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Foliar Nutrient Applications: Boosting Productivity and Quality of Picual Olive Fruits and Oils

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Abstract

Olives are one of the economically important fruit crops in the Mediterranean basin countries, including Egypt. One of the most important types of oils is olive oil, which has many nutritional and medical benefits. Olive oil exports also contribute to the economies of many countries around the world. Despite this, olive trees have suffered productivity problems in recent years for a variety of reasons, including climate change and nutritional reasons. We applied foliar spraying of algae extract, zinc sulfate, and boric acid at different concentrations at three spraying times to olive trees of the Picual cv. in a private orchard located at Ismailia Governorate, Egypt, during the 2022-2023 growing seasons, in an attempt to improve tree productivity, fruit characteristics, and oil quality, The results demonstrated that foliar spraying with 0.2% algae extract, 3000 ppm zinc sulfate, and 300 ppm boric acid resulted in the highest final fruit set, yield, fruit weight, flesh weight, fruit oil content, and potassium content in the leaf. Additionally, the majority of treatments positively impacted oil characteristics such as acidity value, peroxide value, iodine value, and the percentage of unsaturated fatty acids in the oil. Therefore, we recommend applying these treatments to olive trees planted on lands with similar conditions.

Keywords: algae extract, boric acid, fruit quality, olive oil, olive trees, zinc sulfate

1. Introduction

The olive tree, or *Olea europaea* L., is one of the world's most extensively spread fruit trees and one of the oldest agricultural commodities with significant cultural and economic value in the Mediterranean Basin. A member of the Oleaceae family, the olive tree is evergreen and comes in a variety of varieties that are used for oil extraction and pickling. Furthermore, olives grow well in a variety of soil types and growth environments. In accordance with statistics from the Food and Agriculture Organization (FAOSTAT) [1], the total cultivated area for olive trees in Egypt was 112,851 hectares, this area yielded 1,137,075 tons of fruits. Introduced to Egypt from Spain, the Picual olive cultivar is regarded as one of the best and most commonly planted varieties in Egypt. Furthermore, the bulk of Egypt's olive trees are planted in recently reclaimed land, much of which has sandy soil deficient in both macro and micronutrients. Furthermore, the goal of effective orchard management techniques is to achieve good fruit quality and an appropriate output. Mineral nutrition is one of the most significant agricultural activities, particularly in the recently reclaimed soil. Therefore, foliar spraying application is more effective than soil application fertilizer at providing plants with the nutrients they need rapidly, directly, and affordably [2].

Marine macroalgae (green, brown, and red) comprise algae extracts and seaweeds, and crop production frequently uses extracts from brown seaweed. The raw material, the geographic location of the harvested algae and algal species, the extraction technique, and the biologically active substances that are moved from the algae biomass to the liquid phase all have a significant impact on the composition of algae extracts. They primarily benefit an organism by shielding it from biotic and abiotic stressors. They also provide a variety of economically valuable goods, including bioenergy, nitrogen fixers, plant growth regulators, medicinal and cosmetical substances, and functional foods [3]. Various orchards, especially those with saline and dry soil conditions, have used algae extract as a novel supplement to improve fruit quality, productivity, and nutritional status. In addition, algae extract contains many macroelements, such as nitrogen, phosphorus, and potassium, as well as some microelements, such as iron, zinc, and manganese. It also contains many growth hormones, such as cytokinin, alginin, and zeatin, as well as oligosccharide, polyamines, and vitamins. All of these substances contribute greatly to increasing the productivity of many crops [4]. The primary mechanism for the effects of algal extract on cell metabolism is the physiological action of macro- and micronutrients, vitamins, amino acids, and growth regulators, which impact cellular metabolism in treated plants and promote growth and crop output [5]. The application of algae extracts on trees enhanced productivity, improved the physical characteristics of fruits, and enhanced the chemical properties of mango juice [6]. In this

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context, Al-Musowi [7] examined orange trees. Also, Alebidi *et al.* [8] showed that applying algae extract foliar spray to date palms produced the best results in terms of yield and fruit characteristics. Meanwhile, researchers on Picual olive trees discovered that spraying them with algae extract alone or with Moringa leaf extract made the trees produce the most fruit. The fruits' weight, volume, and ratio of flesh to seed all got better, as did the amount of oil in the fruits and the chemical properties of the oil [2].

The microelements such as zinc and boron that are required in trace amounts by the plant are crucial for its internal metabolic processes. One of the most important micronutrients for plants is zinc, and deficiencies in zinc are prevalent in many crops [9]. Zinc is necessary for many different enzymes to function, such as RNA and DNA polymerases, aldolases, isomerases, transphosphorylases, and dehydrogenases. It also plays a role in tryptophan synthesis, cell division, membrane structure maintenance, and photosynthesis [10]. Foliar application of zinc sulfate on citrus mandarin trees obtained better physical properties of fruits such as fruit weight and diameter, as well as improved the chemical properties of fruit juice [11]. In this respect, Abd-El-Ghany [12] studied the effect of different concentrations of zinc sulfate and it was found that it had a significant positive effect on improving the physical properties of the fruits and also improved the chemical properties of the pomegranate fruit juice. Boron (B) deficiency is also a common micronutrient problem in agriculture, which results in yield reductions and impaired crop quality. Boron has a wide range of functions in plants, including stimulating the germination of pollen grains, lengthening the pollen tube, increasing fruit set and production, and activating dehydrogenase enzymes, sugar translocation, plant hormones, and nucleic acids [10]. Boron is one of the essential elements for olive trees. Many studies have shown the effect of spraying with boric acid on fruit set and yield, including those by Arafat *et al.* [13], Hegazy *et al.* [14] and Gul *et al.* [15] who found that spraying with boron at different times before flowering led to an increase in the percentage of flowering, the percentage of fruit set, and the quantity and quality of the olive crop.

Researchers have become increasingly interested in studying the effect of adding boron and zinc together to fruit trees, especially olive trees, due to the great importance of these elements in improving productivity and fruit quality. In this respect, in a study conducted on Manzanillo olives, it was observed that spraying the trees with zinc sulfate and boric acid led to a significant increase in the yield and improved the quality of the fruits and the properties of the oil [16]. Moreover, El Gammal [16] found that fruit set, crop yield, and fruit oil quantity of olive trees increased significantly when sprayed with zinc sulfate, boric acid, and urea at the stage of full flowering. In another study on several olive cultivars, Gholami *et al.* [18] noted that foliar spraying with boron, zinc, and potassium four times starting from flowering led to an improvement in the fruit characteristics under study, and there were clear differences in the response of each cultivar separately.

Given the severe decline in olive productivity in recent years due to climate change, the study aimed to improve olive productivity and improve fruit and oil properties by using foliar spraying of algae extract, zinc sulfate, and boric acid at several spraying times, in an attempt to combine the beneficial effects of algae extract with zinc sulfate and boric acid in one experiment. The effect of these materials on final fruit set percentage, yield, physical fruit properties, fruit oil percentage, and chemical oil properties will be studied.

