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Research Article

Influence of Foliar Application of Sulfur at Various Stages on Yield and Oil Content of Olive (*Olea eurapaea* L.)

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Abstract

The present study was conducted to investigate the influence of foliar application of sulfur at various stages on yield and oil content of olive (*Olea europaea* L.) during the year 2018. The experiment was laid out in RCBD with two factors having split plot arrangement and treatments were replicated three times. Factor A was time of foliar application (pre-blooming, fruit set, after 20 days of fruit set) allotted to main plots and factor B foliar spray of Sulfur concentrations (0, 500, 1000, 1500 ppm) were allotted to sub plots. Results showed that maximum number of fruits panicle^{-1} (5.33), number of fruits plant^{-1} (5235.6), minimum fruit drop (55.11%), maximum fruit length (2.79 cm), fruit diameter (2.32 cm), fruit volume (5.35 ml), single fruit fresh weight (7.33g), fruit dry weight (2.04g), fruit pulp (83.34%) and minimum fruit stone (21.44%), maximum yield plant^{-1} (21.72 kg), yield hectare^{-1} (17.73 tons) and oil content (12.62%) were observed in plants treated with 1500 ppm sulfur foliar application. In conclusion better yield of olive is on 1500 ppm should be applied at pre-blooming stage while for maximum oil contents same concentration of sulfur should be applied at fruit set stage.

Keywords: *Olive; Foliar Application; Sulfur; Growth Stages; Production; Oil Content*

Introduction

Olive (*Olea europaea* L. (cultivated), *Olea cuspidate* (wild)) belongs to family Oleaceae, locally known as Zaitoon, Khuna or Kaho with more than 25000 varieties all over the world. Olive was cultivated in 4800 BC in the Mediterranean area. Though, it is widely grown in the central Asia, different areas of Australia, Africa and also in the North and South America [1]. Olive is an evergreen tree with steady growth and either self-pollinated or cross-pollinated; with wind being the main pollinating agent [2]. Fruit of olive is fleshy drupe having hard stone which has enclosed seed [3]. The fruit contains chemical compound i.e. oleuropein which causes bitterness. Average chemical composition of olive fruit is 22% oil, 1.5% protein, 24% carbohydrate, 1.5% minerals and 50% water. Additionally, the fruit is also high in polyphenols content in the range of one percent of fresh weight [4]. Olive oil is the most beneficial, healthiest and tasteful edible oil with rich source of energy, vitamins and unsaturated fatty acids (Patumu., *et al*. 1999). Sulfur is one of an essential element that is required for the growth of plant and its development [5]. Generally, 90% of sulfur is found as organic form in the soil however most of the cultivable soils are

notified as sulfur deficient. Mostly less organic matters in soils, cause losses of sulfur through volatilization [6]. Soil under sulfur deficient conditions, declined the crops growth, its yield and its quality [7]. The plants take up sulfur from the soil solution mainly in the form of sulphates (SO_4^{2-}) [8]. Beside that sulfur can be taken up also via the leaves in the form of foliar applications [9]. Moreover, sulfur plays a key role in the chemical composition of seeds while help in increasing the percentage of oil content [10]. In case the supply of sulfur is sufficient, so the plants are capable to release hydrogen sulphide through the leaf surface, which prevents pathogen attacks [11]. Foliar treatment of nutrient is useful to fulfill the requirements of plant and also it has a high efficiency in plant growth and development [12]. Foliar application gives a fast technique of applying nutrients to correct nutrient deficiencies in plants. Moreover, it is one of a convenient way to apply highly soluble fertilizers, especially in a very small amount [13]. The current study was designed to find effect of sulfur levels on yield and oil contents of olive cultivar (Pendallino) and optimum growth stage of sulfur application for maximum olive production and better oil content.

Materials and Methods

Experimental site and layout

The experiment entitled "Foliar application of sulfur may improve yield and oil content of olive (*Olea eurapaea* L.)" was conducted at Olive Model Farm Sangbatti, Mardan, during 2018. The research farm is situated in district Mardan of Khyber Pakhtunkhwa province-Pakistan about 364 meter above the sea level having average summer temperature of almost 45^0C and in winter the temperature decline to 0^0C. Relative humidity of the area is about 65%. The experiment was carried out in Randomize Complete Block Design (RCBD) with two factors in split plot arrangements having three replications. Eight years old trees of olive cultivar Pendolino was selected for the experiment. The trees were applied with recommended fertilizer rates nitrogen, phosphorus and potash as well as the normal horticultural practices remained constant for all experimental units that were practiced in the farm. Detail of the proposed treatments is given as below.

