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# Effect of some Soil Amendments on Productivity of Olive Trees in Calcareous Soil

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## ABSTRACT

A field experiment was carried out during 2018 and 2019 seasons on Olive trees (*Olea europaea* L) on orchard located at El Alamein Road, Matruh Governorate, Egypt. In this study, Sulfur and zeolite which was private applied at two equal, the first was done before the season and the second was applied after fruit set at three levels (0, 1000 and 2000 g) for individually or mixing on yield characteristics of manzanelo olive growing under calcareous soil condition. The experiment was carried out a complete randomize block design. The result showed that soil application of (sulphur 1000g/tree + zeolite at 1000g/tree) gave the highest values of number of shoots, average leaf area and chlorophyll content in leaves. Moreover, foliar application sulphur especially at a level of 2000 g / tree zeolite at a level of 2000 g / tree each alone or with each significantly increased the highest values of flowering density, Perfect flower %, fruit set %, fruit length, fruit weight, yield/tree, fruit volume, fruit flesh (%) and fruit oil content (%), In addition, results indicated that sulphur application especially at a level of 2000 g sulphur / tree and zeolite at a concentration of 2000 g / tree each alone or with each other significantly decreased of fruit acidity.

***Keywords:*** Soil Amendments, Zeolite, Sulfur, Olive trees, Yield, Fruit quality.

## 1. Introduction

Olive tree (*Olea europaea* L.) is one of the most important fruit crops in Egypt. It is considered as a part of the social and culture tradition of some Governorates of Egypt especially Matrouh and both North Sinai and South Sinai Governorates. It is export crop for foreign markets. It is an important perennial crop in Mediterranean countries, as it is the most important olive growing region. Olive oil has high nutritional properties, besides, both oil and olive leaves has medicinal properties especially in traditional systems from time immemorial (Soni *et al.,* 2006).

Olive trees face many factors which induced a negative effect on olive productivity, among those factors the depression of olive yield which is caused by poor soil fertility and low water holding capacity which are generally the principal soil problems. Olive has high adaptability to versatile conditions and it is capable of growing under drought stress conditions such as Matrouh conditions.

Under Matrouh conditions, calcareous soils are problem face olive grown and productivity and oil quality.

Manzanillo olive cultivar is considered one of the most important commercial olive varieties in Egypt and needs special treatments under calcareous soil condition, since pH is high and CaCO3 is dominated, low water holding capacity, high infiltration rate, poor structure, low organic matter and clay content, low CEC, loss of nutrients via leaching or deep percolation, surface crusting and cracking, loss of nitrogen fertilizers, low availability of phosphorous and micronutrients, and a nutritional imbalance between elements such as potassium, magnesium and calcium (Khalefa, 2007; FAO, 2016;Taalab *et al.,* 2019). All of these in generally are the main calcareous soil problems that influence on Manzanillo yield and fruit quality.

In this research, to solving olive low growth and productivity grown in calcareous soil, it use horticulture practices such as zeolites (natural sources) and sulfur applied to the soil to improvement the growth and yield.

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Natural zeolites belong to the group of cationic exchangers and it tends to be utilized to improve the soil exchangers (Najafi-Ghiri, 2014). it increased soil water holding capacity by (18-19%) and cation exchange capacity by 30-40%, lead to increase crop water use efficiency and it reflected in preventing nutrient leaching (Jakkula and Wani, 2018). Recently, zeolite used in agriculture a slow-release source of nutrients that are made available when the plant needs those (Bernardino *et al.,* 2008).

Zeolites stimulated soil microbiological activities, reduce the harmful effects of water stress in arid and semi-arid area (Peter, 2015; Ghanbari and Ariafar, 2013). Furthermore, zeolite also preventing the occurrence of environmental problems through increasing N, P, and water-use efficiency and increasing soil P availability for plants (Shokouhi *et al.,* 2015).

However, little is known about the effectiveness of zeolite application on the growth of fruit crops.

In this respect, Markovic and Zilin (1995) indicated that zeolite induced a positive effect on plant growth of pepper and tomato seedlings. Moreover, Leggo (2000) pointed out that zeolite helped to enhance nitrogen and potassium availability in soil, which increase biomass and yield of wheat. Furthermore, Noori *et al.,* (2007) applications of zeolite in radish improve soil quality and increase crop yield grown in saline soils. In addition, Tsintskaladze *et al.* (2017) pointed out that the addition of zeolite to the soil can be used on minimizing the amounts of mineral fertilization. It increases the water holding capacity of soils, due to the fact that it gradually retains and releases water and nutrients. The results of Roxana (2015) confirmed that, the suitability of using natural Zeolite in agriculture had a positive role in plant nutrition and microbial community stability, as evidenced subject experimentation crops. All these unique properties of Zeolite materials promise to contribute significantly too many years of agricultural technology.

In calcareous soil, the high soils pH limits to uptake many nutrients by plants. Sulfur is an important mineral in control soil pH and when applied to soil it reduced high pH that make nutrient in unavailable forms become available in root zone which enhanced nutrients uptake (Wiedenfeld, 2011).

Sulfur is ranked in fourth rank place in priority after nitrogen, phosphorus, and potassium. It is a necessary plant nutrient for plant growth and development; it is an essential part of several compositions such as vitamins, co-enzymes and phytohormones (Nazar *et al.,* 2011).

Elemental sulfur make nutrient in available forms in calcareous soils by decreasing soil pH and it is converted quickly to sulfuric acid in the soil by soil microorganisms, supply $SO_4$ to plants, make P and micronutrients more available (Havlin *et al.,* 2005). Moreover, Sulfur is an essential element required for plant growth and development as it is required for synthesis of methionine and cysteine amino acids as well as chlorophyll (Eriksen *et al.,* 2004; Ghosh *et al.,* 2007 and Orman and Kaplan, 2011; Nagesh *et al.,* 2019). Oilseeds crops have high demand of Sulfur (Valla, *et al.,* 2014).Furthermore, sulfur is a part of phospholipids and thus, it directly contributes to the formation of fats (Hrivna *et al.,* 2002).

