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Impact of Some Macro and Micro Nutrients on Productivity and Oil Properties of Coratina Olive Trees

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Abstract

This experiment was conducted in two successive seasons (2018, 2019) on Coratina olive trees planted in a private orchard located at El Khatatbah district, El Behera governorate, Egypt; to study the effect of potassium dihydrogen phosphate (KH_2PO_4), magnesium sulphate ($MgSO_4$) and boric acid (H_3BO_3) on olive yield per tree, fruit quality, also content and characteristics of fruit oil. The treatments were applied twice in September and November of each season. Generally, using any of the treatments under this investigation is led to increase the fruit yield per trees, and the fruit physical characteristics, also the oil accumulation percentage in the fruits, with maintaining its characteristics and quality as extra-virgin olive oil, compared to the untreated trees (control). However, treating the trees with magnesium sulphate alone recorded the highest fruit yield in the first season compared to the control. While, treating trees with potassium dihydrogen phosphate + boric acid + magnesium sulphate treatment, led to the highest oil percentage in the fruits, in the second season.

Keywords: Coratina; olive; fruit quality; olive oil; potassium dihydrogen phosphate; magnesium sulphate; boric acid.

1. Introduction

The worldwide olive oil consumption has increased up to 73% over the last 25 years which encourages the producers to increase its quality and quantity.

Low productivity of olive trees grown in sandy soil is a serious problem in Egypt, as evidenced by the new introduced varieties Koroneiki, Boutillan and Arbequina, which are related to water requirements, pruning and harvesting, planting density, and fertilization, particularly the method and doses of fertilizers [1]. The availability of nutrients is strongly influenced by soil properties. Clay soils, for example, have a high Potassium (K) fixing capacity and so show minimal reaction to K fertilizers added to the soil because much of the available K is quickly fixed to the clay particles [2]. If the mineral has been leached with excessive irrigation and/or rainfall in sandy soils, application has absolutely little impact [3].

Nutritional absorption is influenced by the availability of nutrients in the root system, as well as the nutrient need level and uptake period [4]. A high magnesium concentration in the soil inhibited plant calcium absorption, implying that plants grown in such conditions may soon suffer from calcium deficiency [5]. Magnesium and calcium, as well as potassium and magnesium, have antagonistic relationships [6]. Excessive potassium application might have adverse or antagonistic effects on calcium and magnesium absorption due to potassium accumulation in the soil, and that the intensity of this impact on plants depended on plant variety and soil type [7]. It's possible that the negative interaction between potassium and magnesium consumption is due to their effects on leaves' sodium content [8].

Foliar application of fertilizers is generally beneficial in fulfilling plant needs and provides a quick way to restore nutrient deficits in plants. Furthermore, it is a convenient way to apply highly soluble fertilizers, especially in smaller doses; [9, 10].

Because of potassium, as a mineral osmosis, plays an important role in osmotic and pressure regulation, it is considered an essential element in higher plants. This element is crucial for cell expansion, plant development, and, lastly, the opening and shutting of stomata on leaves [11]. This element is also important for the activation of several photosynthetic enzymes, protein synthesis, oxidative metabolism,

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and the electrical balance of plant cell membranes [12]. Potassium, more than any other macro-element, is thought to enhance flowering [13], since it promotes the production of amino acids, which stimulate the creation of indole acetic acid (IAA) oxidase, which accelerates flower induction [14, 15]. As a result, potassium is critical to olive yield, quality and oil yield [16]. Olive needs a high K supply due to the high K concentration in the olive fruit [17]. Foliar treatment with potassium nitrate at 4% increased Picual olive fruit vegetative growth, nutritional status, productivity, fruit quality, and flesh oil content [18].

Magnesium is an important nutrient that aids in the development and creation of numerous sink organs, such as roots and seeds. Furthermore, in many horticultural crop species, fertilization has a significant influence on several physiological processes and productivity. Nonetheless, adequate foliar supply is critical for plant physiological and biochemical activities such as carbohydrate metabolism, enzyme activation, protein synthesis, and electricity transmission [19].

Magnesium foliar application plays an important role in the biochemical and physiological cycle of plants [20], for example, in the initiation of starch metabolism, protein synthesis, and electricity transfer. Magnesium acts as an impetus in the oxidation and reduction responses within plant tissues, and enhances plant resistance to drought [21].

Magnesium deficit during the plant development lowers yield and reduces quality [22]. Spraying magnesium sulphate four times on Manzanillo olive trees, led to a considerable increase in shoot and leaf development [23]. In January, olive trees receiving magnesium sulphate fertilizer (12-24 g/tree/year) showed an improvement in magnesium levels, as well as a substantial improvement in vegetative growth, flowering density, fruit set, and yield [24].

On the other hand, most soils have relatively low boron concentration, which is an issue. Plants can only use soluble boron in soils, which accounts for around 10% of the total soil boron concentration. Multiple factors contribute to boron deficit, including reduced soluble boron availability in the soil, weather conditions (drought, excessive precipitation), boron leaching, calcareous soils, and the cultivated crop species. Boron is involved in a variety of plant processes, including hormone transport, activated salt absorption, flowering and fruiting, and pollen germination, particularly its effects on pollen tube development directionality [25]. In addition, boron appears to play a significant role in fruit set [26], sugar and carbohydrate transport and synthesis. Boron deficiency reduces pollen production and results in poor fruit set in the olive plant's reproductive organs. Cuticle, cuticular cracks and imperfections, stomata, trichomes, and specialized epidermal cells all play a role in foliar absorption of liquid solutions.

The consumption of extra virgin olive oil(EVOO) is currently gaining popularity due to its nutritional and health-promoting properties, which have been linked to the optimal balance of saturated, monounsaturated (MUFA), and polyunsaturated (PUFA) fatty acids, as well as minor components such as sterols, chlorophyll, polyphenols, and tocopherols; [27, 28].