Preparation of sulfur concentrations and its application

Powder sulfur was used for preparing different concentrations for experimental use. The product used for foliar application was Netzschwafel Stulln (80% sulfur). Sulfur was taken in ppm (1 ppm= 1 mg/L or 0.001 g/L) and weighed on digital balance for each and every level and then dissolved in water. 100 liters solutions were prepared of different sulfur concentrations @ 500, 1000 and 1500 ppm for 12 trees at one stage.

These levels were sprayed at pre-blooming, fruit set and after 20 days of fruit set.

Parameter studied attributes

Data were collected on the following parameters.

Number of fruits panicle^{-1}

From each plant 10 panicles were randomly selected and then number of fruits were counted from each randomly selected panicle, then the average were calculate as:

$$\text{Number of fruits panicle}^{-1} = \frac{\text{total number of fruits}}{\text{number of panicles}}$$

Number of fruits plant^{-1}

From each tree one kg fruits sample was taken, counted all fruits of the sample and then multiplied by total yield plant^{-1} to get total number of fruits plant^{-1}. The number of fruits plant^{-1} was calculated using formula:

$$\text{Number of fruits plant}^{-1} = \text{number of fruits kg}^{-1} \times \text{total yield of plants (kg)}$$

Fruit drop (%)

Fruit drop percentage was measured for each treatment with the following formula:

$$\text{fruit Drop(\%)} = \frac{\text{initial fruits per panicle -final fruits per panicles}}{\text{initial fruit per panicle}} \times 100$$

initial fruit per panicle^{-1}

Fruit length (cm)

The fruit length was measured, when the fruit become ripen (i.e. black ripe). Randomly fruits plant^{-1} in each selected branch of the tree was measured with the help of Vernier Calliper.

Fruit diameter (cm)

The fruit diameter was also measured when fruit become ripe i.e. black ripe, then randomly fruits plant^{-1} were measured of each selected branch of the tree with the help of Vernier calliper.

Fruit size (ml)

Fruit size (ml) was measured with the help of graduated Cylinder by water displacement method. Briefly, take 100 ml graduated Cylinder, filled with water up to 50 ml and at that time put fruit inside the Cylinder which raised the volume. Fruit size was calculated by subtracting initial reading from final reading:

fruit size (ml) = final reading - initial reading

Fruit pulp (%)

Fruit were first weighed with stone, then fruit stone was individually weighed and subtracted from total fruit weight. Fruit pulp percentage calculated by the following formula:

$$\text{fruit pulp}(\%) = \frac{\text{fruit weight - stone weight}}{\text{fruit weight}} \times 100$$

Fruit stone (%)

Each fruit was weighed with stone then pulp was weighed alone and then subtracted from fruit weight. Fruit stone (%) was calculated by following formula:

$$\text{fruit stone}(\%) = \frac{\text{fruit weight - fruit pulp weight}}{\text{fruit weight}} \times 100$$

Single Fruit fresh weight (g)

Fruit fresh weight was measured by electric balance. Fruits were taken from each treatment, weighed and then its average was calculated:

$$\text{single fruit fresh weight (g)} = \frac{\text{weight of fruits}}{\text{number of fruits}} \times 100$$

Fruit dry weight (g)

The dry weight of the fruit was taken after drying fruit with stone in the oven at 70 ^{0}C for 48 hours and then it weighed by using electric balance.

Fruit yield plant^{-1} (kg)

All fruits were collected from each selected plant manually (27 October), weighed and then average fruit yield plant^{-1} was estimated for each treatment separately.

Yield hectare^{-1} (Ton)

All fruits were collected after harvesting from trees in each treatment, weighed and then average yield hectare^{-1} was calculated for each treatment. First counted all trees hectare^{1} and then multiplied with total yield plant^{-1} for each treatment.