Sulfur adding to soil gave the high positive effect on yield of "Valencia" orange trees because sulfur reducing soil pH and soil salinity that reflected in increasing uptake of nutrients and enhanced protein biosynthesis (Nijjar, 1985 and Miller *et al.,* 1990).The results of Zeerban *et al.,* (2000) and El-Desouky *et al.,* (2002) supported the benefits of sulfur on growth and yield of other fruit crops.

In this research, application of zeolites and Sulfur may be overcoming soil problems and enhancing olive productivity. This study aims to evaluate the effect of zeolite and sulfur in alone or in combinations on vegetative growth, flowering and yield, fruit quality as well as nutrients status of "Manzanillo" olive trees in calcareous soil under Matrouh conditions.

## 2. Materials and Methods

This study was carried out during two successive seasons (2018 and 2019) on twelve years old Manzanelo olive trees (*Olea europaea* L) planted at 4×6 meters in private farm on El Alamein Road, Matruh Governorate, Egypt.

Twenty seven healthy trees were selected nearly similar in vigour and size, zeolite and sulfur were applied at rates of zero, 1000, 2000kg / tree. Factorial experimental with nine treatments were designed in a complete randomize block with three replicated. However, the application was at approximately three weeks after full bloom during the two seasons of study. Twelve years old Manzanelo olive grown in calcareous soil, under drip irrigation system from well were devoted for this

study. Surface soil sample (0-30 cm) was taken before beginning of the first season to determine. Physical and chemical analysis of the experimental soil according to AOAC, (1995), and listed in Table (1). Zeolite was taken from the El-Ahram Mining Company. The chemical analyses and some characteristics of zeolite listed in Table (2).

**Table 1:** Physical and chemical characteristics of the calcareous soil

| Characteristics | | | | | | | |
|---|---|---|---|---|---|---|---|
| Particle size distribution (%) | | | | | | | |
| Sand% | Silt% | Clay% | Texture | EC $dsm^{-1}$ | pH | $CaCO_3$% | OM |
| 26.3 | 32.0 | 41.6 | Clay loam | 3.82 | 8.5 | 30.56 | 0.365 |
| Chemical analysis soil | | | | | | | |
| Soluble Cations (meq. $l^{-1}$ ) | | | | Soluble inons (meq. $l^{-1}$ ) | | | |
| Ca++ | Mg++ | Na+ | K+ | $Hco^{-3}$ | Cl- | $so^{-}$ | $CO_3$ |
| 22.0 | 8.71 | 24.30 | 1.50 | 6.38 | 34.62 | 26.20 | -- |

**Table 2:** Chemical composition of zeolite

| Element | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $TiO_2$ | CaO | MgO | $Na_2O$ | $K_2O$ | $P_2O$ | $SO_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| % | 69.22 | 11.60 | 0.71 | 0.32 | 1.24 | 1.34 | 0.32 | 2.62 | 0.04 | 1.54 |

**2.1. Experiment design and the treatments:**

The first factor was sulfur at the following rats:

1- Zero g (control).
2- Sulfur at 1000 g/ tree.
3- Sulfur at 2000 g/tree.

The second factor was zeolite at the following rats:

1- Zero (control).
2- Zeolite at 1000 g/ tree.
3- Zeolite at 2000 g/tree.

The experiment was arrangement in a complete randomized block design 3 sulfur x 3 zeolite = 9 treatments.

**2.2. The following parameters were recorded for both seasons:**

**I. Vegetative growth measurements**

At the end of each growing season (during first week of September) the following characteristics were measured in terms of main shoot length (cm), leaf area ($cm^2$) using a planimeter and chlorophyll contents according to Ahmed and Morsy, (1999).

**II. Flowering characteristics**

**1-Flowering Density**

Twenty shoots per each tree were employed for determine average shoot length and number of inflorescence per one meter of shoot was calculated.

Flowering density = No. of inflorescences x100/shoot length (cm)……...…..(1)

**2- Perfect flower percentage:**

Twenty inflorescences at ballon stage were collected from the middle portions of shoots from each tree, number of perfect and total flowers on each inflorescence were recorded and percentage of perfect flowers was calculated (Mofeed, 2002).

**3-Fruit set**

**I. Percentage of fruit set**

Fruit set percentage at two times first after 21 days from full bloom as initial fruit set and the second 60 days after full bloom as final fruit set according to (Mofeed, 2002).

Fruit set (%) =No. of fruits/No. of total flowers x100……..….(2)

**II. Fruit physical characteristics:** Thirty fruit per each tree were randomly selected for carrying out the fruit quality measurements**:**

**1-Fruit length (cm):** It was measured by digital caliper for the length of the sample (30 fruits).
**2-Fruit diameter (cm):** It was measured by a digital caliper for the diameter of the sample (30 fruits).
**3-Fruit weight (g):** It was determined by weighting the samples (30 fruits) by ordinary balance with 0.01 g sensitivity, and average weight per fruit was calculated**.**
**4-Fruit volume (ml):** Fruit size was determined by using water displacement (Scale cylinder) method.100 ml graduated cylinder was filled with water up to 50 ml, then fruit was put in the cylinder that raise the volume and the fruit size was calculated by subtracting the initial reading from final reading.

**5-Fruit yield (kg/tree)**

Fruits were harvested at ripening stage on end of October in the years 2018 and 2019. Each individual tree was harvested manually, and weight of fruits/tree was recorded. Average yield (kg) /tree wa**s** determined for each treatment.

**6-Fruit flesh (%):** Each fruit was weighed by the stone, then stone weighed separately and subtracted from fruit weight and flesh percentage was calculated.

Fruit flesh (%) = fruit weight **-** stone weigh / fruit weight×100……(3)

**2.3. Fruit chemical characteristics**

**1. Fruit oil content (%):** as a dry weight was determined according to A.O.A.C. (1975) method by extraction the oil from the dried fruits with soxhlet for extraction apparatus using petroleum ether at 60-80C of boiling point.