Several studies showed that the beneficial properties of extra-virgin olive oil (EVOO) are due to the phenolic component [29] that confers to the EVOO free radical scavenging activity. Olive oils contain different classes of phenolic compounds such as cinnamic (caffeic acid and p-coumaric acid) and benzoic (vanillic acid) acids, phenyl ethyl alcohol (hydroxytyrosol and tyrosol), secoiridoids (oleuropein and ligtroside derivatives) and flavones (apigenin and luteolin), [30 - 32]. The main polyphenol in EVOO, hydroxytyrosol is a Reactive Oxygen Species (ROS) scavenger that reduces oxidized Low Density Lipoprotein (LDL) and platelets aggregations [33]. Oleuropein is an anti-inflammatory molecule that promotes nitric oxide production in macrophages [34]. Oleocanthal exerts anti-inflammatory properties similar to ibuprofen [35]. Polyphenols-rich EVOO is able to reduce heterocyclic amines and plasmatic C-reactive protein levels [36, 37], and ameliorate lipid metabolism and platelets function [38, 39], as well as glycaemia and insulin sensitivity [40]. Most of the phenolic compounds effects are due to their in vivo bioavailability [41].

The present study was carried out to improve the productivity and quality of olive fruit and olive oil of Coratina cultivar by foliar spray of potassium, magnesium and boron.

2. Experimental

2.1. Plant material

This experiment was carried out during 2018 and 2019 seasons on 36 years old Coratina olive trees in a private orchard located at El Behera governorate, Egypt. Trees were planted in a sandy soil under drip irrigation system, and they were almost similar in vigor and planted at 6.5 × 6.5 meters apart.

The experimental trees had received the same horticultural practices that suitable for tree age and the area weather conditions according to Ministry of Agriculture and Land Reclamation recommendation.

2.2. Treatments

Foliar applications with potassium dihydrogen phosphate (KH_2PO_4) [known as mono potassium phosphate (MKP)] at 1%, magnesium sulfate ($MgSO_4$) at 0.5 % and boric acid (H_3BO_3) at 500 ppm, were sprayed solely or in combinations. Trees were sprayed twice a year, in July and September. Eight treatments were arranged in three replicates on one tree plot as follows:

1- (Control): Water spray only
2- (Mg): $MgSO_4$ at 0.5 %
3- (MKP): KH_2PO_4 at 1%
4- (B): H_3BO_3 at 500 ppm
5- (Mg + MKP): $MgSO_4$ at 0.5 % + KH_2PO_4 at 1%
6- (Mg + B): $MgSO_4$ at 0.5 % + H_3BO_3 at 500 ppm
7- (MKP + B): KH_2PO_4 at 1% + H_3BO_3 at 500 ppm
8- (Mg + MKP + B): $MgSO_4$ at 0.5 % + KH_2PO_4 at 1% + H_3BO_3 at 500 ppm

2.3. Measurements

At harvest time (late December), the examined trees were separately harvested and the following measurements were carried out as follows:

2.3.1. Yield and fruit quality

Fruits of each replicate (tree) were separately harvested, weighed and the yield as kg/tree was measured, then samples of 90 fruits from the sprayed trees (30 fruits from each replicate tree) were picked randomly around the tree to determine the following parameters: Average fruit weight (gm), fruit length (cm) and fruit diameter (cm), [42].

2.3.2. Oil extraction and its characteristics

After harvesting, about 5 Kg of fruits from treated and untreated Coratina olive trees were washed, crushed and packed in cheese cloth then pressed using a laboratory hydraulic press (carver). The pressure was 12.000 Ib/in² for 30 min/ each sample which was reached gradually. The obtained juice was collected and left in a separator funnel until complete separation. The upper layer was separated and centrifuged. The extracted oil was dried using anhydrous sodium sulfate, then filtered with cotton wool and stored in dark glass bottles at -5ºC till analysis.

- **Total lipid content:** It was determined as a percentage on dry matter weight in the oil samples according to the methods of A.O.A.C. [43].
- **Quality characteristics:** Peroxide value (PV) and free fatty acids % (FFAs) were evaluated following the methodology proposed by A.O.A.C. [43]. UV spectrophotometric indices (K232, K270, and ΔK) were measured according EEC. regulation methods [44].
- **Fatty acids composition:** Analysis and determination were carried out by preparation of methyl ester according to Cossiganani *et al.*, [45] followed by the identification of methyl esters using an Agilent 6890 series gas chromatograph apparatus equipped with a DB23 column (60 m X 0.32 mm X 0.25 µm), one micro liter of FAME mixture was injected into the GC system with split/splitless injector and flame ionization detector (FID). The inlet temperature was 250 °C and the split ratio was 50:1. The carrier gas was nitrogen at 1.6 ml/min constant flow. The oven temperature was programmed at initial 150 °C, held for 1 min, followed by increase of 10 °C/min up to 170 °C, held for 5 min, followed by increase to 220 °C during 10min. held for 3 min. The detector was set at 270 °C with 450 ml/min airflow, 40 ml/min hydrogen flow, and 25 ml/min nitrogen makeup flow. Fatty acids standards were used to identify the peaks [45].
- **Total phenols content:** It was determined according to the method described by Gutfinger [46], and the results were expressed as mg of caffeic acid per kg of oil.
- **Phenolic compounds** of oil samples were identified and determined using HPLC (HP 1050) equipped with auto-sampling injector, solvent degasser, ultraviolet (UV) detector set at 280 nm and quaternary HP pump (series 1100). The column temperature was maintained at 35ºC. Gradient separation was carried out with methanol and acetonitrile as a mobile phase at flow rate of 1 ml. Phenolic acids standards were dissolved in a mobile phase and injected into HPLC. Retention time and peak area were used to calculate of phenolic compounds concentrations by the data analysis of HP software [47].
- **Total pigments** (Chlorophyll and Carotenoids): 7.5 g of olive oil was accurately weighed and dissolved in cyclohexane up to a final volume of 25 ml., then chlorophyll and carotenoids were determined by measuring absorption at 670 and 472 nm, respectively, using a spectrophotometer (JENWAY 6405 UV/Vis., England) [48]. Results were expressed (mg/kg oil) as pheophytin and β-carotene for chlorophyll and carotenoids, respectively.
- **The unsaponifiable matter percentage** was evaluated as stated in A.O.A.C. [43].
- **Organoleptic test:** The organoleptic test was determined for the extracted oil according to IOOC [49].