2. Material and Methods

This experiment was conducted on a private orchard located in the Sarabium region in Ismailia Governorate, Egypt, during the 2022 and 2023 study seasons. The study was conducted on 10-year-old olive trees of the Picual cv., and the trees were planted at a distance of 4 X 6 meters in sandy soil. The chemical analysis of the soil is shown in (Table 1). The trees were irrigated by a drip irrigation system and Table (2) shows the chemical analysis of the irrigation water. The experimental trees were homogeneous in shape and age. The common horticultural practices were applied to all trees under study.

Table (1): Analyzing the orchard soil's chemical composition:

pH	EC(dSm^{-1})	Soluble cations (meq/l)				Soluble anions (meq/l)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
8.19	1.23	2.7	1.3	7.5	1.0	-	1.0	10.0	1.5

Table (2): Analysis of the orchard well water:

pH	EC(dSm^{-1})	Soluble cations (meq/l)				Soluble anions (meq/l)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$
7.84	6.27	15.0	10.5	42.6	0.20	-	1.9	43.5	22.9

2.1. Experimental design and treatments

The experiment was conducted as a factorial experiment in a completely randomized block design. The first factor was foliar spraying with algae extract at three concentrations as follows (0, 0.1%, and 0.2%). As for the second factor of the experiment, it was foliar spraying with zinc sulfate + boric acid at several concentrations as follows:

1- (Control) $ZnSO_4$ or H_3BO_3

2- $ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)

3- $ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)

4- $ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)

5- $ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)

The experiment contains 15 treatments (3 X 5), and each treatment contains three replicates, and each replicate contains one tree. The trees were sprayed with the previous materials on three spraying dates i.e. the first in mid-December (during differentiation of buds), the second before flowering, and the third after the initial fruit set.

The readymade algae extract was obtained from National Research Centre (NRC), algal Biotechnology Unit, Egypt, Prof. Dr. Abo El-Khair B. El-Sayed. The chemical composition of the extract was earlier described by [3, 4].

2.2. Measurements

Before the beginning of the growing season in December, trees of similar age and shape were selected for the experiments, and the following measurements were made:

2.2.1. Final fruit Set

The number of fruits per meter was determined using the following formula after 60 days of full bloom:

Final fruit set (%) = Fruit set count (60 days following full bloom) / shoot length (cm) * 100

2.2.2. Fruit Yield

In the years 2022 and 2023, the fruits were harvested in the middle of October when they were fully ripe. Every single tree was carefully harvested, and the weight of fruits per tree was recorded for every tree. For every treatment, the average yield (kg) per tree was calculated.

2.2.3. Fruit physical characteristics

Twenty fruits were randomly collected from each tree to perform various measurements on the fruits, including the weight of fruits and seeds using a sensitive balance. Then the flesh weight was calculated by subtracting the weight of the seed from the total weight of the fruit. The size of the fruits was measured using a graduated cylinder using the displacement method, and then the length and diameter of the fruit were measured using a vernier caliper diagram according to Hassan *et al.* [2].

2.2.4. Moisture content

The prior fruit samples were evaluated for fruit moisture %. The samples were dried in an electrical air oven at 70ºC until their weight remained constant. The fruit moisture percentage was then computed according to A.O.A.C [19].

2.2.5. Fruit oil content %

According to Banat *et al.* [20], the oil percentage in the fruit flesh was calculated on a dry weight basis using a soxhlet oil extraction device with a boiling point of hexane between 60 and 80 degrees Celsius.

2.2.6. Leaf mineral contents

During the month of July, leaf samples were taken from different directions around each tree under study, then they were washed and dried in a drying oven until the weight was constant at a temperature of 70°C, then they were ground and digested using concentrated sulfuric acid and perchloric acid, then the solution was diluted with distilled water to a known volume to measure the following elements in it:

Nitrogen was measured using the Kjeldahl method according to Pregl [21] potassium was measured using the Flame photometer according to Brown and Lilleland [22]. Meanwhile, zinc was measured using atomic absorption according to Jackson [23]. Additionally, boron was measured according to Dible *et al.* [24].

2.2.7. Fruit oil characteristics

2.2.7.1. Acid Value (AV)

The acid value was assessed using a modified method [25]. Approximately 5 g of the oil sample was dissolved in a neutralized mixture of ethanol and diethyl ether (1:1 v/v). The resulting solution was titrated with 0.10 M potassium hydroxide while stirring continuously until a stable pink hue persisted for 15 seconds, utilizing 1% phenolphthalein as an indicator. The percentage of free fatty acids was calculated as oleic acid using the following formula:

FFA % as oleic acid = (Titration volume (mL) × 0.0282 × 100) / Sample weight (g)

2.2.7.2. Iodine Value (IV)

The iodine value was determined according to the Hanus method [25]. About 0.25 g of the oil sample was dissolved in 20 mL of chloroform within a 500 mL glass-stoppered flask. Following this, 25 mL of Hanus iodine solution (13.2 g of pure I2 in 1 L of acetic acid) was added, and the mixture was allowed to stand in the dark for 30 minutes. Afterward, 10 mL of 15% potassium iodide (KI) solution was incorporated, and the mixture was shaken thoroughly. Then, 100 mL of distilled water was added. The liberated iodine was titrated with 0.10 N sodium thiosulfate solution while stirring until the yellow solution nearly became colorless. A few drops of 1% starch solution were added as an indicator, and titration continued until the blue color completely disappeared after vigorous shaking to release all iodine from the chloroform. A blank titration was performed without the oil sample, and the iodine value was calculated as grams of iodine per 100 g of oil using the formula:

Iodine value = [(Blank titration (mL) - Sample titration (mL)) × Normality of $Na_2S_2O_3$ × 12.69] / Sample weight (g)

2.2.7.3. Peroxide Value (PV)

The peroxide value was determined following a specified method [25]. Approximately 2 g of the oil sample was placed in a flask with a ground-glass stopper. After adding 10 mL of chloroform, the mixture was shaken for 10 minutes. Then, 15 mL of glacial acetic acid and 2 g of sodium bicarbonate ($NaHCO_3$) were added. The solution was stirred, and 1 mL of saturated potassium iodide (KI) solution was introduced, followed by shaking for 1 minute and letting it sit in the dark for 5 minutes. Subsequently, 75 mL of distilled water and 0.5 mL of starch solution were added, and the resulting mixture was titrated with 0.01 N sodium thiosulfate solution until the blue color disappeared. A blank titration was performed using the same procedure without the sample. The peroxide value of the oil was calculated using the equation:

PV = [(Sample titration (mL) - Blank titration (mL)) × Normality of $Na_2S_2O_3$ × 1000] / Sample weight (g) [meq. O_2/kg]

2.2.7.4. Determination of Fatty Acid Composition

The fatty acid composition was analyzed by converting fatty chains into fatty acid methyl esters (FAMEs) through a modified method [26]. FAMEs were separated using an HP 6890 plus gas chromatograph (Hewlett Packard, USA) equipped with a Supelco™ SP-2380 capillary column (60 m × 0.25 mm × 0.20 µm). The detector was set to flame ionization detection (FID), with the injector and detector temperature maintained at 250°C. The column temperature was initially set at 140°C (held for 5 minutes) and then increased to 240°C at a rate of 4°C/min, holding at 240°C for an additional 10 minutes. Helium was used as the carrier gas at a flow rate of 1.2 mL/min. A 1 µL sample (dissolved in n-hexane) was injected using a split injector with a splitting ratio of 100:20. FAMEs were identified by comparing their retention times to those of authentic FAME standards (Supelco™ 37-component FAME mix). The fatty acid composition was reported as a relative percentage of the total peak area.

