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Influence of Zn and K Sprays on Fruit and Pulp Growth in Olive (*Olea europaea* L. cv. 'Amygdalifolia')

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ABSTRACT- This study was carried out on olive trees cv. Amygdalifolia, to investigate the effect of spraying potassium nitrate, KNO_3, and zinc sulfate, $ZnSO_4$, on the fruit weight, dimension and volume. The plants were sprayed with 0, 0.5, 1.0 and 1.5% KNO_3 and 0, 0.25, 0.50 and 0.75% $ZnSO_4$ and their combinations in August about halfway through the fruit growth period. The highest fruit weight was observed using 0.5% $ZnSO_4$ + 0.5% KNO_3. Fruit length and diameter were affected significantly using different $ZnSO_4$ concentrations especially in combination with KNO_3. The fruit, pulp and pulp/pit volume increased by increasing $ZnSO_4$ concentrations. The highest fruit, pulp and pulp/pit volume were also obtained from trees treated with 0.5% $ZnSO_4$ + 0.5% KNO_3. Our results emphasize the importance of an appropriate fertilization management, particularly for table olives, in which fruit size, and pulp/pit ratio are important characteristics.

Keywords: Fruit dimension, KNO_3, Olive, $ZnSO_4$

INTRODUCTION

Olive fruit is a drupe composed of three distinct tissues: the thin protective exocarp, the fleshy mesocarp (pulp) and the stony endocarp (10). The last section contains the seed. These three fruit components follow distinctive growth periods (1). The mesocarp is the edible portion of table olives and the tissue is where oil is accumulated. A high mesocarp/endocarp (pulp/pit) ratio is considered desirable, particularly for table olives (6). Also, in the case of pitted table olives, it makes pit removal easier, reducing processing costs. Potential cultural management to improve the pulp/pit ratio is complex; as the growth and development of these two tissues are closely interrelated due to their common origin in the ovary pericarp and their overlapping activity as competing sinks (17). Although the olive is able to grow on very poor soil conditions with relatively low nutrient content, for regular and high production it demands basic nutrients just like other fruit species.

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Many previous investigations have demonstrated the effect of irrigation on final olive fruit size and a high pulp/pit ratio (2, 11, 14, 15). However, according to our knowledge, there are few studies on the effect of nutrients on mesocarp and endocarp growth. Morales-Sillero et al. (15) reported that fruit fresh and dry weight, longitudinal and equatorial diameters, and the pulp/pit ratio were increased by using macro elements (N-P-K) in irrigation water. Lavee (12) indicated that N deficiency may lead to a decrease in both fruit set and size, while B deficiency may alter fruit shape because of modified lignification of the mesocarp. Also, K deficiency may cause a decreased in fruit size, particularly in conditions of low availability of soil water (5).

Rapoport et al. (2004) suggested that endocarp growth had a higher sink priority than mesocarp growth in 'Leccino' olive trees. The irrigation regime may affect both the absolute and relative growth of mesocarp and endocarp, as well as the timing of development of those two tissues (7, 8, 11, 13, 16). Ramezani and Shekafandeh (19) reported that zinc sulfate had positive effects on fruit characteristics in terms of fruit weight and fruit dimensions of 'Shengeh' olive cultivar.

This study was conducted to elucidate the effect of different nutrient sprays on fruit growth and pulp/pit ratio of 'Amygdalifolia' cultivar. For identification of the exact stage and time of nutrient spraying, the fruit growth pattern has been determined.

MATERIALS AND METHODS

This research was conducted on 11-year-old olive trees (*Olea europaea* L. cv. Amygdalifolia) grown in sandy, clay, loam soil with the following properties: 55% sand, 30% clay and 15% silt, pH = 7.8 and EC = 1.4 ds m^{-1}. The trees spacing was set to 5 m × 5 m apart under a drip irrigation system in the Olive Research Station of Kazerun located in Fars province of Iran. Kazerun, as a center of olive production, is located at the west of Shiraz between 29° 49′ latitude and 51° 37′altitude with an average annual rainfall of 350 mm. The minimum and maximum temperature reaches -3°C and 43°C in winter and summer respectively (http://www.weather.ir). The trees were subjected to the same cultural practices.