2.3.3. Leaf mineral content

Leaf samples were picked from each replicate tree then washed and dried at 70ºC till a constant weight to determine nitrogen (N), phosphorus (P), and potassium (K) as percentage of dry weight basis due to the method described by Cottenie *et al.,* [50]. Boron as ppm was determined by the curcumin method of Dible *et al.,* [51]. Calcium and magnesium were determined following the criteria described by Moody *et al.,* [52].

2.4. Statistical Analysis

The experimental layout was a randomized complete block design (RCBD) with three replicates for each treatment; one tree was represented as a replicate. The obtained data were subjected to analysis of variance (ANOVA) according to Snedecor and Cochran [53] and the least significant differences (LSD) at probability of 5% were applied to separate the means using Co-Stat 4.11 software.

3. Results and discussion

3.1. Fruit physical characteristics and yield

The physical measurements of Coratina olive sprayed with various treatments which previously mentioned, gave strong evidence that all treatments significantly affected them compared to water sprays (control) in the two studied seasons as shown in Table (1).

Regarding average fruit weight, the heaviest fruits (3.43 and 3.44 g) were weighed with B sprays, followed by Mg treatment (3.42 and 3.36 g) in both seasons, successively with significant differences among treatments. Whereas, the finest fruits (2.28 and 2.26 g) were weighed with the control sprays in the two seasons, respectively.

Concerning fruit length, the maximum values (2.31 and 2.29 cm) were recorded with B sprays, while the minimum lengths (2.00 and 1.97 cm) were measured with the control in both seasons, by order without significant difference among them.

As for fruit diameter, results show that the highest value of fruit diameter (1.66 and 1.68 cm) was scored by B sprays, followed by Mg treatment (1.64 cm) in the first season and MKP spray (1.66 cm) in the second season without significant differences among them. Whereas the lowest significant fruit diameter (1.39 and 1.40 cm) were obtained due to MKP+B sprays in the two seasons, respectively.

Considering the average of yield/ tree, it differed significantly among treatments, since in the first season; the highest value (103.33 kg) was recorded with Mg spray followed by 98.33 kg with MKP+B spray. On the contrary in the second season, the highest value 102.33 kg was recorded with MKP+B treatment followed by 96.33 kg that obtained by Mg spray. However, the lowest yield (63.33 and 66.00 kg) was measured with the control in both seasons, successively.

The above effects regarding fruit physical properties (fruit weight, fruit length and fruit diameter) show that the treatments improved the fruit physical parameters compared to the control. So, spraying boron alone was the most effective treatment followed by magnesium one. However, the tremendous impact of boron on the physical fruit properties may be due to that boron performs an crucial roles in the plant functions which include activate salt absorption, hormone movement, flowering and fruiting, and its effects on the directionality of pollen tube growth and pollen germination [25]. Also, boron appears to play a critical function in achieving sufficient fruit set synthesis, transport of carbohydrate and sugars which could have an effect on fruit weight, length and diameter [26]. These outcomes are in agreement with the ones acquired through Abd-El-Migeed *et al.,* [54] on olive, Merwad *et al.,* [55, 56] on date palms and Merwad *et al.,* [57] on mango trees.

The acquired effects concerning the advanced impact of magnesium on fruit yield/tree can be attributed to the essential role of magnesium, due to the fact that sufficient supply via foliar application plays an essential role in physiological and biochemical processes of the plants such as metabolism of carbohydrates, enzymes activation, proteins synthesis and energy shifting [19]. In the current observe, magnesium sulphate treatment enhanced N, K and Mg leaves content (Table 6) than the other treatments which might also affect positively the fruits number/tree, consequently the consistent final yield/tree.

The received results are in harmony with the ones of Mostafa *et al.,* [58] who investigated the effect of foliar Mg treatment on leaf chlorophyll, vegetative growth, mineral content, yield and fruit quality of banana and found that Mg application affected positively the growth parameters, fruit quality and yield. Also, applying olives with magnesium sulphate in each of January, April, June and August enhanced the carbohydrates and leaf mineral contents (N, P, K and Mg), photosynthetic pigments, vegetative growth, flowering, fruit quality and caused an increase in fruit oil content (18-20%) compared to (12%) within the untreated trees, also the yield was doubled (43 kg/tree) compared to (20 kg/tree) for the untreated trees [59].

3.2. Olive oil Percentage and quality parameters

Results in Table (2) show the effect of different foliar applications of magnesium (Mg), mono potassium phosphate (MKP), boron (B), and their mixtures on oil contents and quality parameters; free fatty acids% (FFAs) as oleic acid, peroxide value (PV) meq O_2 Kg^{-1} oil and ultraviolet (UV) absorbency of the oils obtained from Coratina fruits in 2018 and 2019 seasons.

Acidity values ranged between 0.14–0.16 and 0.15–0.2% during 2018 and 2019, respectively. Concerning PV, it ranged from 2.5-2.7 and 2.59–2.9 meq O_2 Kg^{-1} oil in 2018 and 2019 seasons, respectively.

There was a slight increase in values of FFAs and PV in the second season, these changes may be due to the extraction and climate conditions. On the other hand, these changes were not significant in the two successive seasons.

The highest value for acidity was 0.2% and for the PV was 2.8 meq O_2 Kg^{-1} which were less than 0.8% and $\leq$ 20 meq O_2 Kg^{-1}, respectively which are considered as reference values for these qualities[60]. So, all oil samples in this study are classified as extra virgin olive oil.