**2. Oil acidity (%):** total acidity % as Malic acid (mg/100 gm fruit juice) according to A.O.A.C (1975).

**2.4. Leaf mineral contents**

At the end of the experimental season (the end of September), thirty leaves/tree were collected representing the four main directions. The samples were washed, dried, grounded and digested according to Chapman and Pratt (1978). Total nitrogen was determined as percentage using the micro-Kjeldahl method as described by Pregl (1945). Phosphorus was determined colourimetrically methods as described by Murphy and Riley (1962). Potassium content was determined by Flame photometer as percentage according to method of Jackson (1958). Calcium and Magnesium was determined spectrophotometerically using Atomic Absorption (Perkin Elmer-3300) according to Chapman and Pratt (1978).

**2.5. Statistical analysis**

The data were subjected to analysis of variance and Duncan's multiple range test were used to study the differentiate between means as described by Duncan (1955).

## 3. Results and Discussion

**Leaf characteristics**

**3.1. Effects of sulphur and zeolite on shoot length, leaf area and chlorophyll contents of Manzanelo olive trees**

**I. Shoot length**

Data presented in Table (3) show that all treatments were significantly effective on Manzanelo olive shoot length, leaf area and total chlorophyll. However, application at 2000g sulphur increased significant shoot length (20.72-and 21.33) in both seasons. On the other hand, there were significant

increased by using 2000 g zeolite increased shoot length (19.67 and 20.11 cm) in two seasons. Moreover, the combined 2000g sulphur with zero g zeolite gave the highest significant values (22.17 and - 23.17 cm) in the two seasons when compared with any other treatments.

**II. Leaf area**

Result in the same table **(**Table3**)** show significant increase in leaf area in response to (2000 g sulphur) application (4.61- 4.51cm$^2$) compared to the control and all other treatments in both seasons**.** However, leaf area was affected significantly by 2000 g zeolite gave the highest significant values (4.22-4.578 cm$^2$**)** in the both seasons compared to all treatments. Also, the combined 2000g sulphur with 0 or 2000 g zeolite gave the highest significant values (4.67 - 4.70 cm$^2$) in the first and the highest significant values (4.80**)** of leaf area was recorded in the second season**.** While, the lowest value was obtained by control (2.27 - 2.40 cm$^2$).

**III. Chlorophyll content in leaves (SPAD value)**

Regarding total chlorophyll content in the leaves, it is observed that significant differences were among the treatments, since the highest value was obtained with 2000g sulphur treatments (82.81-82.21). While, the lowest value was obtained by control (67.22- 67.96). Chlorophyll content was also significantly affected by zeolite. Maximum increase (78.54 and 78.99) SPAD in chlorophyll content was observed with the application of zeolite at the rate of 2000g / tree in both seasons. On the other hand, the maximum value was obtained with 2000g sulphur +2000g zeolite (84.77- 83.90) during the two seasons. While, minimum value was (57.23 -59.71) of control treatments in the both seasons.
Many investigators reported the importance of sulphur is increasing growth of grapevine cultivars (Kassem, 2002; El-Dsouky *et al.,* 2002; El-Akkad, 2004). On the other hand, sulphur application at rate of 200 g/tree caused significant increase in total chlorophyll and leaf area in peach trees cv Dixired Jassim *et al.,* (2020).

Joao. Lopes (2020) reached similar results on young olive trees after zeolites application increased the vegetative growth and nutrients in the leave planted that in very acidic soil and under rainfed conditions.These results are in agreement with those obtained by Bybordi *et al.,* (2018) who suggested that zeolite increased chlorophyll content by improving water and nitrogen supply. Moreover, the increased SPAD values might be because zeolite takes up nutrients from the soil and makes them available to the plants, leading to enhanced chlorophyll synthesis. However, the improving of vegetative growth characteristics might be attributed to the importance of magnesium as a part of the main plant pigment; chlorophyll which is essential to perform the photosynthesis process. It plays an important role in pathway in plant cell. Moreover, magnesium salphate application was effective in enhancing the vegetative growth characteristics; mentioned results are in harmony with (El-Khawaga (2007) and Wael (2005).

**3.2. Effects of sulphur and zeolite on flowering density, perfect flower and fruit set of Manzanelo olive trees**

**I. Flowering density**

Shows the effect of sulphur, zeolite and their interactions on the flowering densit**y** for seasons 2018 and 2019 seasons. The obtained data from Table (4) clearly showed that the highest significant value was recorded in application of sulphur at 2000g/tree which for the two seasons and lowest value was obtained in zero sulphur at both seasons. Moreover, significantly increased by increasing the zeolite levels for the two seasons, the highest significant value was recorded with zeolite at 2000g /tree in two seasons. On the other hand, the interaction between two factors the highest significant value was obtained with 2000g sulphur significantly increased and 2000g zeolite in the two seasons when compared with any other treatments.

**II. Perfect flower (%)**

The data presented in Table (4) showed that the highest significant Perfect flower (%) was recorded with (2000g sulphur).In addition, significant increases in Perfect flower (%) were recorded by (2000g zeolite) in both seasons. Regarding the interaction of both factors, the highest values of perfect flowe**r** (%) were obtained with 0 or 2000g zeolite (82.74-82.28 and 82.75-83.45) in the first and second