Oil content (%)

Fruits were collected from each treatment and 15 kg fruits were taken. Oil was extracted from these fruits in oil extraction unit at Olive Model Farm Sangbatti. The fruit oil content percentage was calculated with the following formula:

$$\text{oil content}(\%) = \frac{\text{oil extracted (liter)}}{\text{fruit sample (kg)}} \times 100$$

Statistical analysis

Recorded data were analyzed statistically using analysis of variance (ANOVA) techniques for Randomized complete block design to observe the differences between the different treatments as well as their interactions. In cases where the differences were significant, the means were further assessed for comparison through Least Significant Difference (LSD) test (Steel and Torrie 1980). Statistical computer software, Statistic 8.1, was used for computing both the ANOVA and LSD.

Results and Discussion

Number of fruits panicle^{-1}

It is confirmed from mean table that plants treated with sulfur concentrations at 1500 ppm showed maximum (5.33) fruits panicle^{-1}, which was also at par with 1000 ppm and 500 ppm sulfur levels that produced (5.0) and (4.0) fruits panicle^{-1} respectively. While the minimum fruits panicle^{-1} was recorded in trees sprayed with distilled water. Sulfur nutrition has been significantly important in improving fruit yield and quality as well as the availability of certain micronutrients [14]. Also reported that nutrient foliar applications can cause improvement of yield and fruit size of olive. The application of Sulfate to rape seed at seeding time provides the maximum improvement in yield and sulfur uptake [15]. While foliar application of some other nutrients such as boron also increase fruits panicle^{-1}. Similar results were also found by [16] that boron foliar application significantly increased fruit set, fruit quality and yield of olive.

Number of fruits plant^{-1}

Data in mean table exposed that maximum the number of fruits plant^{-1} (4979.3) were recorded in trees that when sulfur were sprayed at the pre-blooming stage, while the minimum number of

Sulphur (ppm)	Number of fruit spike^{-1}
Control	2.67b
500	4.00ab
1000	5.00a
1500	5.33a
Mean	4.25

Table 1: Number of fruits panicle^{-1} of olive as influenced by foliar Sulfur application at pre-blooming stage.

fruits plant^{-1} (4650.9) were observed in plants that received sulfur spray after 20 days of fruit set stage. Similarly, among different concentrations the maximum number fruit plant^{-1} (5235.6) were obtained in the trees that were sprayed with 1500ppm sulfur foliar application, although minimum number fruits plant^{-1} (4387.5) were observed from control plants sprayed with distilled water. (Mirannivi, 1990) Also reported that number of fruit is correlated with size of fruit, lower number of fruits per tree will be the bigger fruit size. Therefore, foliar nutrient application plays an important role to increase number of fruits spike^{-1} of olive clarified by many research studies. Though some other foliar nutrient sprays such as boric acid have been shown in increase olive fruits plant^{-1} conformed by [17] found that application of boric acid increased number of fruits plant^{-1}, similar results were also reported by Osman (1999) and Shahhen (1995).

Fruit drop (%)

Mean value of fruit drop percentage for various growth stages showed that the minimum fruit drop (53.67%) was recorded for plants that were received sulfur foliar spray after 20 days of fruit set, while the maximum fruit drop (59.17%) was recorded in the trees when foliar sulfur spray was done at pre- blooming stage. Fruit set of 1-2% is essential for commercial production, whereas in case of less number of inflorescence produce on a tree, with 10% fruit set might be necessary for the commercial yield production [18]. However, plants with higher percentage of fruit set could lead to improved yield even if there were less number of flowers [19]. According to [20] revealed that natural thinning in plants removes the excess fruit load on plant and allows the remaining fruits for proper development.

Fruit length (cm)

Interaction between sulfur and growth stages indicated that the application of 1500 ppm sulfur, at fruit set showed maximum fruit length (2.96 cm) of olive, followed by (2.82 cm) when plants were sprayed with 1500 ppm after 20 days of fruit set. However, control plants (sprayed with distilled water) observed with minimum fruit length (2.40 cm) when sprayed at fruit set stage. Foliar application of sulfur may provide pecan to increase the size and quality of the nut as well as get high improvement in the productivity of their crop [21,22] Also stated that high amount of sulphate concentrations may affect plant development and crop yield. Current findings are in agrees with the findings of [23] who stated from their results that Sulfur containing Humic-Acid showed significant impact on length of olive fruit. Therefore foliar sprays of sulfur are more affective on olive.

