.145 b			0.168 a				
Av. Nano silicon	0.140 b	0.159 ab	0.171 a					
Interaction between silicon and folic acid			Interaction between silicon and cultivars			Interaction between folic acid and cultivars		
silicon	folic acid		Nano silicon	Cultivars		folic acid	cultivars	
	0	100		Nabali	Surani		Nabali	Surani
0	0.128 c	0.148 bc	0	0.127 b	0.155 ab	0	0.142 b	0.164ab
5	0.160 ab	0.152 bc	5	0.177 a	0.152 ab	100	0.148 b	0.173 a
10	0.170 ab	0.183 a	10	0.163 a	0.166 a			

The averages followed by different letters indicate the presence of significant differences between them according to the Duncan multinomial test at the 5% probability level.

K in leaves% In Table (3) that spraying with a concentration of 100 gL⁻¹ of folic acid recorded the highest value for the trait and significantly exceeded the control treatment. The same applies to a concentration of 10 mgL⁻¹ of silicon, and the varieties had no significant effect on the trait values. When interacting with folic acid and silicon, the treatment 100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon significantly exceeded all interactions. When interacting with folic acid and cultivars, we note that the highest value was recorded by the treatment 100 g L⁻¹ folic acid for both cultivars. In the case of interaction between silicon and cultivars, the treatment 10 mg L⁻¹ silicon for the Sorani cultivar recorded the highest significant values. In the case of interaction between the three factors, we find that the highest significant value for the trait was the result of the treatment (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon for the Sorani cultivar).

Table (3). Effect of foliar spraying with folic acid and silicon on the potassium concentration in the leaves of olive seedlings cultivars Sorani and Nabali

cultivars	folic acid						Av. cultivars	
	0			100				
	silicon (mg L ⁻¹)							
	0	5	10	0	5	10		
Nabali	1.08d	1.63c	1.72bc	1.03d	1.68bc	1.71bc	1.59 a	
Surani	1.55c	1.72bc	1.82ab	1.62c	1.63c	1.94a	1.60 a	
Av. folic acid	1.43 b			1.76 a				
Av. silicon	1.37 c	1.65 b	1.77 a					
Interaction between silicon and folic acid			Interaction between silicon and cultivars			Interaction between folic acid and cultivars		
silicon	folic acid		Nano silicon	Cultivars		folic acid	cultivars	
	0	100		Nabali	Surani		Nabali	Surani
0	1.06 d	1.59 c	0	1.40 c	1.63b	0	1.42b	1.45 b
5	1.65 bc	1.68 bc	5	1.72ab	1.33c	100	1.75 a	1.76 a
10	1.71 b	1.88 a	10	1.67b	1.81a			

The averages followed by different letters indicate the presence of significant differences between them according to the Duncan multinomial test at the 5% probability level.

Z in leaves (mg kg⁻¹ dry weight): In Table (4) show that foliar spraying with folic acid and silicon concentrations significantly affected the trait values. The treatment of 100 g L⁻¹ of folic acid and 10 mg L⁻¹ of silicon achieved the highest significant values, while the cultivars did not affect the trait values. When interacting with folic acid and silicon, it was found that all interactions significantly exceeded the comparison treatment, especially the treatment of 100 g L⁻¹ folic acid + 5 mg L⁻¹ silicon. As for the interaction between folic acid and varieties, the highest value was recorded by the treatment of 100 g L⁻¹ folic acid for the Sorani variety. In the case of interaction between silicon and varieties, the treatment of 5 mg L⁻¹ silicon for the Nabali variety recorded the highest values. As for the interaction between the three factors, the treatment (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon for the Sorani variety) recorded the highest values, but it only outperformed the comparison treatment.

Fe in leaves (mg kg⁻¹ dry weight): In Table (5) Spraying Transplant with 100 g L⁻¹ folic acid resulted in a significant increase in leaf iron values, exceeding the control treatment. Spraying with 10 mg L⁻¹ silicon also significantly increased this trait, while neither variety had a significant effect. When combining folic acid with silicon, the treatment (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon) recorded the highest values for this trait. The interaction between folic acid at a concentration of 100 g L⁻¹ for the Sorani variety also produced the highest values, significantly exceeding the other interactions. There were no significant differences between the interactions between silicon and the other varieties. Regarding the interaction between the three factors, the table indicates that the highest value was achieved by the treatment (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon for the Sorani variety).