**Table 3:** Effect of sulphur and zeolite on shoot length, leaf area ($cm^2$) and total chlorophyl of Manzanelo olive in the 2018 and 2019 seasons

| Sulphur (g) | Shoot length (cm) | | | | Leaf area ($cm^2$) | | | | Total chlorophyl (SPAD) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zeolite g/ tree | | | | Zeolite g/tree | | | | Zeolite g/tree | | | |
| | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean |
| | | | | | 1st season | | | | | | | |
| **0** | 8.83 g | 7.33 de | 18.50 c | **14.89 B** | 2.27 f | 3.47 de | 3.77 c | **3.17 C** | 57.23 h | 71.13 e | 73.30 d | **67.22 B** |
| **1000** | 13.00 f | 16.50 e | 18.33 cd | **15.94 B** | 3.23 e | 3.60 cd | 4.20 b | **3.68 B** | 61.80 g | 64.87 f | 77.75 c | **68.08 B** |
| **2000** | 20.83 b | 19.17 c | 22.17 a | **20.72 A** | 4.67 a | 4.47 ab | 4.70 a | **4.61 A** | 81.37 b | 82.30 b | 84.77 a | **82.18 A** |
| **Mean** | **14.22 C** | **17.67 B** | **19.67 A** | | **3.39 C** | **3.84 B** | **4.22 A** | | **66.80 C** | **72.77 B** | **78.54 A** | |
| | | | | | 2nd season | | | | | | | |
| **0** | 8.17 h | 17.67 e | 18.50 de | **14.78 B** | 2.40 d | 3.57 c | 4.50 ab | **3.50 C** | 59.71 f | 70.97 de | 73.20 d | **67.96 B** |
| **1000** | 13.67 g | 16.00 f | 18.67 cd | **16.11 B** | 3.77 c | 3.57 c | 4.40 b | **3.91 B** | 62.07 f | 69.40 e | 76.87 c | **69.44 B** |
| **2000** | 21.33 b | 19.50 c | 23.17 a | **21.33 A** | 4.53 ab | 4.20 b | 4.80 a | **4.51 A** | 81.17 b | 81.57 ab | 83.90 a | **82.21 A** |
| **Mean** | **14.39 C** | **17.73 B** | **20.11 A** | | **3.57 B** | **3.78 B** | **4.58 A** | | **67.65 C** | **73.98 B** | **77.99 A** | |

Means followed by the same letter (s) in each row, column or interaction are not significantly different at 5% level.

**Table 4:** Effect of sulphur and zeolite on flowering density, perfect flower and fruit set of Manzanelo olive in the 2018 and 2019 seasons.

| Sulphur (g) | Flowering density | | | | Perfect flower (%) | | | | Fruit set (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zeolite g/tree | | | | Zeolite g/tree | | | | Zeolite g/tree | | | |
| | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean |
| | | | | | 1st season | | | | | | | |
| **0** | 41.87g | 44.20f | 46.62e | **44.23B** | 65.53h | 71.63f | 76.50d | **71.22C** | 24.67g | 31.66e | 35.04d | **30.46C** |
| **1000** | 42.75g | 45.77e | 48.33d | **45.62B** | 69.84g | 73.80e | 78.57c | **74.07B** | 28.48f | 30.98e | 37.53c | **32.33B** |
| **2000** | 50.83b | 49.60c | 52.21a | **50.88A** | 82.74a | 80.58b | 82.28a | **81.87A** | 42.84a | 40.62b | 43.34a | **42.26A** |
| **Mean** | **45.15C** | **46.52B** | **49.05A** | | **72.70C** | **75.34B** | **79.12A** | | **32.00C** | **34.42B** | **38.64A** | |
| | | | | | 2nd season | | | | | | | |
| **0** | 36.47e | 37.40e | 46.62e | **44.23B** | 66.51e | 70.55d | 78.57b | **71.88C** | 21.64e | 24.83d | 29.97c | **25.48B** |
| **1000** | 37.79e | 41.06d | 48.33d | **45.62B** | 69.77d | 73.36c | 79.70b | **74.28B** | 21.65e | 23.71d | 30.72c | **25.36B** |
| **2000** | 46.68b | 44.81c | 52.21a | **50.88A** | 82.75a | 82.43a | 83.45a | **82.87A** | 38.47a | 35.21b | 39.36a | **37.68A** |
| **Mean** | **40.31B** | **41.09B** | **49.05A** | | **73.01C** | **75.45B** | **80.57A** | | **27.25B** | **27.92B** | **33.35A** | |

Means followed by the same letter (s) in each row, column or interaction are not significantly different at 5% level.

seasons, respectively. However, the lower Perfect flower (%) was due to lower concentrations of sulphur.

**III. Fruit set percentage (%)**

Results in Table (4) show that fruit set percentage significantly increased in response to (2000g sulphur ) foliar application (42.26- 37.68%) when compared to the control and other treatments. Moreover, there were significant differences in zeolite treatments which gave the highest values (38.64-33.35**)** were application of 2000g zeolite for the two seasons. Hence, combined application of different treatments gave the highest fruit set percentage with 2000g sulphur with 0 or 2000g zeolite (42.84-43.34% and38.47-39.36%) in the two seasons when compared with control (24.67-21.6) in 2018 and 2019 seasons.

Amending soils with clinoptilolite zeolite (CZ) is able to improve physical and chemical properties acidic soil and significant macronutrients availability through the improves papaya plant growth (Liza Nuriati *et al.,* 2020). As the surface of the CZ becomes more negatively charged with increasing soil pH, this process increases the affinity of CZ for nutrient exchange or adsorption (Do˘gan, and Alkan 2003). Also, Muhammad *et al.,* (2007) ) concluded that application of different sources of sulfur had significant effect on soil properties and reduced fruit drop (20.60 %) of citrus Limon trees grown on alkaline soil. On the other hand, using different amounts of natural zeolite the effect on growth and flowering of strawberry and chemical properties of the soil (Abdi *et al.,* 2006). Moreover, olive trees treated with magnesium salphate rate of 100g/tree was effective in enhanced flowering characteristics and fruit set this was reflected on increasing yield. could be explained by improving photosynthesis efficiency ( Hegazi *et al.,* 2016).Similarly, reported by El-Khawaga (2007) and Wael (2005) notic that olive trees treated with magnesium sulfate in January showed significantly increase in fruit set and yield.