2.3. Statistical Analysis

Data from the experimental seasons of 2022 and 2023 were analyzed using analysis of variance (ANOVA) with the Costas software [27], adhering to the guidelines provided by Duncan [28]. The lowest significant range (LSR) was applied with a probability level of 5%.

3. Results and discussion

3.1. Final fruit set and yield

The findings displayed in Table (3) demonstrate that spraying algae extract separately or in combination with zinc sulfate and boric acid during the two seasons under study had a substantial impact on the final fruit set percentage and yield. The tree spray with algae extracts at 0.2% gave the highest values in the final fruit set percentage and yield in the two seasons under study. Regarding the foliar application with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm had significantly higher values than other concentrations in the two seasons under study. Meanwhile, the trees treated with algae extract at 0.2% + $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm showed the greatest significant values regarding the interaction impact, where the values were as follows; (28.29 and 45.45% for the final fruit set) and (22.5 and 34.67 kg/tree for yield values) in in the two seasons under study, respectively.

3.2. Fruit weight and volume

Spraying algae extract individually or together with zinc sulfate and boric acid throughout the two study seasons had a significant effect on fruit weight and volume, as shown by the results in Table (4). The tree spray with algae extracts at 0.1% was the treatment that demonstrated the highest non-significant values in this regard during both studied seasons. As for the treatment with zinc sulfate and boric acid, the results showed that foliar spraying $ZnSO_4$ at 1500 ppm + H_3BO_3 at 150 ppm recorded the maximum fruit weight and volume in the first season, but in the second season, the highest values recorded by $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 for the same measurements. Regarding the interaction between the study factors, it was found that the best treatment was algae extract at 0.1% + $ZnSO_4$ at 1500 ppm + H_3BO_3 at 150 ppm, which gave the highest fruit weight (9.35 g) and fruit volume (9.3 cm^3) in the first season of the study. But, spraying with algae extract at 0.1% + $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 ppm recorded the largest fruit weight (10.16 g) and fruit volume (10.40 cm^3) compared to other study treatments in the second season.

3.3. Fruit length and diameter

Results in Table (5) cleared that spraying algae extract separately or in combination with zinc sulfate and boric acid during the two seasons under study had a significant effect on the length and diameter of fruit. There were no significant differences between the algae extract treatments on the length and diameter of the fruit during the two experimental seasons. Regarding the foliar spraying with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm gave the highest fruit length, while the largest fruit diameter was recorded with treatment with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 ppm in the two studied seasons. Moreover, the trees treated with algae extract at 0.2% + $ZnSO_4$ at 1500 ppm + H_3BO_3 at 300 ppm showed the largest fruit length regarding the interaction effect, where the values were 2.88cm in the first season and 3.12cm in the second season. On the other hand, the largest fruit diameter was recorded by foliar spraying with algae extract at 0.1% + $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 ppm during the two study seasons, and the values were 2.42cm in the first season and 2.53cm in the second one.

Table (3): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on final fruit set percentage and yield of Picual olive trees in 2022 and 2023 seasons.

Treatment	2022				2023			
	Final fruit set (%)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	16.24 k	26.73 gh	29.91 cd	24.29 C	20.00 h	28.75de	27.49 f	25.41 C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	24.70 i	29.07def	27.72 fg	27.16 B	24.43 g	24.43 g	31.13d	26.66BC
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	28.01efg	22.22 j	30.60 c	26.90 B	24.82 g	32.65 c	23.88g	27.12 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	26.66 gh	25.56 hi	29.32cde	27.18 B	23.64 g	27.87ef	26.46 f	25.99BC
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	29.96 cd	33.33 b	38.29 a	33.86 A	29.52 d	35.59 b	45.45 a	36.85 A
Means	25.11 C'	27.38 B'	31.17 A'		24.48 B'	29.86 A'	30.88 A'	
	Yield (Kg/tree)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	10.00 k	11.00 j	13.25 h	11.42 E	17.67 j	19.25 i	20.67 h	19.20 E
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	12.00 i	13.00 h	16.75 e	13.92 D	18.33 ij	21.33 gh	28.33 e	22.66 D
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	13.75 gh	14.50 g	17.00 e	15.08 C	19.33 i	24.00 f	31.67 c	25.00 C
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	15.75 f	16.50 ef	21.00 b	17.75 B	22.33 g	27.67 e	33.00 b	27.67 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	18.00 d	19.00 c	22.50 a	19.83 A	27.67 e	30.00 d	34.67 a	30.78 A
Means	13.90 C’	14.80 B’	18.10 A’		21.07C’	24.45 B’	29.67 A’	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter.

Table (4): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on fruit weight and volume of Picual olive trees in the 2022 and 2023 seasons.

Traetment	2022				2023			
	Fruit weight (g)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	7.49 g	7.81 fg	7.83 efg	7.71 D	8.63 f	8.66 f	8.85 f	8.71 D
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	8.79 bc	9.35 a	8.91 b	9.02 A	8.70 f	9.76 abcd	9.34 de	9.27 C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	8.22 def	8.53 bcd	8.51 bcd	8.42 BC	9.25 ef	9.83 abc	9.60 bcde	9.56 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	8.25 de	8.47 cd	8.43 cd	8.38 C	10.03 ab	10.16 a	10.14 a	10.11 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	8.23 def	8.28 d	8.46 cd	8.32 C	10.13 a	9.55 cde	9.85 bc	9.84 AB
Means	8.20 A’	8.49 A’	8.43 A’		9.35 A’	9.59 A’	9.56 A’	
	Fruit volume (cm^3)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	7.60h	7.80 gh	7.90 fg	7.77 C	8.70 f	8.80 f	9.10 ef	8.87 D
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	8.50 c	9.30 a	9.00 ab	8.93 A	8.80 f	9.90 bcd	9.50 de	9.40 C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	8.00 efgh	8.50 cd	8.60 bc	8.37 B	9.50 de	10.00 abc	9.70 cd	9.73 BC
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	8.10 defg	8.40 cde	8.20 cdefg	8.23 B	10.20 ab	10.40 a	10.30 ab	10.30 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	8.00 efgh	8.10 defg	8.30 cdef	8.13 BC	10.30 ab	9.70 cd	10.10 abc	10.03 AB
Means	8.04 A’	8.42 A’	8.40 A’		9.50 A’	9.76 A’	9.74 A’	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter.

3.4. Fruit flesh weight, seed weight, and flesh/seed ratio

The results shown in Table (6) indicate that during the two study seasons, foliar spraying by zinc sulfate and boric acid alone or in combination with algae extract had a significant effect on the flesh and seed weight of fruit, as well as the flesh/seed ratio. As for the fruit flesh weight, the results showed that there were no significant differences between the different algae concentrations. While, the foliar spraying with $ZnSO_4$ at 1500 ppm + H_3BO_3 at 150 ppm gave the highest flesh weight in the first season, moreover in the second season, the largest value was recorded with ($ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 ppm) compared with other concentrations. As for the interaction between the two experimental factors, the highest flesh weight was recorded with algae extract at 0.1% + $ZnSO_4$ at 1500 ppm + H_3BO_3 at 150 ppm (8.30 g) in the first season and algae extract at 0.2% + $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 ppm (9.32 g) in the second one, respectively.