Fruit diameter (cm)

Mean values showed that the largest fruit diameter (2.32 cm) was obtained from the plants that were sprayed with 1500 ppm sulfur foliar application, which is at par when plants were sprayed with 1000 ppm i.e. 2.30 cm. While the smallest fruit diameter (1.84 cm) was obtained from fruits when plants were sprayed with only distilled water (control plots). Fruit diameter of olive increased with increase sulfur concentration because it is present in the major metabolic compounds such as amino acids (methionine and cysteine), glutthionione, sulpho-lipid and proteins [24]. Ramezani and Shekafandeh [25] also reported that increased in fruit weight and diameter of olive with foliar sprays of zinc sulphate and gibberellic acids. While further supported by [26] that fruits shape index (length/diameter) of olive tended to increase due to zinc sulfate sprays compared with control.

Fruit size (ml)

Interaction between sulfur and growth stages showed that the application of 1500 ppm sulfur, at fruit set stage gives maximum fruit size (6.93 ml) followed by (6.43 ml) when plants were sprayed with 1500 ppm after 20 days of fruit set stage. However minimum fruit size (3.87 ml) was recorded in control plants (sprayed with distilled water) when sprayed at fruit set stage. Foliar sulfur sprays may run pecan production with an implement which maximize size of nut and also increased productivity of the crop [21]. However, from other studies of macronutrients such as potassium nitrate, reported by Hagzi., *et al*. (2011) that fruit volume of olive was significantly affected by different potassium nitrate spray during both seasons. Potassium nitrate spray at the rate of 4% gave highest value of fruit volume of olive after fruit pit hardening in both seasons.

Fruit pulp (%)

From mean value of fruit pulp (%) forvarious growth stages showed that maximum fruit pulp (81.99%) was noted in the plants when sprayed at fruit set, whereas minimum pulp (79.94%) was reported in trees that received sulfur spray at preblooming stage. Similarly, among different concentrations of sulfur, plants that were treated with 1500 ppm sulfur foliar application achieved maximum fruit pulp (83.33%) and while the minimum fruit pulp (77.72%) were obtained from control plots. Sulfur plays an important role in chemical composition of seeds and also it increasing oil percentage [10]. Wani., *et al*. [27] also observed a significant increase in protein content and seed yield of Sunflower by increasing sulfur level. Current findings are in agreement with the research conducted by [28] who concluded from their result that oilseeds have high demand of Sulfur. While fruit pulp also influence by zinc sulfate stated by [26] that pulp/pit was increased by zinc sulfate treatments in both seasons at before and during blooming stages compared with control.

Fruit stone (%)

For different growth stages mean value of fruit stone showed that minimum fruit stone (23.91%) was obtained from plants sprayed at fruit set, whereas the maximum fruit stone (25.58%) was recorded for plants that received spray in pre blooming stage. As well, among different sulfur concentrations minimum fruit stone (21.44%) was obtained from trees that were treated with foliar application of 1500 ppm, and maximum fruit stone (28.55%) was observed from control plots. Gul., *et al*. [20] suggested for their findings that plants used most of their energy for the enlargement of pulp of the fruit rather than fruit stone. As from other sulfur source such as $ZnSO_4$ has positive impact on fruit pulp/ pit. Plants treated with $ZnSO_4$ at 0.5% obtained the highest fruit pulp and pulp/pit volume, that is confirmed by Ramezani and Shekefandeh (2011). Similarly fruit pulp/pit was increased by zinc sulfate at preblooming and full blooming stages by [26].

Single fruit fresh weight (g)

Maximum value of fruit fresh weight (8.13g) was recorded for the trees that received sulfur spray with 1500 ppm during fruit set, followed by (7.70g) when plants were sprayed with 1500 ppm after 20 days of fruit set. However the minimum fruit weight (4.56g) was reported in control plants sprayed with distilled water at both stages of pre-blooming and fruit set stage. Sulfur is one of macronutrient for plants so according to [29] that macronutrient mineral status affect the productivity stages of olive trees. Presents findings are in agreement with [23] who concluded that Sulfur-containing humic acids increased fresh weight and dry weight of olive fruit. Similarly, foliar sulfur spray enhanced pecan nut weight reported by [21].