**3 3. Effects of sulphur and zeolite on fruit length, fruit diameter and fruit weight of Manzanelo olive tree**

**I. Fruit length**

It is clear from Table (5) showed that there was a significant in fruit length, on Manzanelo olive fruit. Maximum fruit length (2.12- 2.11 cm) was recorded in plants treated with 2000g sulphur in the first and second seasons. While, found that soil application of 2000g zeolite recorded the highest values (2.08-2.08cm) of fruit length in in both seasons. As interaction effects, the obtained data revealed that 2000g sulphur + 2000g zeolite gave the highest values (2.19-2.19 cm) in the first and second seasons compared to control.

**II. Fruit diameter**

The data the same Table (5) showed that increased the rate of sulphur application significant increased fruit diameter. Maximum fruit diameter was obtained with 2000g sulphur (1.75- 1.76 cm) in both seasons of study. While, the minimum value of fruit diameter was (1.51 -1.53 cm) the control treatments. Data also indicated that, trees at high doses application of zeolite (2000g) showed that highest obtained the significant values for fruit diameter (1.80- 1.73 cm) in both seasons of study compared to control. As interaction effects, the obtained data revealed that application sulphur by 2000g with zeolite by 2000g was the best value for increasing fruit diameter (1.88 and 1.80) in the second season, only.

**III. Fruit weight (g)**

Regarding fruit weight, all treatments produced higher weight than the control in Table (5). The highest significant value and recorded (3.81-3.75) by 2000g sulphur treatment in both seasons. While the control had the lowest fruit weight during this study (3.02 and3.14g).The highest rate of 2000g zeolite caused average increase (3.98-3.98g) in both seasons for fruit weight (g). Combination of 2000g sulphur with 2000g zeolite gave increased of fruit weight (4.12 and 4.06g) in both seasons.

These results are in agreement with those obtained by Danyaei *et al.,* (2014) and Sara *et al.,* (2017) who applied sulfur improve fruit physical characteristics working on olive fruit. Also, notest that "Mit Ghamr" peach trees that application at 500g / tree of sulfur coated urea recorded the highest values

of fruits number, yield per tree, fruit weight and volume were positively affected in increase of the sulfur coated urea Kandil *et al.,* (2010).

In addition, results go in line with the findings of Liza Nuriati *et al.,* (2020) who noted that amending soils with clinoptilolite zeolite is able to improve physical and chemical properties acidic soil and significant macronutrients availability effective on fruit weight, fruit length and fruit diameter of papaya trees.

### 3.4. Effects of sulphur and zeolite application on yield, fruit volume and fruit flesh weight on Manzanelo olive tree.

**I. Yield / tree (Kg)**

As shown in table (6) the results showed that under calcareous soil condition there were statistically different with in all treatments. Trees treated with 2000g / tree of sulfur recorded the highest fruit yield /tree compared with control where he gave the lowest yield recorded (31.51-29.22) in both seasons. Moreover, the maximum yield was produced with trees treated by 2000g zeolite significant value and recorded (41.21and 38.87**)** in the two seasons. when combing sulfur and zeolite levels up to treatment (2000g +2000g) gave the highest values of yield which had (47.95-44.49) in the first and second seasons. While the control had the lowest value (27.47- 25.54) in both seasons.

**II. Fruit volume**

In (Table 6) data revealed that the effect of sulphur application at high doses (2000g) maximum fruit size (3.80-3.76 ml) was recorded. While, maximum fruit size (3.69- 3.62 ml) was found in treated with 2000g zeolite in both seasons. Furthermore, the application with 2000g in each of sulphur and zeolite resulted in the highest fruit size (3.92-3.62 ml). While, minimum fruit size (2.35- 2.26 ml) was obtained from control in both seasons.

**III. Fruit flesh weight (g)**

It is obvious from (Table 6) that different application treatments sulphur and zeolite well as combinations significantly increased some of fruit flesh (g) at both seasons of this study. The highest increase of fruit flesh (2.34 and 2.18) was existed by treatment with 2000g sulphur in both seasons. Meanwhile, maximum fruit flesh (2.15 and 2.04 g) was produced with trees treated by 2000 g zeolite in the first and second seasons. Furthermore, the application of with 2000 g + 2000g zeolite resulted gave the highest significant fruit flesh (2.44 and 2.28g ), While minimum fruit flesh weigh was obtained from control (1.04 and 1.07 g) in both seasons respectively.

These results are in harmony with those of Zayan *et al.,* (2006) and El-Shenawy and Fayed (2005) stated that elemental sulphur application improved the berry quality, the addation of sulpher as soil was significantly improving fruit quality on Valencia orange trees.Increasing yield components by soil application of sulfur by decrease soil pH and it is converted quickly to sulfuric acid in the soil by soil microorganisms,supply $SO_4$ to plants, make P and micronutrients more available Ahmed *et al.,* (2013).Furthermore, amending soils with clinoptilolite zeolite (CZ) is able to improve physical and chemical properties acidic soil and significant macronutrients availability effective in productivity of papaya through the improves fruit yield per plant and fruit quality of Liza Nuriati *et al.* (2020).

### 3.5. Effects of sulphur and zeolite application on fruit oil percentage and oil acidity of Manzanelo olive fruit

**I. Fruit flesh %**

Fruit flesh percentage values significantly were affected by the various treatments in the two seasons when compared with each other. Data in Table (7) showed that fruit flesh % values related with 2000g sulphur treatments significantly were higher than all others, while fruit flesh (%) of control treatment was the lowest value significantly. Meanwhile, fruit flesh percentage values were significantly affected by 1000g zeolite in the first and1000g or 2000g zeolite in the second season. On the other side, that the interaction between sulphur and zeolite caused significant effect in fruit flesh percentage, the highest significant value was recorded with the application of sulphur at 2000g +1000g of zeolite compared with other treatments in the two seasons, control treatment significantly had the lowest value for the both seasons.