Table (5): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on fruit length and diameter of Picual olive trees in the 2022 and 2023 seasons.

Treatment	2022				2023			
	Fruit length (cm)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	2.55 c	2.59 c	2.61 bc	2.59 B	2.85 d	2.86 d	2.87 d	2.86 B
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	2.61 bc	2.87 a	2.65 bc	2.71 AB	2.92 cd	3.09 ab	2.95 bcd	2.99 AB
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	2.82 a	2.74 ab	2.88 a	2.81 A	3.09 ab	3.04 abc	3.12 a	3.08 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	2.78 ab	2.77 ab	2.82 a	2.79 A	3.05 abc	3.06 abc	3.07 abc	3.06 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	2.85 a	2.83 a	2.87 a	2.85 A	3.09 ab	3.07 abc	3.11 a	3.09 A
Means	2.72 A’	2.76 A’	2.77 A’		3.00 A’	3.02 A’	3.02 A’	
	Fruit Diameter (cm)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	2.23 c	2.28 abc	2.29 abc	2.27 B	2.30 d	2.33 cd	2.35 bcd	2.33 B
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	2.28 abc	2.38 ab	2.40 a	2.35 AB	2.33 cd	2.46 ab	2.49 ab	2.43 AB
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	2.24 c	2.30 abc	2.27 bc	2.27 B	2.38 bcd	2.46 ab	2.45 abc	2.43 AB
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	2.39 ab	2.42 a	2.40 a	2.41 A	2.51 a	2.53 a	2.52 a	2.52 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	2.37 ab	2.32 abc	2.35 abc	2.35 AB	2.51 a	2.44 abc	2.48 ab	2.48 A
Means	2.31 A’	2.34 A’	2.34 A’		2.41 A’	2.44 A’	2.46 A’	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter.

Regarding the same table, as for fruit seed weight, the data showed that there were no significant differences between the different algae concentrations in the first season, but in the second one the tree spray with algae extract at 0.2% demonstrated the lowest value in this regard. As for the treatment with zinc sulfate and boric acid, the results showed that foliar spraying $ZnSO_4$ at 1500 ppm + H_3BO_3 at 150 ppm recorded the minimum seed weight in the first study season, however in the second one, spraying by $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 gave the lowest seed weight. Concerning how the two experimental factors interact, it was found that the best treatment was algae extract at 0.2% + $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 ppm, which gave the lowest seed weight in the two studied seasons, and the values were 0.86 g and 0.82 g, respectively.

As for the percentage of fruit flesh to seed, the results in Table (6) showed that spraying with algae extract at 0.2% gave the highest value compared to the low concentration during the two study seasons. As well as, as for the zinc sulfate and boric acid factor, it became clear that the trees sprayed with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 increased the maximum flesh/seed ratio during the two experimental seasons. Meanwhile, the trees treated with algae extract at 0.2% + $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm showed the largest flesh/seed ratios regarding the interaction impact, where the values were 8.80 in the first season and 11.37 in the second one, respectively.

Table (6): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on fruit flesh weight, seed weight, and flesh/seed ratio of Picual olive trees in the 2022 and 2023 seasons.

Treatment	2022				2023			
	Fruit flesh weight (g)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	6.63 e	6.56 e	6.54 e	6.58 C	7.64 fg	7.54 g	7.75 fg	7.64 C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	7.91 b	8.30 a	7.59 bc	7.93 A	7.42 g	8.57cd	8.20de	8.06 C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	7.56 bc	7.52 c	7.14 d	7.41 B	8.08 ef	8.70 bc	8.62 bcd	8.47 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	7.57 bc	7.57bc	7.27 cd	7.47 B	9.04 ab	9.24 a	9.32 a	9.20 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	7.35 cd	7.13 d	7.32 c	7.27 B	9.29 a	8.37 c	8.78 b	8.81 AB
Means	7.40 A’	7.4 A’	7.1 A’		8.29 A	8.48 A	8.53 A	
	Fruit seed weight (g)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	0.95 hi	1.25 a	1.20 ab	1.13 A	0.99 g	1.12 def	1.10 ef	1.07 BC
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	1.20 ab	1.05 ef	1.00 fgh	1.08AB	1.28 a	1.19 b	1.14 bcde	1.20 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	1.08 de	1.01 fg	0.95 hi	1.01 C	1.17 bcd	1.13 cde	0.98 g	1.09 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	0.98 g	0.90 i	0.86 j	0.91 D	0.99 g	0.92 h	0.82 i	0.91 D
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	0.91 ij	1.15bc	1.11 cd	1.06BC	0.84 i	1.18 bc	1.07 f	1.03 C
Means	1.02 A’	1.07A’	1.02A’		1.05AB’	1.11A’	1.0 B’	
	Flesh /Seed ratio							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	6.88 e	5.25 h	5.53 h	5.89 D	7.72 e	6.73 g	7.05fg	7.16 D
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	6.33 fg	7.90 c	7.91 c	7.38 B	5.80 h	7.20 f	7.19 f	6.73 E
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	6.61 ef	7.45 d	7.96 c	7.34 B	6.91 fg	7.70 e	8.80 c	7.80 C
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	7.42 d	8.41 b	8.80 a	8.21 A	9.13 c	10.04b	11.37a	10.18A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	8.04 c	6.20 g	6.62ef	6.96 C	11.06 a	7.09 g	8.21 d	8.79 B
Means	7.06 A’	7.04A’	7.36A’		8.12AB’	7.75B’	8.52A’	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter .

3.5. Fruit moister and oil content

The findings displayed in Table (7) demonstrate that foliar spraying with zinc sulfate and boric acid alone or in conjunction with algal extract had a significant effect on fruit moister and oil content during the course of the two study seasons. The data showed that there were no significant differences between the algae extract treatments on fruit moister percentage of the fruit during the two study seasons. Otherwise, it also became clear that spraying with zinc sulfate and boric acid did not record significant differences between the treatments during the first season, but in the second season, the untreated trees recorded the highest moisture percentage with no significant differences among the treatments. Furthermore, the untreated trees and trees treated with algae extract at 0.2% + $ZnSO_4$ at 1500 ppm + H_3BO_3 at 150 ppm gave the highest values regarding the interaction effect in the first season, where the values were 66.36% and 66.61% respectively. While the maximum percentage was recorded by untreated trees (67.39%) Compared to other sprayed trees in the second season.

As for fruit oil content, the results in the same table cleared that spraying with algae extract at 0.1% gave the highest value with no significant difference to the high concentration during the two study seasons. As well as, as for the zinc sulfate and boric acid factor, the data cleared that the trees sprayed with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 recorded the maximum fruit oil percentage with no significant difference to the other treatments in the two experimental seasons. Meanwhile, as for the interaction between the two experimental factors, the highest oil percentages were recorded with foliar spraying by algae extract at 0.2% + $ZnSO_4$ at 1500 ppm + H_3BO_3 at 300 ppm in the two study seasons, and the percentages were 39.77% and 39.93%, respectively.