Total Carbohydrates in Leaves(%): In Table (6) confirm that spraying folic acid and silicon individually significantly affected the trait values, with the 100 g L⁻¹ folic acid and 10 mg L⁻¹ silicon concentrations being superior. However, neither variety recorded any increase in this trait. All bilateral interactions between the factors also significantly affected this trait, with the treatments (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon), (100 g L⁻¹ folic acid for the Sorani variety), and (10 mg L⁻¹ silicon for the Sorani variety). In the case of an interaction between the three factors, the treatment (100 g L⁻¹ folic acid + 10 mg L⁻¹ silicon for the Sorani variety) produced the highest significant increase in this trait.

Table (4). Effect of foliar spraying with folic acid and silicon on the zinc concentration in the leaves of olive seedlings cultivars Sorani and Nabali

cultivars	folic acid						Av. cultivars	
	0			100				
	silicon (mg l ⁻¹)							
	0	5	10	0	5	10		
Nabali	20.77b	39.25a	33.88a	20.07 b	32.55a	40.40a	33.97 a	
Surani	33.88a	39.66a	36.40a	32.62a	38.21a	41.33a	34.19 a	
Av. folic acid	29.85 b			38.31 a				
Av. silicon	29.67 b	35.19 a	37.38 a					
Interaction between silicon and folic acid			Interaction between silicon and cultivars			Interaction between folic acid and cultivars		
Nano silicon	folic acid		Nano silicon	Cultivars		folic acid	cultivars	
	0	100		Nabali	Surani		Nabali	Surani
0	20.42 b	33.25 a	0	30.21 ab	33.88 ab	0	31.30 bc	28.41 c
5	35.90 a	38.93 a	5	37.83 a	29.14 A	100	36.65ab	39.98 a
10	37.14 a	38.86 a	10	36.51 ab	36.94a b			

The averages followed by different letters indicate the presence of significant differences between them according to the Duncan multinomial test at the 5% probability level.

Table (5). Effect of foliar spraying with folic acid and silicon on the iron concentration in the leaves of olive seedlings cultivars Sorani and Nabali

cultivars	folic acid						Av. cultivars	
	0			100				
	silicon (mg l ⁻¹)							
	0	5	10	0	5	10		
Nabali	31.33 bc	50.66ab	51.60ab	26.66c	47.00a-c	53.29ab	45.53 a	
Surani	38.29 a-c	47.66a-c	53.66a	38.29a-c	50.66ab	59.66a	45.93 a	
Av. folic acid	38.70 b			52.75 a				
Av. silicon	39.08 b	45.37 ab	52.74 a					
Interaction between silicon and folic acid			Interaction between silicon and cultivars			Interaction between folic acid and cultivars		
Nano silicon	folic acid		Nano silicon	Cultivars		folic acid	cultivars	
	0	100		Nabali	Surani		Nabali	Surani
0	29.00 c	38.29 bc	0	39.49 a	44.94a	0	40.09bc	37.32 c
5	48.83 ab	49.16 ab	5	52.16 a	a 38.66	100	50.97 ab	54.54 a
10	52.44 ab	56.66 a	10	45.79 a	53.33 a			

The averages followed by different letters indicate the presence of significant differences between them according to the Duncan multinomial test at the 5% probability level.

Table (6). Effect of foliar spraying with folic acid and silicon on the carbohydrate concentration in the leaves of olive seedlings cultivars Sorani and Nabali

cultivars	folic acid						Av. cultivars	
	0			100				
	silicon (mg l ⁻¹)							
	0	5	10	0	5	10		
Nabali	19.03d	32.74 c	33.92 c	20.18 d	32.69 c	38.20bc	32.47 a	
Surani	33.20c	32.87c	43.07ab	32.50 c	36.54 c	45.92 a	34.34 a	
Av. folic acid	28.39 b			38.42 a				
Av. silicon	c 27.16	34.45 b	38.60 a					
Interaction between silicon and folic acid			Interaction between silicon and cultivars			Interaction between folic acid and cultivars		
Nano silicon	folic acid		Nano silicon	Cultivars		folic acid	cultivars	
	0	100		Nabali	Surani		Nabali	Surani
0	19.61 c	32.85 b	0	25.95 d	33.56 c	0	28.32c	28.46 c
5	32.72 b	34.71 b	5	37.90 ab	28.36 d	100	36.62 b	40.22 a
10	36.06 b	44.49 a	10	35.35 bc	39.30 a			

The averages followed by different letters indicate the presence of significant differences between them according to the Duncan multinomial test at the 5% probability level.