Fruit dry weight (g)

For different growth stages mean value (Table) showed that maximum fruit dry weight (1.88g) was recorded for the plants that received sulfur spray during fruit set, whereas minimum fruit dry weight (1.71g) was observed in plants that received sulfur spray at pre blooming stage. As well, from mean value among different sulfur concentrations maximum fruit dry weight (2.04g) was obtained from trees that were treated with 1500 ppm sulfur foliar application, while minimum (1.41g) was observed from control plots. The results agreed with the research conducted by [23] who reported that analysis of variance revealed significant affect of sulfur containing humic acid on fruit fresh weight and dry weight of olive at 1% probability levels. Foliar application of macronutrient on olive plant further supported by [30] reported that potassium nitrate spray at 4% after pit hardening gave the highest flesh dry weight while control treatment gave lowest dry weight.

Fruit yield plant^{-1} (kg)

Mean value of fruit yield plant^{-1} for different growth stages showed that maximum fruit yield plant^{-1} (20.66 kg) was recorded in plants sprayed during fruit set, whereas minimum fruit stone (19.30 kg) was recorded for plants that received sulfur spray ats pre blooming stage. Similarly, maximum fruit yield plant^{-1} (21.72 kg) was obtained from trees that were treated with 1500 ppm sulfur foliar application, while the minimum (18.21 kg) was observed from control plots. Sulfur fertilization of oilseed crops have also shown an increase in both of oil content and yield of seed [31,32]. Wani., *et al*. [27] also reported significant increase in yield and protein content of sunflower application response was positive and consistent, which had progressively improved the yield attributes, yield and oil contents. Similarly, reported by [32] that sulfur application not only increased crops yield but improved quality as well.

Yield hectare^{-1} (ton)

Mean value of yield hectare^{-1}for different growth stages showed that maximum yield hectare^{-1} (16.81 tons) was recorded in plants

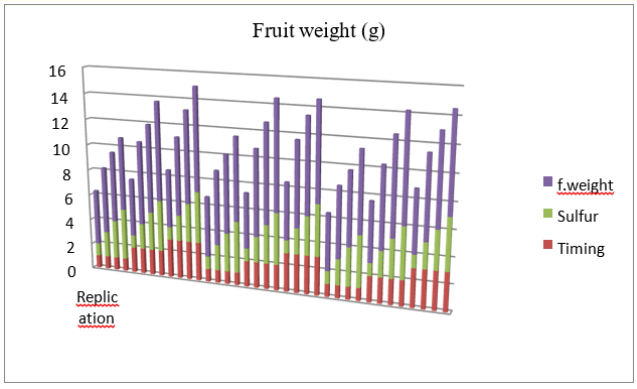
sprayed during pre-blooming stage, whereas minimum yield hectare^{-1} (15.75 tons) was recorded for plants that received sulfur spray at 20 days after fruit set. Similarly, among different concentrations maximum fruit yield hectare^{-1} (17.73 tons) was obtained from trees that were treated with 1500 ppm sulfur foliar application, while the minimum (14.86 tons) was observed from control plots. Sulfur plays an important role in chemical composition of seeds and also it increasing oil percentage [10]. Oilseeds crops have high demand of Sulfur (Vella., *et al*. 2014). Oilseed crops have also shown an increase in both of oil content and yield of seed Sulfur fertilization [31,32]. Current findings agreed with [23] who reported that sulfur-containing humic acid significantly increased olive yield plant^{-1} [33-35].

Oil content (%)

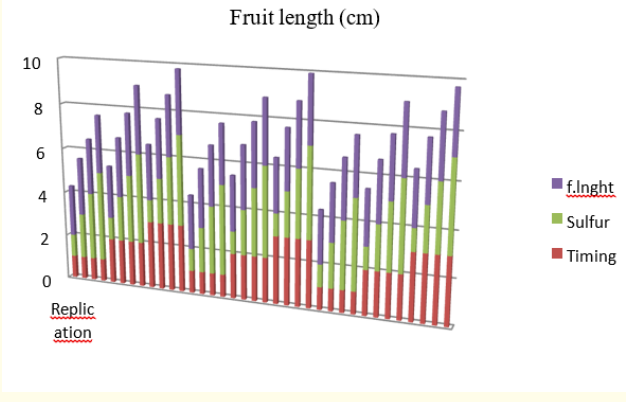
For different growth stages mean data of oil content percentage showed that maximum oil contents (11.56%) was recorded in plants sprayed during fruit set, whereas minimum oil contents (10.92%) was recorded for plants that received sulfur spray in pre blooming stage. For different sulfur concentrations maximum olive oil (12.27%) was extracted from the plants that received sulfur spray of 1500 ppm and then followed by 1000 ppm (11.2%), while minimum olive fruit oil (10.20%) was extracted from control plots. Sulphur plays an important role in the chemical composition of seeds, while it also increases oil percentage [10]. Sulfur fertilization has shown to increase the oil content of groundnut [31]. Sulfur application had significant effect on yield dry matter and increased oil content of mustard. While similarly reported by [20] that Boron foliar application has significantly influenced oil content of olive fruit.