Table (7): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on fruit moister and oil content of Picual olive trees in 2022 and 2023 seasons.

Treatment	2022				2023			
	Fruit moister content (%)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	66.36 a	62.94 bcd	63.70 abc	64.30 A	67.39 a	63.55 bcd	64.23 abcd	65.06 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	63.86 abc	63.12 bcd	66.61 a	64.53 A	64.27 abcd	63.11 bcde	66.40 ab	64.59 AB
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	62.50 cd	64.40 abc	64.81 abc	63.90 A	61.73 de	64.41abcd	65.08 abc	63.74 AB
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	66.07 ab	63.54 abc	64.54 abc	64.72 A	65.77 abc	63.79 bcd	64.36 abc	64.64 AB
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	64.31 abc	60.26 d	60.46 d	62.01 A	62.87 cde	60.06 e	61.56 de	61.50 AB
Means	64.62 A’	62.83 A’	64.22 A’		64.41 A’	62.98A’	64.33A’	
	Fruit oil content (%)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	33.40 de	36.80 c	32.63 de	34.28 A	33.07 ef	39.80 a	33.00 ef	35.29 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	37.47 bc	33.07 de	33.13 de	34.56 A	38.93 ab	33.37 ef	33.07 ef	35.12 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	32.19 e	32.40 ef	39.77 a	34.79 A	32.20 f	33.57 ef	39.93 a	35.23 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	34.23 d	33.43 de	34.17 d	33.94 B	36.70 c	34.73 de	35.70 cd	35.71 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	33.33 def	38.57 ab	33.90 de	35.27 A	32.80 ef	38.50 ab	37.15 bc	36.15 A
Means	34.12 A’	34.85 A’	34.72 A’		34.74 A’	35.99 A’	35.77 A’	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter.

3.6. Leaf mineral content

The data shown in Table (8) revealed that during the two study seasons, foliar spraying by zinc sulfate and boric acid alone or in combination with algae extract had a significant effect on leaf content of nitrogen, potassium, zinc, and boron. As for leaf content of nitrogen, the results showed that the trees spraying with algae extract at 0.1% or 0.2% gave the highest values in the first season, meanwhile in the second one; the highest percentage was recorded with algae extract at 0.1%. The foliar spraying with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm gave the highest leaf content of nitrogen in the two experimental seasons compared with other concentrations. In addition, the trees treated with algae extract at 0.2% + $ZnSO_4$ at 1500 ppm + H_3BO_3 at 150 ppm showed the maximum percentages of nitrogen in leaf regarding the interaction impact, where the values were 2.77% in the first season and 2.54% in the second one, respectively.

Concerning the same table, as for fruit leaf content of potassium, the data showed that the trees sprayed by algae extract at 0.2% were recorded as the highest value in the two study seasons. As for the treatment with zinc sulfate and boric acid, the results showed that foliar spraying $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm recorded the maximum percentages in both study seasons. Concerning how the two experimental factors interact, it was found that the best treatment was algae extract at 0.2% + $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm, which gave the highest leaf content of potassium, and the values were 1.09% and 0.65% in the two studied seasons, respectively.

As for the leaf content of zinc, the results in Table (9) showed that spraying with algae extract did not affect the zinc values in the leaves during both study seasons. As well as, as for the zinc sulfate and boric acid factor, the data cleared that, the trees sprayed with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 gave the highest leaf content of zinc during both experimental seasons. On the same side, the trees treated with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 ppm + zero algae extract showed the largest value regarding the interaction impact, where the values were 95.00 ppm in the first season and 94.70 ppm in the second one, compared with other interaction treatments.

Table (8): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on nitrogen and potassium percentage of Picual olive leaves in 2022 and 2023 seasons.

Treatment	2022				2023			
	N%							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	0.58 j	1.89 e	1.51 h	1.33D	1.06 h	1.79 d	1.39 g	1.41C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	1.76 fg	1.76 fg	2.77 a	2.10B	1.59 f	1.69 e	2.54 a	1.94 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	1.84 ef	2.70 ab	1.69 g	2.08BC	1.72 de	2.41 b	1.34 g	1.82 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	2.02 d	1.26 i	2.70 ab	1.99 C	1.96 c	1.34 g	2.51 a	1.94 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	2.60 bc	2.57 c	1.51 h	2.23A	2.47 ab	2.39 b	1.39 g	2.08 A
Means	1.76 B	2.04A’	2.04 A’		1.76 B	1.92 A’	1.83 AB’	
	K%							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	0.71 i	0.82 fgh	1.02 bc	0.85 C	0.45 h	0.50 fg	0.51 fg	0.49 C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	0.83 fg	0.78 hi	1.04 abc	0.88 C	0.52 fg	0.49 g	0.53 ef	0.51 C
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	0.86 ef	0.81 gh	1.06 ab	0.91 B	0.56 de	0.52 fg	0.59 bc	0.56 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	0.94 d	0.83 fg	1.07 ab	0.95 B	0.59 bcd	0.53 ef	0.61 bc	0.58 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	1.01 c	0.95 d	1.09 a	1.02 A	0.62 ab	0.58 cd	0.65 a	0.62 A
Means	0.87 B’	0.84 B’	1.06 A’		0.55 AB	0.52 B	0.58 A	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter.

Table (9): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on zinc and boron content of Picual olive leaves in 2022 and 2023 seasons.

Treatment	2022				2023			
	Zn (ppm)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	30.60 k	32.10 k	38.30 j	33.67 C	36.00 j	37.00 ij	39.40 i	37.47 E
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	78.70 de	77.00 e	67.60 g	74.43 B	69.50 e	64.80 f	61.70 f	65.33 D
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	89.90 b	73.40 f	59.20 h	74.17 B	96.10 a	77.20 c	51.60 g	74.97 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	95.00 a	90.25 b	80.00 de	88.42 A	94.70 a	88.50 b	75.80 d	86.33 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	87.00 b	81.90 cd	44.20 i	71.03 B	90.00 b	79.70 c	43.50 h	71.07 C
Means	76.24 A	70.93 B	57.86 C		77.26 A’	69.44 B’	54.40 C’	
	B (ppm)							
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	26.40 g	27.35 efg	26.22 g	26.66 C	27.82 efgh	28.45 efg	27.02 ghi	27.76 B
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	31.41 b	27.90 ef	26.65 fg	28.65 B	30.61 cd	29.28 de	26.43 hi	28.77 B
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	28.31 de	29.60 cd	25.90 g	27.94 BC	28.60 ef	30.31 cd	25.75 i	28.22 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	32.65 ab	30.55 c	30.38 c	31.19 A	32.90 b	31.42 bc	30.40 cd	31.57 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	33.30 a	30.73 c	27.15 efg	30.39 A	34.85 a	31.70 bc	27.50 fgh	31.35 A
Means	30.41 A’	29.23 A’	27.26 B		30.96 A	30.23 A	27.42 B	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter.

As for leaf content of boron, the results in the same table cleared that spraying with algae extract at 0.1% and without algae extract treatment gave the highest values compared with the high concentration during the two study seasons. As well as, as for the zinc sulfate and boric acid factor, the data cleared that the trees sprayed with $ZnSO_4$ at 3000 ppm + H_3BO_3 at 150 or $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 gave the maximum leaf content of boron in the two experimental seasons. Meanwhile, as for the interaction between the two experimental factors, the highest value was recorded with foliar spraying by $ZnSO_4$ at 3000 ppm + H_3BO_3 at 300 ppm + zero algae extract in the two study seasons, and the values were 33.30 ppm and 34.85 ppm, respectively.