A factorial experiment 4×4 was arranged in a randomized complete block design. Treatments were four levels of KNO_3 (0, 0.5, 1.0 and 1.5 %) and four levels of $ZnSO_4$ (0, 0.25, 0.50 and 0.75%) with four replications. Each block contained 4 trees. A total of 16 trees and 4 branches per trees were sprayed. Fifty olive fruits of the 'Amygdalifolia' cultivar were harvested every two weeks from fruit set till ripening and their dimension were measured to study the pattern of fruit growth. Based on the fruit growth curve, time of sprays were determined. The treatments were applied as foliar spray during second (PS75) and third stages (PS81) (PS75 is a phonological stage in olive growth and development in which pit hardening is completed, and PS81 is the beginning of fruit coloring stage) of olive fruit development (23).

The control treatments were sprayed with water. The similar four branches of every tree in different directions received the spraying solution until the run-off. A rate of 1 ml^{-1} of Rica (commercial detergent) was used as a wetting agent.

A sample of 20 fruits/branch were randomly taken at harvest time to determine fruit weight, flesh and pit weight, fruit and pit length and diameter and fruit volume. The volume of fruit was measured by calculating changes of water volume with and without fruit in a graduated cylinder. Data were analyzed for significant differences using a factorial analysis of variance, using statistical package for social sciences (SPSS Inc., Chicago, USA, 2002; http://www.spss.com). The means were compared using the Tukey test at a probability of 5%.

RESULTS AND DISCUSSION

Fruit growth curve

The fruit growth curve based on fruit dimensions (length and diameter) is shown in Fig.1. The results indicated that olive like other stone fruits had a double sigmoid growth curve. In stage I, which took 45 days (6 weeks) fruits showed rapid growth and the lignification of pit started.

In stage II, which took 75 days (11 weeks) the growth was almost stable with a little increase in fruit length and diameter. In stage III, which took 56 days (8 weeks) the fruit showed rapid growth which coincided with changes in fruit color. Therefore, the two times which were selected for nutrient sprays were in August, about 12 weeks after fruit set in which pit hardening was completed (PS75) and in September, about 16 weeks after fruit set in which the fruits started rapid growth at the beginning of fruit coloring (PS81).

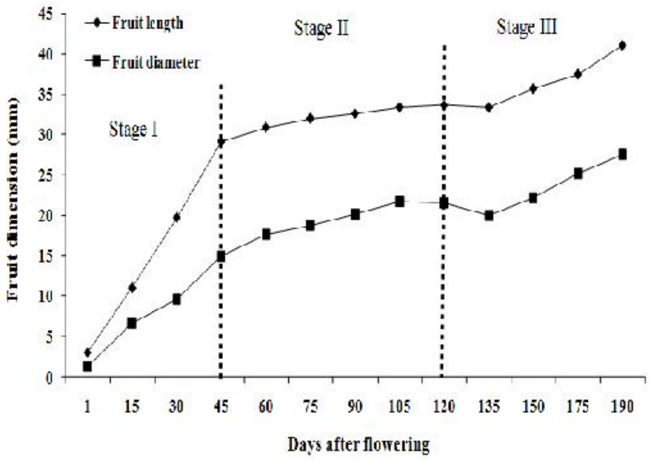

Fig. 1. Fruit growth curve based on fruit length and diameter of 'Amygdalifolia' olive cultivar

Fruit weight (g)

All concentrations of $ZnSO_4$ increased the fruit weight compared with the control (Fig.2). The fruit weight significantly decreased using 0.5 and 1 % and increased with 1.5 % KNO_3 which was not significantly different in comparison with the control. There was a significant interaction between the $ZnSO_4$ and KNO_3 concentrations. An increase in the fruit weight was observed, when 0.5% Zn SO_4 and 0.5% KNO_3 were sprayed (Fig 2).