**Table 5:** Effect of sulphur and zeolite on fruit length, fruit width and fruit weight of Manzanelo olive in the 2018 and 2019 seasons.

| Sulphur (g) | Fruit length (cm) | | | | Fruit diameter (cm) | | | | Fruit weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zeolite g/tree | | | | Zeolite g/tree | | | | Zeolite g/tree | | | |
| | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean |
| | | | | | | 1st season | | | | | | |
| **0** | 1.49f | 1.91d | 2.06bc | **1.82B** | 1.21f | 1.56d | 1.75b | **1.51C** | 2.03f | 3.21d | 3.82b | **3.02C** |
| **1000** | 1.79e | 1.97cd | 1.99cd | **1.91B** | 1.48e | 1.64cd | 1.77b | **1.63B** | 2.97e | 3.37c | 3.98a | **3.44B** |
| **2000** | 2.09b | 2.05bc | 2.19a | **2.12A** | 1.64c | 1.71bc | 1.88a | **1.75A** | 3.81b | 3.49c | 4.12a | **3.81A** |
| **Mean** | **1.79C** | **1.98B** | **2.08A** | | **1.44C** | **1.64B** | **1.80A** | | **2.94C** | **3.36B** | **3.98A** | |
| | | | | | | 2nd season | | | | | | |
| **0** | 1.56f | 1.94de | 2.06bc | **1.84C** | 1.24f | 1.63d | 1.73b | **1.53C** | 2.14i | 3.37g | 3.91b | **3.14C** |
| **1000** | 1.89e | 1.98bcde | 1.99cd | **1.95B** | 1.54e | 1.66cd | 1.65cd | **1.62B** | 3.21h | 3.43f | 3.73c | **3.46B** |
| **2000** | 2.07bc | 2.07b | 2.19a | **2.11A** | 1.88a | 1.69bc | 1.80a | **1.76A** | 3.64d | 3.55e | 4.06a | **3.75A** |
| **Mean** | **1.84C** | **1.99B** | **2.08A** | | **1.52C** | **1.66B** | **1.73A** | | **2.99C** | **3.45B** | **3.98A** | |

Means followed by the same letter (s) in each row, column or interaction are not significantly different at 5% level.

**Table 6:** Effect of sulphur and zeolite on yield, fruit volume and fruit flesh of Manzanelo olive in the 2018 and 2019 seasons.

| Sulphur (g) | Yield (kg) | | | | Fruit volume ($cm^3$) | | | | Fruit flesh weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zeolite g/tree | | | | Zeolite g/tree | | | | Zeolite g/tree | | | |
| | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean |
| | | | | | | 1st season | | | | | | |
| **0** | 27.47g | 31.53f | 35.53e | **31.51C** | 2.35i | 3.37f | 3.54e | **3.09C** | 1.04i | 1.75g | 1.95e | **1.58C** |
| **1000** | 31.02f | 34.44e | 40.14d | **35.20B** | 3.26h | 3.32g | 3.61d | **3.39B** | 1.66h | 1.87f | 2.05d | **1.86B** |
| **2000** | 44.67b | 42.36c | 47.95a | **45.00A** | 3.69c | 3.79b | 3.92a | **3.80A** | 2.33b | 2.25c | 2.44a | **2.34A** |
| **Mean** | **34.39C** | **36.11B** | **41.21A** | | **3.10C** | **3.49B** | **3.69A** | | **1.68C** | **1.96B** | **2.15A** | |
| | | | | | | 2nd season | | | | | | |
| **0** | 25.54g | 28.86f | 33.26d | **29.22C** | 2.26h | 3.28g | 3.48e | **3.01C** | 1.07g | 1.84e | 1.90cd | **1.61C** |
| **1000** | 28.58f | 30.88e | 38.86c | **32.77B** | 3.31g | 3.39f | 3.55d | **3.42B** | 1.56f | 1.88de | 1.95c | **1.79B** |
| **2000** | 41.67b | 40.45b | 44.49a | **42.20A** | 3.67c | 3.76b | 3.85a | **3.76A** | 2.11b | 2.15b | 2.28a | **2.18A** |
| **Mean** | **31.93C** | **33.39B** | **38.87A** | | **3.08C** | **3.48B** | **3.62A** | | **1.58C** | **1.96B** | **2.04A** | |

Means followed by the same letter (s) in each row, column or interaction are not significantly different at 5% level.

**II. Fruit oil percentage (%)**

The highest average oil production of (15.08- 15.14) was reached at treatment 2000g sulphur was applied in both seasons compared to the control treatment. Also, found that the highest oil production of (14.82-14.03) at treatment was applied 2000g zeolite in two seasons**.** The lowest average oil production was the control. It is clear from the same Table (7) that, the interaction between sulphur and zeolite caused significant effect in fruit oil percentage, the highest significant value was recorded with the application of Sulphur at 2000g +2000g of zeolite for the first season, while in the second season, application sulphur at 2000g + zero zeolite resulted in significant highest value, and lowest values were found in control for the both seasons.

**III. Oil acidity**

According to data in Table (7) significant differences between application with sulphur, zeolite and their interaction during 2018 and 2019 seasons. Trees treated with zero sulfur in both seasens recorded the highest oil acidity (4.98-5.07%) compared with in all treatments. Also, found the lowest oil acidity at 2000g sulfur recorded with (4.16-4.23%) in both seasons. Meanwhile, the lowest of oil acidity (4.31 and 4.37%) was existed by 2000g zeolite treatment in the first and second seasons compared to the control treatment (4.87 and 5.05%). Where the best treatment was combing sulfur and Zeolite levels up to 2000g in each of gave the lowest values of oil acidity which had (4.09 and 4.01%) in the first and second seasons, while the control had the highest value (5.53 and 5.66) in both seasons. Also, a positive was found importance of sulfur in orange trees, grapevine Abdel-Nasser and El-Shazly (2000) and Younisa *et al.,* 2020 who reported that in calcareous soil sulphur nutrition increased oil quality of the canola crop.Elemental sulphur maybe role of decrease soil pH due to sulfur oxidized in soil by Thiobacillus bacteria an increase of nutrient availability (Abd-Ella, 2011).