3.7. Chemical characteristics of olive oil

The provided figure presents the acid value, peroxide value, and iodine value of olive oil samples subjected to various foliar treatments with algae extract, boric acid, and zinc sulfate. These parameters are crucial indicators of olive oil quality and can be influenced by various factors, including cultivar, environmental conditions, and treatment applications. By analyzing these values and comparing them to previous studies, we can gain insights into the effects of the treatments on olive oil quality.

3.7.1. Acid Value

Data in Table (10) and Figure (1) showed that the acid value measures the amount of free fatty acids present in the oil, which is an indicator of oil quality and stability. A lower acid value is desirable, as it suggests a lower degree of hydrolytic rancidity and better oil quality. The acid values across the treatments range from 1.13 to 1.52 mg/g. The control sample has an acid value of 1.33 mg/g, which is within the acceptable range for virgin olive oil (≤ 2 mg/g) according to the International Olive Council (IOC) standards. Treatments with 1500 ppm $ZnSO_4$ + 150 ppm H_3BO_3 (1.13 mg/g) and 1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 (1.52 mg/g) show the lowest and highest acid values, respectively. The lower acid value in the 1500 ppm $ZnSO_4$ + 150 ppm H_3BO_3 treatment suggests that this combination may help maintain oil quality by reducing the formation of free fatty acids.

3.7.2. Peroxide Value

The peroxide value measures the degree of primary oxidation in the oil, which is an indicator of freshness and storage conditions. A lower peroxide value is desirable, as it indicates a lower degree of oxidation and better oil quality. In table (10) and figure (1) the peroxide values across the treatments range from 10.45 to 16.61 meq./Kg. The control sample has a peroxide value of 12.85 meq./Kg, which is within the acceptable range for virgin olive oil (≤ 20 meq./Kg) according to IOC standards. The treatment with 1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.2% algae extract shows the lowest peroxide value (10.45 meq./Kg), suggesting that this combination may help protect the oil from oxidation and maintain its freshness. The highest peroxide value is observed in the 3000 ppm $ZnSO_4$ + 150 ppm H_3BO_3 treatment (16.61 meq./Kg), indicating a higher degree of oxidation compared to other treatments.

3.7.3. Iodine Value

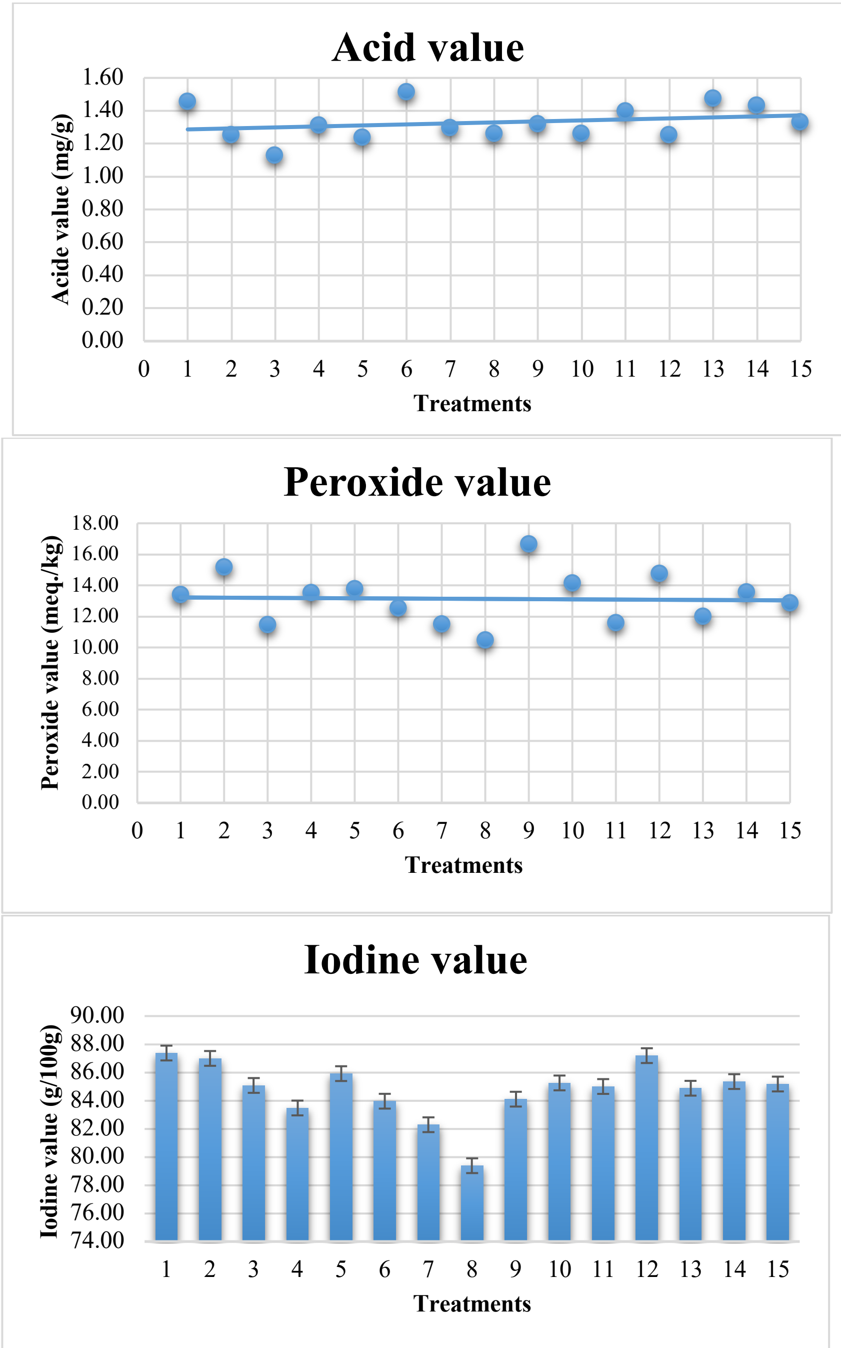
The iodine value measures the degree of unsaturation in the oil, which is related to its stability and health benefits. A higher iodine value indicates a higher degree of unsaturation and a more favorable fatty acid profile. Results in table (10) and figure (1) showed that the iodine values across the treatments range from 79.38 to 87.38 g/100g. The control sample has an iodine value of 85.18 g/100g, which is within the typical range for Picual olive oil (80-90 g/100g) according to previous studies [29]. The treatment with 0.1% algae extract shows the highest iodine value (87.38 g/100g), suggesting a higher degree of unsaturation and potentially more favorable health benefits. The lowest iodine value is observed in the 1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.2% algae extract treatment (79.38 g/100g), indicating a lower degree of unsaturation compared to other treatments. The application of specific nutrients, such as zinc sulfate and boric acid, has been shown to impact oil quality parameters. For instance, studies have demonstrated that the availability of these nutrients can influence the formation of free fatty acids and the degree of oxidation in olive oil [30].