Treatment	Fruit weight (gm)		Fruit length (cm)		Fruit diameter (cm)		Yield/ tree (Kg)	
	2018	2019	2018	2019	2018	2019	2018	2019
Control	2.28	2.26	2.00	1.97	1.43	1.40	63.33	66.00
Mg	3.42	3.36	2.24	2.26	1.64	1.63	103.33	96.33
MKP	3.19	3.22	2.16	2.23	1.64	1.66	68.33	71.33
B	3.43	3.44	2.31	2.29	1.66	1.68	91.67	94.67
MKP+Mg	2.59	2.74	2.22	2.13	1.52	1.49	73.33	80.00
B+Mg	3.09	3.16	2.23	2.21	1.58	1.56	83.33	89.33
MKP+B	2.30	2.29	2.02	1.99	1.39	1.40	98.33	102.33
MKP+B+Mg	3.10	3.25	2.28	2.24	1.61	1.57	88.33	92.33
LSD (0.05)	0.09	0.14	0.16	0.12	0.03	0.03	4.67	4.17

Table 1
Effect of different fertilizing treatments on fruit physical characteristics and yield/tree in 2018 and 2019 seasons
Control: water spray only, Mg: $MgSO_4$ at 0.5 %, MKP: KH_2PO_4 at 1% and B: H_3BO_3 at 500 ppm

Regarding to K_{232} and K_{270} are mainly indicating the conjugated dienes and trienes and also, the presence of carbonylic compounds. The results in Table (2) show that the values of K_{232} and K_{270} in all fertilizing treatments were lower than the control value with no significant differences in the two successive seasons. However, ΔK in the first season (2018) had the lowest value with MKP+B treatment (-0.0081) followed by MKP + B + Mg treatment (-0.0072), MKP treatment (-0.0071) and MKP+Mg treatment (-0.0059). The results were significantly different when compared to the control. In season 2019, there was a slight increase in ΔK, since MKP+B treatment had the lowest value of ΔK (-0.0074) followed by MKP treatment (-0.0067), B+Mg treatment (-0.0055) with a significant difference when compared to the control. All values of K_{232}, K_{270} and ΔK of Coratina olive oil were lower than the maximum permitted values of K_{232}, K_{270} and ΔK for extra virgin olive oils (2.50, 0.22 and 0.01), respectively [60].

It is clear from Table (2) that all treatments significantly increased oil content on fresh weight basis than the control in both seasons. Spraying trees with MKP+B+Mg gave the highest oil content (24.89% and 25.02%) in the two consecutive seasons respectively, followed by Mg (24.75% in the first season and 24.95% in the second one) and B+Mg (24.45% in 2018 and 24.90% in 2019). On the other hand, the control trees exhibited the lowest oil content (20.20% and 20.90%) in both seasons, respectively. The previous studies show that oil content in Coratina olive fruits based on dry weight ranged between 40% - 46.3% and 35.97% - 46.48% [61, 62], while, it was 18.5% on fresh weight basis [63]. This progress in oil content for the two successive seasons of the study could be attributed to the increase of total photo-assimilates (e.g., lipids) as a result of applying magnesium and potassium which may control the biosynthesis of oil by enzymes[64] during the main metabolic pathway. Also, potassium fertilization is considered as essential in olive, particularly because K is found in high concentration in the fruit [65]. Moreover, potassium deficiency was found to diminish photoprotection mechanisms due to reduced photosynthetic and photorespiratory capacity. The lower CO_2 and O_2 assimilation rate in K-deficient trees caused elevated levels of exited energy [66]. Boron deficiency is more common than any other micronutrient; it also causes a reduction in pollen viability, poor pollen germination and pollen tube development [67]. This deficit decreases crop yield, consequently the oil content decreases, by reducing the number of perfect flowers. This is due to fertilizer applied at the right time and throughout the vital phases of the olive tree's development. Indeed, the accumulation of oil in the olive is a process that is influenced by the amount of carbohydrates present in fruits and old leaves [68].

Table 2
Effect of different fertilizing treatments on oil content of Coratina olive fruits and quality parameters of their oils in 2018 and 2019 seasons

Treatment	FFA% as oleic acid		PV (meqO_2/kg oil)		K232		K270		ΔK		Oil %	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Control	0.14	0.18	2.59	2.90	1.622	1.732	0.072	0.085	-0.0026	-0.0013	20.02	20.90
Mg	0.14	0.16	2.57	2.80	1.612	1.632	0.067	0.071	-0.0039	-0.0027	24.75	24.95
MKP	0.14	0.20	2.60	2.59	1.259	1.342	0.039	0.045	-0.0071	-0.0067	22.60	23.62
B	0.15	0.20	2.61	2.72	1.416	1.690	0.056	0.077	-0.0045	-0.0020	23.50	24.34

MKP+Mg	0.14	0.18	2.59	2.80	1.317	1.510	0.045	0.061	-0.0059	-0.0043	24.21	24.80
B+Mg	0.15	0.15	2.59	2.74	1.399	1.388	0.051	0.053	-0.0053	-0.0055	24.45	24.90
MKP+B	0.16	0.15	2.70	2.61	1.113	1.210	0.031	0.035	-0.0081	-0.0074	23.90	23.80
MKP+B+Mg	0.15	0.19	2.57	2.70	1.243	1.530	0.038	0.068	-0.0072	-0.0035	24.89	25.02
LSD (0.05)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	-.00299	-.00243	2.18	1.26

3.3. Olive oil minor components and sensory attributes

Table (3) shows the minor components unsaponifiable matters% (UNSAP %), total polyphenolic contents, chlorophyll and carotenoids (in mg/kg) and organoleptic attributes (fruity, bitter and punent) of the olive oils in different fertilizing treatments. The bioactive components of extra virgin olive oil are resulted from a number of variables acting before extraction (such as variety, environmental, climatic, soil and cultivation conditions, olive ripeness and olive healthy) and during olive oil extraction and storage [69].