However, application of zeolite resulted in increasing of seed oil content Mehdi Oshri (2018) and Wafaa *et al.,* (2019) reported similar results about application of zeolit increased significantly of soil characteristics, reduced nitrogen leaching to increased yield components in sesame and wheat. The oil yield and oil qualities of canola significantly improved with zeolite application (15/hectar) Shahsavari (2014).

**3.6. Effects of sulphur and zeolite application on leaf nutrients uptake of Manzanelo olive trees.**

**I. Nitrogen percentage**

Data presented in Tables (8) shows that nitrogen percentage content in the leaves of Manzanillo olive trees increasing during the two seasons. However, the foliar application of 2000g sulphur / tree recorded the highest value in nitrogen percentage in the leaves (1.67 and 1.66) as compared to control. Regarding the effect of zeolit, also the same table indicates that highest value for nitrogen percentage (1.53and1.55) was found at zeolit application at a rate of 2000 g/tree. The interactions between sulphur and zeolit significantly affected in leaves nitrogen percentage content at both seasons, the highest means of these parameters found at the interactions between of each factor was obtained at the treatment of 2000g sulphur with1000g and 2000g/tree zeolit in first season but the treatment of 2000g sulphur with 2000g/tree zeolit second season recorded the highest value (1.76 and 1.80-1.79), the lowest significant value with control.

**II. Phosphorus percentage**

Phosphorus content in olive leaves was significantly affected by treatments in both seasons. The highest value was obtained with 2000g sulphur/tree but the lowest significant values were obtained by the control. Regarding zeolit applications higher significant of phosphorus percentage in leaves for 2000g/tree in first and second seasons. On the other hand,the intraction between different sulphur and zeolit on leaf posphorus percentage, the highest values were recorded with 2000g sulphur + 2000g zeolit in both seasons. But the lowest significant value with control.

**III. Potassium percentage**

Data presented in table (9) as for potassium percentage in leaves results in the same table indicated that all treatments increased the K% than control. Meanwhile, applcations trees with 2000g sulphur in two seasons, significantly higher in leaf potassium content (0.23 and 0.24) than their leaves in the other treatments and the control. Whereas, zeolit at 2000g/tree increased the K% in both seasons

**Table 7:** Effect of sulphur and zeolite on fruit flesh, fruit oil percentage and oil acidity of Manzanelo olive in the 2018 and 2019 seasons.

| Sulphur (g) | Fruit flesh % | | | | Fruit oil percentage (%) | | | | Oil acidity (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zeolite g/tree | | | | Zeolite g/tree | | | | Zeolite g/tree | | | |
| | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean |
| | | | | | 1st season | | | | | | | |
| **0** | 49.45d | 51.15d | 54.72c | **51.77C** | 11.76g | 12.57f | 13.80df | **12.71C** | 5.53a | 4.85b | 4.55c | **4.98A** |
| **1000** | 55.89c | 55.45c | 51.51d | **54.28B** | 12.43f | 13.67e | 14.72c | **13.61B** | 4.917b | 4.43cd | 4.30de | **4.56B** |
| **2000** | 61.08b | 64.55a | 59.10b | **61.58A** | 15.43b | 13.87d | 15.95a | **15.08A** | 4.16fg | 4.24ef | 4.09g | **4.16C** |
| **Mean** | **55.48B** | **57.05A** | **55.11B** | | **13.21C** | **13.37C** | **14.82A** | | **4.87A** | **4.51B** | **4.31C** | |
| | | | | | 2nd season | | | | | | | |
| **0** | 48.64e | 50.24e | 54.75c | **51.21B** | 12.17h | 12.88f | 13.51e | **12.85C** | 5.66a | 4.91c | 4.64d | **5.07A** |
| **1000** | 48.70e | 54.96c | 52.32d | **52.00B** | 12.48g | 12.87f | 13.67d | **13.01B** | 5.17b | 4.56e | 4.46f | **4.73B** |
| **2000** | 58.13b | 60.66a | 56.20c | **58.33A** | 15.87a | 14.64c | 14.91b | **15.14A** | 4.32g | 4.34g | 4.01h | **4.23C** |
| **Mean** | **51.82B** | **54.43A** | **54.43A** | | **13.50B** | **13.47B** | **14.03A** | | **5.05A** | **4.60B** | **4.37C** | |

Means followed by the same letter (s) in each row, column or interaction are not significantly different at 5% level.

**Table 8:** Effect of sulphur and zeolite application on leaf nutrients uptake of Manzanelo olive in the 2018 and 2019seasons.

| Sulphur (g) | N % | | | | P % | | | | K % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Zeolite g/tree | | | | Zeolite g/tree | | | | Zeolite g/tree | | | |
| | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean | 0 | 1000 | 2000 | Mean |
| | | | | | 1st season | | | | | | | |
| **0** | 0.97f | 1.25d | 1.38c | **1.20C** | 0.16bc | 0.17abc | 0.20ab | **0.13 C** | 0.88 e | 0.12f | 1.17 c | **0.72C** |
| **1000** | 1.09 e | 1.23d | 1.42bc | **1.26B** | 0.00 d | 0.12 c | 0.16bc | **0.17 B** | 1.01d | 1.05 d | 1.18 c | **1.08 B** |
| **2000** | 1.45b | 1.76 a | 1.80a | **1.67A** | 0.12 c | 0.18ab | 0.22a | **0.23A** | 1.26 ab | 1.22ab | 1.31 a | **1.26 A** |
| **Mean** | **1.17C** | **1.41B** | **1.53A** | | **0.16B** | **0.17AB** | **0.20A** | | **1.05B** | **0.80 C** | **1.22 A** | |
| | | | | | 2nd season | | | | | | | |
| **0** | 0.92h | 1.313e | 1.40 d | **1.21B** | 0.12f | 0.14 ef | 0.16def | **0.14 B** | 0.94 g | 1.09 e | 1.50cd | **1.18 B** |
| **1000** | 1.04g | 1.247f | 1.47 c | **1.25B** | 0.19cde | 0.23abc | 0.26 ab | **0.23 A** | 1.02 f | 1.10 de | 1.20bc | **1.11 C** |
| **2000** | 1.48c | 1.710b | 1.79 a | **1.66A** | 0.28a | 0.21bcd | 0.24abc | **0.24A** | 1.25 ab | 1.23 ab | 1.28a | **1.25 A** |
| **Mean** | **1.15C** | **1.42B** | **1.55A** | | **0.20A** | **0.19A** | **0.22 A** | | **1.07C** | **1.14 B** | **1.21 A** | |

Means followed by the same letter (s) in each row, column or interaction are not significantly different at 5% level.

than control. The interaction between different sulphur and zeolit results revealed that the highest potassium leaf content significantly were obtained by2000g sulphur +2000g zeolit / tree in all seasons, the lowest value was obtained by control.