Fruit pulp and pit weight and pulp/ pit ratio

Application of different zinc sulfate concentrations increased fruit pulp weight and pulp/pit ratio compared with the control (Table 1). Pit weight was influenced by different treatments. The highest pit weight (1.57 g) was obtained with 0.5% $ZnSO_4$ which was significantly higher than the control (1.26 g). The lowest pit weight was obtained from trees treated with 0.25% $ZnSO_4$ and 1.5% KNO_3 which was not significantly different from the control (1.26 g). The highest pulp/pit ratio (6.11g) was observed using 0.5% $ZnSO_4$ in combination with 1% KNO_3 which was significantly higher than the control (4.46 g).

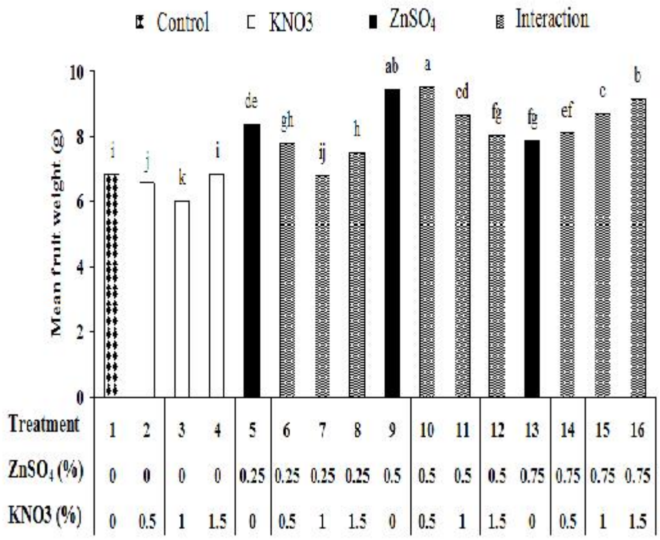

Fig. 2. Effect of different levels of zinc sulfate and potassium nitrate on mean fruit weight (g) of olive 'Amygdalifolia' cultivar. Columns with the same letters are not significantly different for p = 0.05 (Tukey's multiple test)

Table 1. Effect of Zinc sulfate and potassium nitrate on olive pulp and pit growth

Treatment mixing (%) ZnSO$_4$	and KNO$_3$	Mean pulp weight (g)	Mean it Weight (g)	Pulp/pit weight
0	0	5.62 h†	1.26b-e	4.46 ef
0	0.5	5.22 i	1.34 bcd	3.92 f
0	1.0	4.87 j	1.14 de	4.32 ef
0	1.5	5.62 h	1.26 b-e	4.46 ef
0.25	0	7.00 d	1.33 bcd	5.28 bcd
0.25	0.5	6.54 fg	1.24 cde	5.28 bcd
0.25	1.0	5.57 h	1.25 b-e	4.47 ef
0.25	1.5	6.41 g	1.10 e	5.83 ab
0.50	0	7.86 b	1.57 a	5.02 cde
0.50	0.5	8.07a	1.46 ab	5.55 a-d
0.50	1.0	7.42 c	1.22 cde	6.107 a
0.50	1.5	6.73 e	1.33 bcd	5.08 b-e
0.75	0	6.67 ef	1.20 cde	5.58 a-d
0.75	0.5	6.76 e	1.36abc	4.97 de
0.75	1.0	7.42 c	1.29 b-e	5.77 abc
0.75	1.5	7.79 b	1.40 abc	5.589 a-d

Means followed by the same letters within the column are not significantly different at p = 0.05 (Tukey's multiple test)

Fruit dimension

Effect of Zn, K and their interactions on fruit dimensions (length and diameter) are shown in Table 2. Fruit length and diameter were affected significantly using $ZnSO_4$ concentration especially in combination with KNO_3. No significant differences were found in fruit and pit diameter using different levels of KNO_3. Application of zinc sulfate increased fruit and pit length. The highest fruit and pit length were obtained with the 0.75% $ZnSO_4$ + 1.5% KNO_3 treatment (48.76 and 26.50 mm/fruit, respectively). Also, higher fruit and pit diameter were obtained with 1% KNO_3. Maximum amounts of fruit and pit L/D were produced by using 0.5% $ZnSO_4$ in combination with 0.5% KNO_3.