The results show that spraying with a concentration of 100 g L⁻¹ of folic acid caused a significant increase in all traits. This is due to the role of vitamins, including folic acid, in enhancing the absorption of mineral elements by regulating many vital processes in the plant, including the synthesis of proteins, amino acids, and nucleic acids. It also accelerates cell division and elongation, stimulates the production of plant hormones, and increases the chlorophyll content of leaves, which increases the efficiency of photosynthesis. In addition, folic acid plays a natural chelating role that helps facilitate the absorption of mineral elements from the soil and their transfer to the leaves, where they accumulate and their concentration increases. As for the increase in carbohydrates when spraying with folic acid, this is due to its role in increasing the absorption of mineral elements and increasing the products of photosynthesis, which leads to an increase in the accumulation of carbohydrates in the leaves (**Ati and Wasan, 2020 & Hekmat and Alalaf, 2025**). This is consistent with what was found by (**Belal *et al.*, 2016 and Hussien, 2020**).

As for the increase in the concentration of mineral elements and carbohydrates in the leaves when spraying with organic silicon, it may be due to its important role in balancing plant hormones and increasing the efficiency of photosynthesis by increasing the size of chloroplasts, thus encouraging the plant and increasing its ability to absorb elements from the soil and transfer them to the leaves, thus increasing their concentration. In addition, it is important in enhancing the effectiveness of the plant's root system and increasing its efficiency in absorbing the mineral elements it requires in growth processes, especially photosynthesis, when these elements accumulate in the leaves (**Nascimento-Silva *et al.*, 2022 and Fekry *et al.*, 2022**). This is consistent with what was confirmed by both (**Abdulkadhim and Hashem, 2025 and AL-Jaleely *et al.*, 2025**).

4. Conclusions

Foliar spraying with folic acid and organic silicon had a positive effect on the studied traits, especially when spraying with a concentration of 100 gL⁻¹ of folic acid + 10 mgL⁻¹ of organic silicon, as an increase in the content of mineral elements and carbohydrates in olive Transplant leaves was

recorded. Therefore, the study recommends using different types of fertilizers containing sugar alcohols and organic fertilizers on fruit seedlings in general and olives in particular because they are environmentally safe and inexpensive compared to traditional chemical fertilizers.

Significance Statement

Applying sugar alcohols such as sorbitol, as well as fertilizers containing organic elements, as a spray on plant leaves is one of the most important agricultural practices, as they are quickly absorbed by the foliage, thus treating the symptoms of nutrient deficiency, and they also directly enter the metabolic cycles of plant tissues.

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الاستدامة في اضافة حامض الفوليك والسيليكون العضوي في المحتوى المعدني والكربوهيدرات لشتلات الزيتون صنفى صوراني ونبالي

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قسم البستنة وهندسة الحدائق، كلية الزراعة والغابات، جامعة الموصل، العراق

الملخص

تعتمد التغذية الجيدة لشتلات الفاكهة، بما في ذلك الزيتون، على كمية العناصر المعدنية الموجودة في التربة أو المضافة على شكل أسمدة ورقية لهذه الشتلات، هدفت التجربة إلى معرفة استجابة شتلات صنفين من الزيتون (صوراني ونبالي) للرش الورقي بتركيزين من حامض الفوليك (0 و 100 غم لتر) وثلاثة تراكيز من السيليكون العضوي (0 و 5 و 10 ملغم لتر)، وتأثير ذلك على نمو الشتلات ومحتواها المعدني، أظهرت النتائج أن الرش الورقي بحامض الفوليك بتركيز 100 غم لتر والسيليكون العضوي بتركيز 10 ملغم لتر أعطى أعلى القيم المعنوية في محتوى الأوراق من العناصر المعدنية (النيتروجين والفوسفور والبوتاسيوم والزنك والحديد بالإضافة إلى الكربوهيدرات) وقد تجاوزت بشكل ملحوظ معاملة المقارنة، بينما لم يكن لصنفي الزيتون المدروسين أي تأثير في قيم هذه الصفات، كما اتضح أن جميع التفاعلات بين العوامل، وخاصة بين التراكيز العالية أعطت أعلى قيم لهذه الصفات، لا سيما عند التداخل الثلاثي بين (100 غم لتر من حامض الفوليك + 10 ملغم لتر من السيليكون العضوي للصنف صوراني).

الكلمات المفتاحية: الاستدامة في الزراعة - حامض الفوليك - السيليكون العضوي - شتلات - الزيتون - الأصناف