**IV. Calcium percentage**

Data in Table (9) show clearly that all treatments significantly increased leaf calcium content of Manzanelo olive trees during two seasons of study. Treated with sulphur gave highest concentration at 2000g/tree resulted in the highest leaf calcium content (0.68 and 0.70**)** during two seasons. Application of 1000g and 2000g /tree zeolit also increased the Ca% (0.61- 0.62**)** in the first season and application with 2000g zeolit (0.65) in the second season when compared with the control. Foliar application with a combination of (2000g sulphur with 2000g zeolit/tree) gave significantly higher leaf calcium content compared with other treatments and the control.

**V. Magnesium percentage**

The results in Table (9) revealed that all foliar applcations increased leaf magnesium content when compared with the control in two seasons. Manzanelo olive trees applications with 2000g sulphur /tree gave the highest significant values of leaf magnesium content (0.19 and 0.19**)** of all seasons compared with the control. However, trees treated with 1000g or 2000g zeolit gave the highest significant values of leaf magnesium content (0.14 -0.14 and 0.16-0.14 **)** in the first and second seasons, respectively. The interaction between different sulphur and zeolit results revealed that the highest magnesium leaf content significantly were obtained by 2000g sulphur +2000g zeolit / tree in both seasons. The lowest value was obtained by control (water spraying).

**Table 9:** Effect of sulphur and zeolite application on calcium and magnesium percentage of Manzanelo olive in the 2018 and 2019seasons.

| Sulphur (g) | Ca % | | | | Mg % | | | |
|---|---|---|---|---|---|---|---|---|
| | Zeolite g/tree | | | | Zeolite g/tree | | | |
| | **0** | **1000** | **2000** | **Mean** | **0** | **1000** | **2000** | **Mean** |
| | | | | **1st season** | | | | |
| **0** | 0.47 f | 0.58 de | 0.60 cd | **0.55 B** | 0.09 e | 0.12cde | 0.14b-e | **0.12 B** |
| **1000** | 0.54 e | 0.58 de | 0.56 de | **0.56B** | 0.11 de | 0.12cde | 0.15a-d | **0.13 B** |
| **2000** | 0.64 bc | 0.68 ab | 0.71 a | **0.68 A** | 0.17abc | 0.18ab | 0.20 a | **0.19 A** |
| **Mean** | **0.55 B** | **0.61 A** | **0.62 A** | | **0.12 B** | **0.14 AB** | **0.16 A** | |
| | | | | **2nd season** | | | | |
| **0** | 0.42 g | 0.56 e | 0.62 cd | **0.53 B** | 0.08f | 0.09 f | 0.13de | **0.10B** |
| **1000** | 0.48 f | 0.54 e | 0.59 de | **0.54B** | 0.10 ef | 0.13de | 0.15cd | **0.13B** |
| **2000** | 0.71ab | 0.67 bc | 0.73 a | **0.70 A** | 0.16bc | 0.19ab | 0.21a | **0.19A** |
| **Mean** | **0.54 C** | **0.59 B** | **0.65 A** | | **0.12B** | **0.14 A** | **0.16A** | |

Means followed by the same letter (s) in each row, column or interaction are not significantly different at 5% level.

Results were determined that adding sulphur significantly increased leaves N, P, K, S, Fe, Mn and Zn in parallel with the studies conducted by Al-Tuhafi (2004) who worked in Kamali and Halwani grapevines, Jassim *et al.,* (2020) on Dixired Peach trees. Also, application of sulphur, the absorption N, P and used to the plants raised on alkaline soils as a result of a decrease in soil pH (Muhammad *et al.,* 2007), adding elemental sulphur is probably due to raising the oxidation rate of elemental sulphur resulting in improving some physical and chemical properties of soil and increasing nutrient availability, the obtained results were similar to those of El-Akkad (2004) and Zayan *et al.,* (2006).

Many studies a positive effect of using zeolite on plant and effect on the main nutrients (N, P, K, Ca and Fe) in leaves and fruits (Jakab and Jakab, 2010). For example, Perez Caballero *et al.,* (2008) similarly found that the levels of K and N in olive tree leaves increased the addition of zeolite to the soil, and Liza Nuriati *et al.,* (2020) who found that amending soils with CZ is able to improve soil acidity and significant macronutrients availability effective in productivity of papaya through the improves mineral contents in leaves.The possible reason could be that Natural zeolites improve soil electrical conductivity, nutrient retention capacity, and usually increases soil pH and rich source in some nutrients such as N, K, Ca, Mg and micronutrients (Milosevic *et al.,* 2013).

## 4. Conclusion and Recommendations

The results of the present study proved that using Sulfur and zeolite at different levels sulfur alone or in combinations on vegetative growth, flowering and yield, fruit quality as well as nutrients status of "Manzanillo" olive trees in calcareous soil under Matrouh conditions.

However, soil application of sulphur especially at a level of 2000 g / tree and zeolite at a level of 2000 g / tree each alone or with each other significantly increased the highest values of flowering density, Perfect flower %, fruit set %, fruit length, fruit weight, yield/tree, fruit volume, fruit flesh (%) and fruit oil content (%). Meanwhile, fruit acidity was significantly decreased with the increase the level of sulfur or zeolite.

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