Table (10): Effect of foliar spraying with algae extract, zinc sulfate, and boric acid on acid value, peroxide, and iodine value of Picual olive oil in an average of two seasons.

Treatment	Acid value				Peroxide value (meq/kg oil)			
	(Control) algae	0.1% algae	0.2% algae	Means	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	1.33 de	1.46 abc	1.25 f	1.35 A	12.85 fg	13.35 e	15.14 b	13.78 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	1.13 g	1.31 e	1.24 f	1.23 B	11.42 i	13.50 def	13.73 de	12.88 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	1.52 a	1.30 ef	1.26 f	1.36 A	12.51 gh	11.49 i	10.45 j	11.48 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	1.32 ef	1.26 f	1.40 cd	1.33 A	16.61 a	14.12 cd	11.57 i	14.10 A
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	1.26 f	1.48 ab	1.43 abc	1.39 A	14.75 bc	11.95 hi	13.52 de	13.41 A
Means	1.31 A'	1.36 A'	1.32 A'		13.63 A'	12.88 B'	12.88 B'	

	Iodine value (mg/kg oil)			
	(Control) algae	0.1% algae	0.2% algae	Means
(Control) $ZnSO_4$ or H_3BO_3	85.18 ab	87.38 a	87.00 a	86.52 A
$ZnSO_4$ (1500 ppm) + H_3BO_3 (150 ppm)	85.08 ab	83.48 abc	85.92 ab	84.83 AB
$ZnSO_4$ (1500 ppm) + H_3BO_3 (300 ppm)	83.96 ab	82.29 bc	79.38 c	81.88 B
$ZnSO_4$ (3000 ppm) + H_3BO_3 (150 ppm)	84.10 ab	85.26 ab	85.00 ab	84.79AB
$ZnSO_4$ (3000 ppm) + H_3BO_3 (300 ppm)	87.19 a	84.88 ab	85.35 ab	85.81 AB
Means	85.10 A'	84.66 A'	84.53 A'	

The means do not differ at the 5% level in any column, row, or interaction that contains a similar letter or letter.



Treatments:
1=algae extract 0.1%
2= algae extract 0.2%
3= $ZnSO_4$ 1500 ppm + H_3BO_3 150 ppm
4= algae extract 0.1% + ($ZnSO_4$ 1500 ppm + H_3BO_3 150 ppm)
5= algae extract 0.2% + ($ZnSO_4$ 1500 ppm + H_3BO_3 150 ppm)
6= $ZnSO_4$ 1500 ppm + H_3BO_3 300 ppm
7= algae extract 0.1% + ($ZnSO_4$ 1500 ppm + H_3BO_3 300 ppm)
8= algae extract 0.2% + ($ZnSO_4$ 1500 ppm + H_3BO_3 300 ppm)
9= $ZnSO_4$ 3000 ppm + H_3BO_3 150 ppm
10= algae extract 0.1% + ($ZnSO_4$ 3000 ppm + H_3BO_3 150 ppm)
11= algae extract 0.2% + ($ZnSO_4$ 3000 ppm + H_3BO_3 150 ppm)
12= $ZnSO_4$ 3000 ppm + H_3BO_3 300 ppm
13= algae extract 0.1% + ($ZnSO_4$ 3000 ppm + H_3BO_3 300 ppm)
14= algae extract 0.2% + ($ZnSO_4$ 3000 ppm + H_3BO_3 300 ppm)
15= Control (without treatment)

Fig (1): Chemical characteristics of extracted olive oil (acid, peroxide, and iodine values) resulting from the interaction between treatments of algae extract and (boric acid + zinc sulfate).

The findings in Table (10) and Figure (1) from the current study suggest that foliar treatments with algae extract, boric acid, and zinc sulfate can influence the quality parameters of Picual olive oil. The combination of 1500 ppm $ZnSO_4$ + 150 ppm H_3BO_3 shows promising results in maintaining a low acid value, while the treatment with 1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.2% algae exhibits a low peroxide value, indicating better protection against oxidation. The 0.1% algae extract treatment yields the highest iodine value, suggesting a more favorable fatty acid profile. These results contribute to the understanding of how specific nutrient applications can optimize olive oil quality. Future research could further explore the underlying mechanisms and interactions between nutrients, cultivars, and environmental factors to develop targeted strategies for improving olive oil quality and stability.

3.7.4. Changes in the fatty acid composition of Picual olive oil extracted from olive fruits

The study of the effects of foliar spraying with algae extract, boric acid, and zinc sulfate on the fatty acid composition of Picual olive oil provides valuable insights into how these treatments can modify the nutritional profile of olive oil. This analysis can be contextualized by reviewing previous research on fatty acid composition in olive oil, which highlights the importance of various factors including cultivar, environmental conditions, and specific treatment applications. Olive oil is predominantly composed of monounsaturated fatty acids (MUFAs), particularly oleic acid (C18:1), which is associated with numerous health benefits, including reduced cholesterol levels and anti-inflammatory properties. In contrast, polyunsaturated fatty acids (PUFAs) like linoleic acid (C18:2) and alpha-linolenic acid (C18:3) are also present but in lower quantities. The balance between saturated fatty acids (SFAs) and unsaturated fatty acids (UFAs) is crucial for determining the oil's quality and health benefits. The results from the provided Table (11) indicate that different treatments significantly affect the fatty acid composition of Picual olive oil.

Table (11): Effect of foliar spraying interaction between algae extract, zinc sulfate, and boric acid on the fatty acid's composition of Picual olive oil extracted from olive fruits in the average two seasons.

Treatments	Fatty acids									
	C14:0	C16:0	C16:1	C17:0	C18:0	C18:1	C18:2	C18:3	SFA	UFA
0.1% algea	ND	17.07	3.85	2.04	1.38	65.01	8.44	2.21	20.49	79.51
0.2% algea	ND	17.29	2.89	ND	2.14	68.77	7.22	1.70	19.43	80.58
1500 ppm $ZnSO_4$ + 150 ppm H_3BO_3	ND	17.23	3.22	0.57	2.57	67.19	8.47	0.74	20.37	79.62
1500 ppm $ZnSO_4$ + 150 ppm H_3BO_3 + 0.1% algea	ND	18.39	3.63	0.86	3.27	64.04	8.86	0.95	22.52	77.48
1500 ppm $ZnSO_4$ + 150 ppm H_3BO_3 + 0.2% algea	ND	17.54	3.32	0.47	1.49	67.89	8.62	0.67	19.50	80.5
1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3	0.03	17.61	3.46	0.67	3.85	64.03	9.53	0.82	22.16	77.84
1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.1% algea	0.16	18.4	3.50	0.94	3.89	63.47	8.87	0.76	23.39	76.60
1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.2% algea	0.27	18.98	3.10	1.43	3.93	64.33	7.95	0.01	24.61	75.39
3000 ppm $ZnSO_4$ + 150 ppm H_3BO_3	0.500	18.48	3.87	1.40	2.05	63.24	9.35	1.12	22.43	77.58
3000 ppm $ZnSO_4$ + 150 ppm H_3BO_3 + 0.1% algea	0.30	17.22	3.53	0.84	3.56	63.28	9.93	1.34	21.92	78.08
3000 ppm $ZnSO_4$ + 150 ppm H_3BO_3 + 0.2% algea	0.80	17.96	3.82	0.72	3.13	61.72	10.36	1.48	22.61	77.38
3000 ppm $ZnSO_4$ + 300 ppm H_3BO_3	0.14	17.54	3.80	ND	2.24	64.93	10.1	1.25	19.92	80.08
3000 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.1% algea	0.87	18.64	3.54	0.70	2.86	62.37	8.90	2.12	23.07	76.93
3000 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.2% algea	0.82	16.85	3.29	0.29	2.57	66.31	9.07	0.81	20.53	79.48
Control (without treatment)	0.77	16.65	3.19	0.44	3.20	65.16	9.77	0.82	21.06	78.94