Table 2. Effect of potassium nitrate and zinc sulfate sprays on fruit dimension of 'Amygdalifolia' olive trees

Treatments mixing (%)		Mean fruit L* (mm)	Mean fruit D** (mm)	L/D fruit	Mean pit L (mm)	Mean pit D (mm)	L/D pit
$ZnSO_4$ and	KNO_3						
0	0	43.61 abc[†]	19.11 ab	2.28 cde	23.70 abc	10.50 ab	2.26 cde
0	0.5	45.26 ab	18.38 bc	2.46 abc	24.60 ab	10.10 bc	2.44 abc
0	1.0	41.40 bc	20.02 a	2.07 de	22.50 bc	11.00 a	2.05 de
0	1.5	39.01 c	19.11 ab	2.04 e	21.20 d	10.50 ab	2.02 e
0.25	0	44.90 abc	18.56 abc	2.42 bcd	24.40 abc	10.20 abc	2.39 bcd
0.25	0.5	46.00 ab	18.20 bc	2.53 abc	25.00 ab	10.00 bc	2.50 abc
0.25	1.0	44.62 abc	19.11 ab	2.33 bcde	24.25 abc	10.50 ab	2.31 bcde
0.25	1.5	46.00 ab	17.29 c	2.66 ab	25.00 ab	9.50 c	17.29 c
0.50	0	47.84 a	19.11 ab	2.50 abc	26.00 a	10.50 ab	2.48 abc
0.50	0.5	48.21 a	17.29 c	2.79 a	26.20 a	9.50 c	2.76 a
0.50	1.0	45.08 ab	18.20 bc	2.48 abc	24.50 ab	10.00 bc	2.45 abc
0.50	1.5	45.63 ab	18.38 bc	2.48 abc	24.80 ab	10.10 bc	2.46 abc
0.75	0	45.08 ab	18.38 bc	2.45 abc	24.50 ab	10.10 bc	2.43 abc
0.75	0.5	47.47 a	18.75 abc	2.53 abc	25.80 a	10.30 abc	2.50 abc
0.75	1.0	47.84 a	18.56 abc	2.58 abc	26.00 a	10.20 abc	2.55 abc
0.75	1.5	48.76 a	18.20 bc	2.68 ab	26.50 a	10.00 bc	2.65 ab

[†]Means followed by the same letters within the column are not significantly different at $p = 0.05$ (Tukey's multiple test) ***L: length,** ****D: diameter**

Fruit volume

The volume of 'Amygdalifolia' fruits ranged from 2.6 to 4.0 cm^3 (Fig. 3). All concentrations of KNO_3 treatments did not significantly affect fruit, pulp, pit volume and pulp/pit ratio, although 1% KNO_3 increased this ratio. The fruit, pulp and pulp/pit volume increased with the increase of zinc sulfate concentration (0.0, 0.25, 0.50 and 0.75%). A significant interaction between zinc sulfate and potassium nitrate concentrations was observed for fruit volume. The greatest increase in fruit, pulp and pulp/pit ratio occurred when 0.5% $ZnSo_4$ + 0.5% KNO_3 was applied (4, 3.52 cm^3 and 0.292, respectively) (Table 3).