The unsaponifiable fraction that represents less than 2% of olive oil is composed of a very large number of minor compounds which are very important for the flavour and the nutritional properties of EVOOs [70]. Results in Table (3) show that UNSAP% ranged from 1.01–1.32% and 0.99–1.41% in the two successive seasons respectively. The highest percentage was found due to MKP+B+Mg treatment in the two successive seasons. The differences between all foliar applications were not significant.

The content of phenolic compounds is an important parameter in the evaluation of extra virgin olive oil quality due to its correlation with oxidative stability and sensorial quality [71, 72]. Our results (Table 3) revealed that total phenols content ranged between 749.7–1056.61 ppm and 793.9–990.15 ppm in the two successive seasons (2018 and 2019) respectively, which were in line with the results of five different extra virgin olive oils (253–1400 ppm), [73]. All treatments showed high significant differences of total phenol content compared with the control treatment in the two successive seasons except MPK and MPK+B treatments which were lower than the control treatment in the first season (2018/2019). B + Mg treatment foliar application has the highest phenolic content in the two successive seasons (1056.61 ppm in 2018 and 990.15 ppm in 2019) followed by Mg treatment (972.4 ppm in 2018 and 989.6 ppm in 2019). Extra-virgin olive oil contains a considerable amount of phenolic compounds that are responsible for peculiar taste and for its high stability. Recent findings demonstrate that olive oil phenolics are powerful antioxidants, both in vitro and in vivo, and possess other potent biological activities that could partially account for the observed healthful effects of the Mediterranean diet [74].

The main carotenoids and chlorophylls in olive oil are lutein and pheophytin, respectively. They are mainly responsible for the colour of virgin olive oil, ranging from yellow-green to greenish gold as well as oxidative stability due to their antioxidant nature in the dark and pro-oxidant activity in the light, [73]. There are also some reports about the benefits of dietary chlorophylls and carotenoids for human health [75]. Also chlorophyll act as pro-oxidant under light storage, whereas β-carotene minimizing lipid oxidation by its light filtering effect [48].

It is obvious from Table (3) that chlorophyll content ranged from 2.15 to 3.36 mg/Kg and from 2.89 to 3.5 mg/Kg in the two consecutive seasons 2018 and 2019, respectively. There were no significant differences between all treatments but, it is noticed that all magnesium treatments had the highest chlorophyll content. This may be related to that magnesium is considered the main component of chlorophyll.

Regarding to carotenoids content in Table (3), it ranged from 1.89 to 2.9 ppm and from 1.95 to 2.7 ppm in the two successive seasons 2018 and 2019, respectively. Also our results showed that all treatments were higher than that in control treatments in the two seasons except MKP foliar application was (1.89 ppm) lower than control treatments (1.93 ppm) in 2018 with no significant difference. MKP+Mg and MKP+ B+Mg treatments had the highest carotenoids content in the two seasons. Our results agreed with those revealed that the chlorophyll and carotenoid content ranged from 1.2-6.2 mg kg^{-1} and 1-3.8 mg kg^{-1}, respectively for different types of extra virgin olive oils [73].

Results in Table (3) show the effect of different foliar applications on sensory attributes of Coratina olive oils. One of the most important aspects of olive oil classification and value determination is sensory analysis. Human sensory evaluation is much more accurate (100 times) for olive oil than laboratory equipment for certain characteristics.The first and primary objective in sensory evaluation for olive oil is to determine if oils contain one or more of the defects that commonly occur in oils from improper fruit storage, handling, pest infestation, oil storage, or processing problems. The second objective of oil-sensory evaluation is to describe the positive characteristics of the oil in relation to its intensity of olive-fruity character. Bitterness and pungency are often present in olive oils, especially when newly made. These regulations lead to the classification of oil as extra virgin (EVOO), virgin (VOO) or Lampante[64].

Concerning the median of positive fruity attributes ranged from 3.5 – 5.33 in the first season (2018). B+Mg, Mg and MKP+Mg treatments recorded the highest values of fruity 5.33, 4.67 and 4.5, respectively; they have significant differences compared with control value (3.5). Also, values of the other treatments were higher than the control value but with insignificant differences. All foliar applications of second season (2019) have significant increases in comparison with the control value specifically MKP+Mg, B+Mg and Mg treatments. Also, results in Table (3) show that bitterness and pungency considered as positive attributes that detected by tasters. There were no significant differences between their values in all treatments. In addition, there wasn't any defect could be detected in oil samples under study. Our results reveal that all olive oil samples in our study were classified as extra virgin olive oil based on sensory analysis and limits of IOC standards 2016 (fruity ≥ 0.00 and defects = 0.00).

Table 3
Effect of different fertilizing treatments on minor components and sensory attributes of Coratina olive oils in 2018 and 2019 seasons

Treatment	Total phenols Content (mg/kg as caffeic acid)		UNSAP %		Chlorophyll content (mg/kg)		Carotenoids content (mg/kg)		Fruity		Bitterness		Pungecy		Defects	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Control	824.90	793.90	1.01	1.30	2.80	2.90	1.93	1.95	3.50	3.00	2.50	3.00	1.87	1.75	0.00	0.00
Mg	972.40	989.16	1.28	1.20	3.31	3.08	2.50	2.39	4.67	4.83	2.83	3.50	1.83	2.33	0.00	0.00
MKP	749.70	834.35	1.29	1.40	2.15	2.90	1.89	1.98	3.83	4.83	2.00	3.00	1.67	2.17	0.00	0.00
B	866.90	870.34	1.20	0.99	2.96	3.00	2.25	2.00	3.50	3.58	2.33	3.50	1.50	2.57	0.00	0.00
MKP+Mg	921.83	950.19	1.28	1.19	3.01	3.50	2.90	2.60	4.50	5.00	2.53	3.33	1.92	2.27	0.00	0.00
B+Mg	1056.61	990.15	1.31	1.23	3.11	3.34	2.20	2.30	5.33	4.83	2.67	2.80	1.90	1.87	0.00	0.00
MKP+B	794.37	820.23	1.30	1.31	2.82	2.89	2.50	1.97	3.83	3.88	1.93	2.27	1.67	1.92	0.00	0.00
MKP+B+Mg	875.33	946.50	1.32	1.41	3.36	3.40	2.70	2.70	3.58	4.40	2.33	2.73	1.83	2.37	0.00	0.00
LSD (0.05)	9.4	7.5	N.S	N.S	N.S	N.S	0.23	0.40	0.70	0.55	N.S	N.S	N.S	N.S	0.00	0.00