The SFA content across treatments varies, with the control sample showing a moderate level (78.94%). Treatments with higher concentrations of algae extract tend to reduce SFA, particularly the combination of 1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.2% algae, which results in the lowest SFA at 75.39%. This suggests that algae extract may promote a shift towards more unsaturated profiles. The UFA content increases in several treatments compared to the control. For instance, the treatment with 1500 ppm $ZnSO_4$ + 300 ppm H_3BO_3 + 0.2% algae yields a UFA content of 24.61%, significantly higher than the control's 21.06%. This enhancement in UFA is beneficial, as oils with higher UFA content are preferred for their health benefits. Previous studies have demonstrated the variability of fatty acid composition in olive oils based on several factors:

A) Genetic Variability: Research indicates that the olive cultivar plays a significant role in determining fatty acid profiles. For example, studies on various cultivars have shown that oleic acid content can range widely, with some cultivars exhibiting exceptionally high levels of oleic acid [31,32]. The Picual variety is known for its high oleic acid content, which aligns with the findings of the current study.

B) Environmental Factors: Environmental conditions, including climate and soil type, also influence fatty acid composition. For instance, studies have shown that olive oils from different geographical regions exhibit distinct fatty acid profiles due to variations in climate and cultivation practices [33,34].

C): Treatment Effects: The application of specific nutrients, such as boron and zinc, has been shown to impact fatty acid synthesis in olive fruits. For example, the expression of fatty acid desaturase genes, which are crucial for unsaturated fatty acid production, can be influenced by nutrient availability [30]. This aligns with the current study's findings that the combination of nutrients and algae extract can enhance the UFA content in olive oil.

The findings from the current study contribute to a growing body of literature that emphasizes the importance of foliar treatments in modifying the fatty acid composition of olive oil. The observed increase in UFA and decrease in SFA with specific treatments suggests a potential strategy for improving the nutritional quality of olive oil. Future research could further explore the underlying biochemical mechanisms, including the role of fatty acid desaturase enzymes and the impact of environmental factors on fatty acid composition, to optimize olive oil production for health benefits.

The present results showed a significant improvement in tree productivity, physical fruit properties, and fruit oil content, as well as an improvement in oil properties as a result of foliar spraying with algae extract, zinc sulfate, and boric acid. This can be explained by the fact that the materials used in the experiment have significant physiological effects within plants, and these materials play a major role in completing many vital processes within the plant. As algae extract contains many nutrients necessary for plant growth, such as nitrogen, potassium, phosphorus, iron, zinc, and others. Algae extract also contains many plant hormones important for the growth and development of fruits, such as cytokinin and zeatin, as well as many vitamins and polyamines. All of these compounds significantly increase the productivity of tree crops [3,35]. Zinc also contributes too many physiological roles, as it works primarily in the synthesis of the amino acid tryptophan, and it is involved in the work of many enzymes, including enzymes responsible for cell division, and it also plays a major role in the process of photosynthesis [10]. The positive results of the study are also due to the important physiological roles of boron, which plays a major role in the flowering stage, helping pollen grains to germinate and pollen tubes to elongate, which increases the percentage of fruit set [36]. Also, Marschner [10] supported this and confirmed that boron plays a role in activating some enzymes, transporting sugars, and synthesizing some plant hormones.

The results obtained are consistent with those of Hassan *et al.* [2] regarding the enhancement effect of spraying algae extract on research parameters, which explained that foliar spraying with algae extract at a concentration of 0.4% with Moringa leaf extract in December led to an increase in the percentage of fruit set, yield, percentage of oil in the fruits, and chemical properties of the oil (acidity percentage and peroxide value) on Picual olive trees. In this minor, Al-Musowi [7] reported that spraying orange trees with algae extract at a concentration of 3% in early October and November led to an improvement in the length and width of the fruits, as well as the weight and size of the fruits, and the chemical properties of the fruit juice also improved. In another study on date palms, the inflorescences were sprayed with algae extract at different concentrations of potassium nitrate. It was observed that all treatments led to an increase in the yield and improved the physical and chemical properties of the fruits [8]. These results are in agreement with those of studies on mango trees conducted by Adel [37], Ahmed *et al.* [38], and Abd El-Motty and Abd El-Migeed [39], these studies found that spraying mango trees with algae extracts alone or combined with plant extracts from natural sources significantly improved fruit set, fruit retention, yield, and improved fruit quality.

The current results concur with those found by El Gammal [16] investigated that, foliar spraying with zinc sulfate at 6 g/L and boric acid at 4.5 g/L led to a significant increase in the yield and improved the weight, volume, length, and diameter of fruit, the oil content of the fruits increased and the acidity of the oil decreased. Furthermore, Gholami *et al.* [18] reported that, in a different study on several olive cultivars foliar spraying with boron, zinc, and potassium four times beginning from flowering improved the fruit characteristics under investigation, with distinct variations in each cultivar's response. In another study, Sayyad-Amin and Shahsavar [40] studied the effect of zinc sulfate, boric acid, and urea on the weight, size, length, and diameter of olive fruits. He found that spraying with these materials had positive effects on the physical characteristics of the fruits. On the same side, Sayyad-Amin *et al.* [17] found that fruit set, crop yield, and fruit oil quantity increased significantly when sprayed with zinc sulfate + boric acid with urea on olive trees at the stage of full flowering. In the same respect, the results of the experiment were consistent with another study conducted on three olive varieties, where Saadati *et al.* [41] and Atteya *et al.* [42] sprayed the trees with boric acid and zinc sulfate at two different times. He noticed that the oil content of the fruits increased significantly, and the treatments also enhanced the ratio of unsaturated/saturated fatty acids, recording the lowest level of palmitic acid and the highest level of oleic acid compared to untreated trees.

4. Conclusion

In conclusion, it is possible to infer from the data described above that, the application of algae extract, zinc sulfate and boric acid spraying on olive trees had positive effects on most of the experimental measurements. The results showed that spraying trees with algae extract along with zinc sulfate + boric acid gave the highest positive results than using the experimental factors separately. It was noted that the final fruit set percentage, crop quantity, fruit oil percentage, and average fruit weight and size increased significantly with treatment with algae extract at 0.2% + zinc sulfate at 3000 ppm + boric acid at 300 ppm compared to the rest of the concentrations. The results also showed that most of the experimental treatments had a positive effect on oil properties such as acidity, peroxide number, iodine number, and unsaturated fatty acids compared to untreated trees. So, it can be recommended to apply these treatments to olive trees planted in lands with the same conditions.

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