Growth stage	Parameters											
	No of fruit plant^{1}	Fruits drop %	Fruits length (cm)	Fruits diameter (cm)	Fruit volume (ml)	Fruit Pulp (%)	Fruit stone (%)	Fruit fresh weight (g)	Fruit dry weight (g)	Yield plant^{1} (kg)	Yield hectare (Ton)	Oil content (%)
Pre-bloom	4979.3 a	59.17 a	2.53 b	2.15	4.92 b	79.94 b	25.58 a	5.47 b	1.72 b	20.66 a	16.87 a	10.92 b
Fruit set	4847.9 ab	54.42 ab	2.71 a	2.21	5.50 a	82.00 a	23.91 b	6.62 a	1.88 a	20.17 ab	16.42 ab	11.57 a
Fruit set after 20 days	4650.9 b	53.67 b	2.67 a	2.19	5.36 a	81.47 a	24.97 ab	6.46 a	1.77 b	19.30 b	15.75 b	11.43 a
LSD	219.55	10.787	0.0465	NS	0.2648	1.1860	1.2813	0.3223	0.1009	1.1700	0.7437	0.4128
Sulfur concentration												
Control	4387.5 c	56.00	2.39 c	1.84 b	3.91 d	77.72 c	28.56a	4.5 d	1.41 c	18.21 c	14.86 c	10.20 c
500 ppm	4702.2 b	56.11	2.65 b	2.26 a	5.01 c	81.25 b	25.44 b	6.12 c	1.81b	19.51 bc	15.93 b	11.14 b
1000 ppm	4978.8 ab	55.78	2.71b	2.30 a	5.75 b	82.23 ab	23.78 b	6.78 b	1.90 ab	20.66 ab	16.86 ab	11.62 ab
1500 ppm	5235.6 a	55.11	2.79a	2.32 a	6.35 a	83.35 a	21.44 c	7.33 a	2.04 a	21.72 a	17.73 a	12.267a
LSD	298.4	NS	0.0681	0.0736	0.2539							

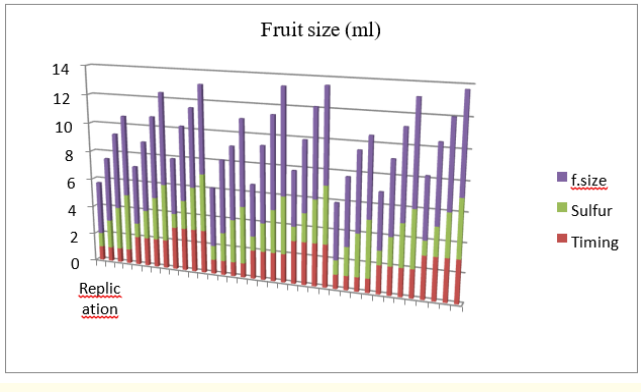
Table 2



Graph 1: Interaction of different treatment concentration with different application of timing and replication of fruit weight.



Graph 2: Interaction of different treatment concentration with different application of timing and replication of fruit length.



Graph 3: Interaction of different treatment concentration with different application of timing and replication of fruit size.

Conclusion

Foliar sulfur application at pre-blooming stage performed better in reducing the fruit drop, increasing the number of fruits plant^{-1}, yield plant^{-1} and yield hectare^{-1}, while at fruit set stage showed best results for fruit length, fruit diameter, fruit weight, fruit size, single fruit fresh weight, fruit dry weight and fruit pulp %. Sulfur at the rate of 1500 ppm performed better in terms of all yield and quality parameters. Interaction of growth stage (fruit set stage) and sulfur concentration (1500 ppm) give maximum fruit length, fruit size and fruit weight. For better yield of olive, sulfur should be applied at the rate of 1500 ppm at pre-blooming stage. While for maximum oil contents, it should be applied at fruit set stage. Further research is suggested on foliar application of sulfur on olive with higher concentrations for better yield and oil contents of olive.

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