Concerning the fatty acids composition, virgin olive oil has a prominent and well-balanced chemical composition of its fatty acids leads to high oxidative stability and health properties [76]. In particular, high levels of MUFAs (mainly oleic acid), which have health benefits and important for human nutrition are among the major components of the Mediterranean diet [77]. The high content of oleic acid in olive oil serves to slow down penetration of fatty acids into arterial walls [78]. Oils with higher monounsaturated fatty acids (MUFAs) and lower saturated fatty acids (SFAs) are preferred because of the proven beneficial effect of MUFAs on serum cholesterol levels, in turn; prevention of cardiovascular disorders [79, 80].

3.4. Olive oil fatty acids composition

Results in Table (4) clarified the changes in fatty acid composition of Coratina olive oil as a result of different foliar fertilizations for olive trees as, total saturated fatty acids (TSFA), total unsaturated fatty acids (TUSFA), polyunsaturated fatty acids (PUSFA), monounsaturated fatty acids (MUSFA), TUSFA/TSFA ratio, and MUSFA/PUSFA ratio. The results in Table (4) reveal that, palmitic acid as main saturated fatty acid (16:0) varied between (12.33–13.06%) and (13.01-14.02%) in the two successive seasons. The highest content of palmitic acid was found in control treatments, this mean that different foliar fertilizations decreased palmitic acid. On the other hand, oleic acid (18:1) as the main MUSFA varies between (70.55–73.81%) and (70.70 – 73.15%) in 2018 and 2019 respectively. The highest contents of oleic acid were found with B+Mg treatment in 2018 and MKP+B in 2019 respectively, while the lowest values of oleic acid were detected with MKP treatment (70.55% and 71.04%) in the two successive seasons, respectively. All foliar applications in the two successive seasons increased the percentage of oleic acid compared with the control except B and MKP treatments in the first season. With regard to linoleic acid (18:2), Mg, B and MKP treatments in the first season have higher contents of linoleic acid. On the other hand, in the second season all fertilizing treatments decreased the percentage of linoleic acid in contrary with control. In addition, linolenic acid (18:3) (which is susceptible to oxidation) contents were found less than 1% in all treatments. Generally, TUSFA increased as a result of most foliar applications in the two successive seasons in contrary with TSFA, which decreased in most foliar applications. Also, MUSFA/PUSFA ratio increased as a result of most foliar applications in the two successive seasons since, by increasing this ratio, the oxidative stability of oil increases [81]. The fatty acids composition of all olive oil samples under study was in the range of International Olive Council (IOC) trade standard for EVOO [60]. The slight changes in fatty acids composition of olive oil in the two seasons may be related to the climate changes

. Table 4

Effect of different fertilizing treatments on relative percentage of fatty acids composition of Coratina olive oils in 2018 and 2019 seasons

Treatment / FA%	Control		Mg		MKP		B		MKP+Mg		B+Mg		MKP+B		MKP+B+Mg	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
$C_{16:0}$	13.06	14.02	12.33	13.80	12.42	14.01	12.72	13.85	13.01	13.16	12.84	13.01	13.02	13.06	13.00	13.05
$C_{16:1}$	0.43	0.55	0.40	0.51	0.40	0.57	0.41	0.59	0.43	0.55	0.44	0.52	0.41	0.51	0.42	0.52
$C_{17:0}$	0.05	0.05	0.05	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.05
$C_{17:1}$	0.07	0.07	0.06	0.07	0.07	0.06	0.07	0.08	0.07	0.07	0.09	0.07	0.07	0.06	0.07	0.07
$C_{18:0}$	1.98	1.79	2.03	1.73	2.01	1.76	2.02	1.70	2.04	1.70	2.03	1.70	2.01	1.75	1.87	1.71
$C_{18:1}$	71.51	70.7	71.73	72.01	70.55	71.04	70.57	72.11	72.41	73.13	73.81	72.60	72.31	73.15	72.71	72.75
$C_{18:2}$	10.98	10.9	11.51	10.00	12.60	10.5	12.28	9.80	10.02	9.50	8.85	10.21	10.15	9.60	9.99	10.1
$C_{18:3}$	0.87	0.90	0.83	0.71	0.87	0.80	0.85	0.75	0.87	0.76	0.88	0.72	0.88	0.73	0.84	0.71
$C_{20:0}$	0.43	0.51	0.44	0.55	0.43	0.57	0.43	0.52	0.46	0.55	0.43	0.55	0.46	0.54	0.43	0.52
$C_{20:1}$	0.49	0.40	0.50	0.45	0.50	0.50	0.49	0.43	0.51	0.40	0.48	0.45	0.51	0.43	0.50	0.40
$C_{22:0}$	0.11	0.13	0.12	0.13	0.11	0.13	0.11	0.12	0.13	0.13	0.10	0.13	0.13	0.13	0.12	0.12
TSFA	15.63	16.48	14.97	16.25	15.01	16.53	15.33	16.24	15.69	15.59	15.45	15.43	15.67	15.52	15.47	15.45
TUSFA	84.36	83.52	85.03	83.75	84.99	83.47	84.67	83.76	84.31	84.41	84.55	84.57	84.33	84.48	84.53	84.55
MUSFA	72.50	71.72	72.69	73.04	71.52	72.17	71.54	73.21	73.42	74.15	74.82	73.64	73.3	74.15	73.70	73.74
PUSFA	11.85	11.80	12.34	10.71	13.47	11.3	13.13	10.55	10.89	10.26	9.73	10.93	11.03	10.33	10.83	10.81
USFA/SFA	5.40	5.07	5.68	5.15	5.66	5.05	5.52	5.16	5.37	5.41	5.47	5.48	5.38	5.44	5.46	5.47
MUSFA/PUSFA	6.12	6.08	5.89	6.82	5.31	6.39	5.45	6.94	6.74	7.23	7.69	6.74	6.65	7.18	6.81	6.80