Our study indicates that applied nutrients have a large influence on olive tree growth and fruit production including fruit size, and fruit shape. The application of nutrients by spray method improved the weight of fruit, pulp, pit and pulp/pit ratio per tree (Table 1). Also our findings are consistent with those reported by Ramezani and Shekafandeh (18) on Shengeh olive. Also, our results are in corroboration with those of Toplu et al . (26) who reported that fertilization increased the fruit size.

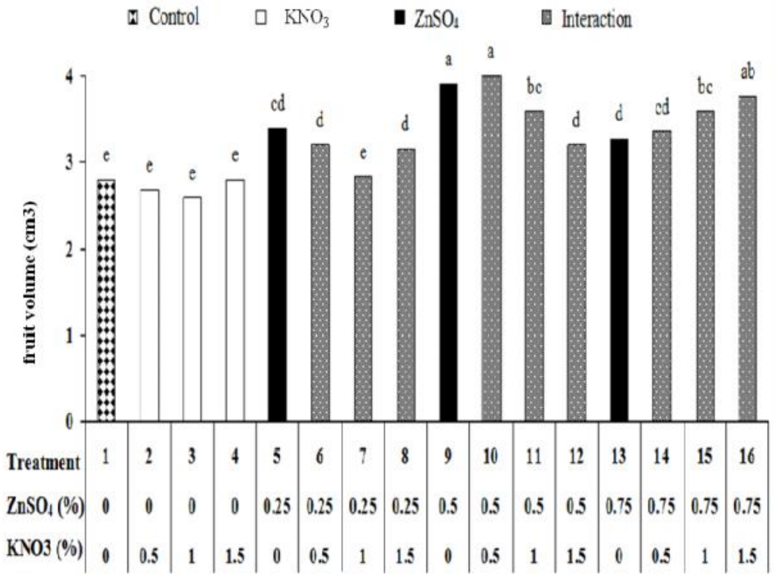

Fig. 3. Effect of different levels of Zinc sulfate and potassium nitrate on Mean fruit volume (cm^3) of olive 'Amygdalifolia' cultivar. Columns with the same letters are not significantly different at p = 0.05 (Tukey's multiple test)

Table 3. Effect of potassium nitrate and zinc sulfate sprays on fruit volume of 'Amygdalifolia' olive trees

Treatments mixing (%) ZnSO$_4$	and KNO$_3$	Pulp volume (cm^3)	Pit volume (cm^3)	Pulp/pit volume
0	0	2.32 e[†]	0.48 ab	0.195 bc
0	0.5	2.20e	0.48ab	0.182c
0	1.0	2.20 e	0.40 b	0.227 abc
0	1.5	2.32 e	0.48 ab	0.195 bc
0.25	0	2.96 cd	0.44 ab	0.270 ab
0.25	0.5	2.76 d	0.44 ab	0.252 abc
0.25	1.0	2.39 e	0.45 ab	0.212 abc
0.25	1.5	2.76 d	0.40 b	0.287 a
0.50	0	3.40 ab	0.52 a	0.265 ab
0.50	0.5	3.52 a	0.48 ab	0.292 a
0.50	1.0	3.16 bc	0.44 ab	0.287 a
0.50	1.5	2.76 d	0.44 ab	0.252 abc
0.75	0	2.84 d	0.44 ab	0.260 abc
0.75	0.5	2.92 cd	0.44 ab	0.270 ab
0.75	1.0	3.16 bc	0.44 ab	0.287 a
0.75	1.5	3.28 ab	0.48 ab	0.272 ab

[†]Means followed by the same letters within the column are not significantly different at p = 0.05 (Tukey's multiple test)