3.5. Olive oil phenolic compounds concentration

Phenolic compounds of olive oil have been of major interest to researchers due to their positive effects on both human health and preservation of olive oil. Results in Table (5) show the influence of different foliar applications on the phenolic compounds of Coratina olive oil. It could be noticed that, 16 phenolic compounds were detected in olive oil samples; 3-OH tyrosol, oleuropin, catechol, and pyrogallol were the predominant phenolic compounds in all olive samples, followed by coumarin, caffeic acid, p-OH benzoic, and benzoic acid. It could be observed that most of phenolic compounds were increased as a result of foliar applications especially MKP+B and MKP+B+Mg treatments, this increase was higher in the second season than the first one. 3-OH tyrosol compound had the greatest content comparing with the other phenolic compounds since; it ranged between 125.6-198.9 ppm and 145.0-212.1 ppm in the two successive seasons. The greatest content of it was found due to MKP+B treatment in the two seasons. The highest concentration of oleuropin compound was detected with MKP+B treatment (198.2 ppm) in the second season and MKP+B+Mg treatment (170.3 ppm) in the first season. MKP and MKP+B+Mg treatments had the higest content of chatecol (183.6 ppm) in the first season and (153.0 ppm) in the second one. Pyrogallol ranged between 83.9-115.09 ppm and 75.3-113.7 ppm in the two successive seasons respectively, where B+Mg treatment in 2018 and MKP+B+Mg treatment in 2019 had the highest content of it. Coumarin, caffiec acid, P-OH-benzoic acid and benzoic acid had considerable concentrations compared to the remained phenolic compounds such as catechein, vanilic and salicylic.

Olive oil phenolic compounds are shown to possess antioxidant, anti-inflammatory, anticancer, antidiabetic, antiobesity, cardioprotective, neuroprotective, antimicrobial, antisteatotic and many other effects [82, 83]. According to numerous investigations, these effects are mostly attributable to the main secoiridoid derivatives such as oleuropein, oleocanthal and oleacein, and simple phenols hydroxytyrosol and tyrosol [84, 85].

Table 5

Effect of different fertilizing treatments on Phenolic compounds concentration (ppm) of Coratina olive oils in 2018 and 2019 seasons

Treatment / Compounds	Control		Mg		MKP		B		MKP+Mg		B+Mg		MKP+B		MKP+B+Mg	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
3-OH Tyrosol	109.5	147.0	143.2	153.7	137.9	145.0	193.9	153.4	125.6	159.5	175.2	189.0	198.9	212.1	187.3	203.6
Oleuropin	99.4	120.2	124.6	135.04	120.8	131.0	145.0	139.0	137.3	149.2	140.9	136.1	147.3	198.2	170.3	155.6
Catechol	91.0	78.0	119.2	117.5	183.6	126.7	99.4	121.2	105.1	132.4	130.7	116.8	142.9	97.6	135.3	153.0
Pyrogallol	77.6	83.0	83.9	89.9	91.9	75.3	104.0	85.6	92.0	90.1	115.09	110.3	101.9	95.9	104.6	113.7
Coumarin	35.8	26.2	44.3	35.2	36.1	44.1	52.9	40.2	46.1	29.1	55.4	61.9	43.5	53.1	54.4	65.2
Caffeic	32.7	63.4	54.7	54.1	42.1	62.9	45.4	55.0	59.3	29.5	45.0	47.8	48.9	48.5	41.7	28.6
P-OH- benzoic	27.9	19.3	25.7	27.0	29.0	25.2	38.5	35.0	43.1	40.6	49.5	55.7	31.4	31.2	52.8	45.1
Benzoic	24.6	35.0	36.8	24.2	40.5	55.1	20.7	39.7	33.2	22.8	44.8	45.5	35.1	43.2	38.1	29.1
Gallic	18.7	27.9	17.3	34.1	19.6	32.1	15.4	29.6	16.3	22.3	27.4	42.8	23.5	29.3	31.4	47.1
chlorogenic	14.5	7.50	15.5	11.9	13.6	5.90	19.2	17.6	14.0	13.2	18.1	15.8	17.3	19.0	20.8	14.1
Vanillic	7.75	5.34	4.85	4.50	9.94	10.1	5.26	4.23	2.46	3.41	5.12	6.73	7.61	8.75	8.44	10.5
Caffeine	3.60	1.30	0.78	0.66	0.35	0.39	0.91	0.41	0.65	0.43	0.99	1.20	1.40	0.89	1.01	0.93
4-NH2 benzoic	2.48	1.91	1.20	2.33	1.41	2.05	0.91	0.79	1.12	1.93	1.26	3.01	0.87	1.74	1.03	2.93
Ferulic	1.23	0.92	0.85	0.55	1.90	1.49	0.48	0.87	0.72	1.29	1.71	1.50	1.43	1.03	1.54	1.70
Salycillic	1.34	1.91	2.57	3.14	2.60	3.87	2.94	2.50	1.29	3.61	1.43	2.91	1.69	3.01	2.26	4.01
Catechein	1.09	3.29	0.83	3.62	1.24	9.11	0.74	4.87	1.14	6.84	0.50	16.1	1.42	7.79	0.41	6.34

3.6. Olive leaves mineral content

As for olive leaves mineral content shown in Table (6), it could be seen that Mg treatment scored the highest N content (2.12 and 1.98%) in the first and second seasons, respectively followed by MKP treatment (1.97 and 1.89%), successively without significant differences between them in both seasons. However, the lowest significant N% (1.52 and 1.61%) was evaluated with the control treatment in both seasons, by order.

Regarding P content, it's obvious from Table (6) that the effect of all treatments was differed significantly and MKP treatment had recorded the maximum values in the two seasons (0.225 and 0.234%), respectively. Whereas the minimum values (0.188 and 0.182%), successively were recorded with the control treatment in both seasons.

Table (6) point out that, K% differed significantly among various treatments. Though, Mg and MKP treatments, recorded the same highest values (1.62%) in the first season, while in the second season recorded 1.67% and 1.65%, respectively. The lowest values (1.24 and 1.29%) were measured with the control in the two seasons, by order.

Considering Ca%, Table (6) show that various treatments did not affect it significantly were the highest values (1.82%) were detected with MKP+ Mg and MKP+ B+ Mg treatments in the first season and (1.86%) with B+ Mg in the second season, while the lowest ones (1.52 and 1.64%), successively were detected with the control treatment in both seasons.

Concerning B leaf content tabulated in Table (6), a significant effect for treatments containing B was recorded since the highest content (35.2 and 34.7 ppm) was scored with B treatment solely, followed by MKP+ B+ Mg treatment (34.8 and 34.3 ppm) without significant difference between them, while the least content (23.2 and 22.8 ppm) was detected with the control treatment in both seasons by order.

Looking to Mg leaf content at Table (6), results show that the treatment containing Mg led to a significant increase in Mg content where the maximum values (2.31 and 2.22 %) were recorded with Mg treatment, followed by MKP+ Mg treatment (2.22 and 2.17 %), respectively without significant difference between them in the two seasons. Whereas, the minimum significant value (1.21 and 1.31 %) was measured with the control treatment in both seasons, successively.

From the above results, it is clear that the treatments included K, B or Mg enhanced leave mineral content especially K, B and Mg percentages. In this respect, magnesium sulphate treatment increased N, K and Mg content than the other treatments; this may explain the priority of magnesium sulphate treatment on increasing the yield per tree comparing with the other treatments including the control.

Table 6

Effect of different fertilizing treatments on leaves mineral content in 2018 and 2019 seasons

Treatment	N (%)		P (%)		K (%)		Ca (%)		B (ppm)		Mg (%)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Control	1.52	1.61	0.188	0.182	1.24	1.29	1.52	1.64	23.2	22.8	1.21	1.31
Mg	2.12	1.98	0.215	0.224	1.62	1.67	1.74	1.65	24.3	25.3	2.31	2.22
MKP	1.97	1.89	0.225	0.234	1.62	1.65	1.71	1.65	24.7	24.9	1.82	1.84
B	1.74	1.65	0.194	0.191	1.31	1.38	1.78	1.72	35.2	34.7	1.85	1.87
MKP+Mg	1.99	1.97	0.212	0.213	1.57	1.59	1.82	1.84	25.4	26.1	2.22	2.17
B+Mg	1.85	1.82	0.194	0.193	1.31	1.28	1.81	1.86	32.4	31.9	1.95	1.91
MKP+B	1.77	1.75	0.195	0.199	1.55	1.58	1.76	1.78	32.4	32.1	1.81	1.72
MKP+B+Mg	1.78	1.85	0.211	0.198	1.46	1.52	1.82	1.79	34.8	34.3	1.98	1.92
LSD (0.05)	0.19	0.21	0.023	0.022	0.14	0.15	N.S	N.S	3.1	2.8	0.21	0.20

4. Conclusion

It is clear from the previous results that the use of any of the examined treatments led to a varied increase among the treatments, in the yield of fruits per tree, the length and width of the fruit (physical characteristics), and also led to an increase in the oil accumulation in the fruits, with maintaining its quality, compared to the untreated trees.

Coratina olive is cultivated specifically for the production of oil, and since all the treatments did not affect the quality of the oil negatively, as they all give the characteristics of extra virgin olive oil, and preference is given to olive growers to obtain the highest economic return of the oil crop. Therefore, when calculating the oil yield per trees by multiplying the yield with the percentage of oil obtained from each treatment as shown in the figure (1), it is observed that spraying Mg solely recorded the highest oil yield (24.8 kg oil/tree) as an average of the two seasons, and thus this treatment was the superior and achieved an increase in oil yield by approximately 87% compared to the control, followed by MKP+B treatment with an average of 23.9 kg in the two seasons(approximately increased by 80% than the control). In this concern, the untreated trees (control) gave an average of 13.2 kg of oil/tree in both seasons.

Thus, the above can be summarized that the use of any of the treatments in this experiment led to a noticeable increase in the yield of the resulting oil, compared to the control treatment, with maintaining its properties as (EVOO). But the treatment of Mg alone was the superior for reaching the highest oil yield followed by B+MKP treatment.

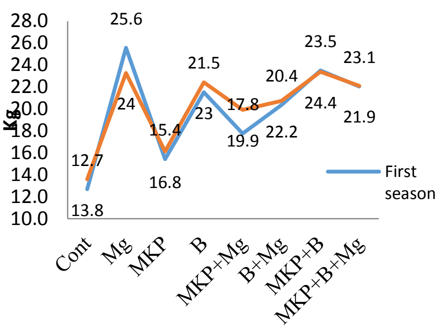

Fig. 1. Oil yeild/ tree (Kg)

5. Conflicts of interest

"There are no conflicts to declare".

6. Formatting of funding sources

"There are no funding sources".

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