The enhancement of fruit characteristics such as weight, dimensions (length and diameter) and volume are due to different roles of zinc and potassium in plant physiological processes. Applying zinc to the trees improved fruit quality by enhancing the formation and translocation of carbohydrates and carbohydrate enzymes (27). Our results show that KNO_3 alone had no significant effect on fruit weight, but in combination with $ZnSO_4$ they resulted in highest fruit weight. Thus, K has positive interaction with Zn. The role of K in an increasing yield can be attributed to its function in plants which include cation transport across membranes, water economy, energy metabolism and enzyme activation on exchange rate and nitrogen activity as well as enhanced carbohydrate movement from the shoot to storage organs (fruits) (4). Zinc has key roles in chlorophyll, protein and DNA synthesis in plants. Zinc effect in photosynthesis may be due to change in structure of chloroplasts, photosynthesis electron transport systems, CO_2 fixation and an increase in chlorophyll content (4). Therefore, we can conclude that zinc sulfate increased fruit weight by influencing photosynthesis enzymes (Carbonic anhydrases, RuBisCO, Super oxide dismutases, Alcohol dehydrogenises, Carboxypeptidase A, Glutamate dehydrogenase, Aldolase and ALA dehydrogenase) causing the increase in carbohydrates.

Fruit pulp contains water, oil, carbohydrates, minerals, vitamins, protein, fibers and pigments. The favorite ratio of pulp/pit weight in processing olives was 5:1 (9). Having high effects on pulp and low effects on pit weights, $ZnSO_4$ and KNO_3 caused increases in the pulp/pit weight ratio. Also, zinc sulfate had a low effect on pit weight, which is a favorible trait. Our results showed that by using mineral nutrients, a higher rate of pulp/pit ratio (6:1) which is more than the desirable ratio (5:1) is achieved. Therefore, the use of nutrients is suggested for the improvement of fruit shape for processing purposes.

The lower effect of potassium nitrate as compared to zinc sulfate on fruit growth was dependent on more factors. Factors such as leaf age, salt types and concentrations, number of foliar applications, water stress or nutritional status of the tree have been observed to influence the foliar K uptake in fruit trees species (25). Cuticular penetration of K salts is a physical process depending on the relative humidity and the point of deliquescence of each K salt, which is the humidity over a saturated salt solution containing solid salt (24). Previous experiments on olives showed that absorption of foliar applied K by leaves is restricted by water stress or K deficiency (21, 22). Dikmelik *et al* (3) state that using potassium nitrate during second and third stages of olive fruit growth have best results on fruit size. Also, Razzaquea and Hanafib (20) report an increase in the length and diameter of pineapple fruit by using K_2O. Our results are in agreement with these studies.

The results indicated that pit volume changes were not similar to fruit and pulp volume variation patterns and pit volume variation was more limited during the growth period. The pit is lignificate in the second stage of fruit growth and has its maximum size. Hence, nutrient treatments had no significant effect on pit growth. Increased fruit volume was caused by the enlargement of pulp volume.

CONCLUSION

In summary, our results emphasize the importance of appropriate fertilization management in irrigated olive orchards, particularly for table olives, in which fruit size, pulp/pit ratio and pulp quantity are important characteristics. Therefore, for increasing fruit yield, application of 0.5% zinc sulfate + 0.5% potassium nitrate is suggested during second and third stages of fruit growth.

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اثرات روی و پتاسیم بر رشد و گوشت میوه زیتون (*Olea europaea* L.)

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چکیده- این پژوهش روی درختان زیتون رقم 'آمیگدالیفولیا' برای بررسی اثر محلول پاشی نیترات پتاسیم و سولفات روی بر ویژه گی های وزن، ابعاد و حجم میوه انجام شد. درختان با غلظت های صفر، ۰/۵، ۱ و ۱/۵ ٪ نیترات پتاسیم و صفر، ۰/۲۵، ۰/۵، ۰/۷۵ ٪ سولفات روی و ترکیبی از آنها در ماه مرداد زمانی که میوه ها در اواسط دوره رشد خود بودند محلول پاشی شدند. بیشترین وزن میوه در کاربرد ۰/۵٪ سولفات روی و ۰/۵٪ نیترات پتاسیم مشاهده شد. طول و قطر میوه بطور معنی داری تحت تاثیر سوالفات روی بویژه در ترکیب با نیترات پتاسیم قرار گرفتند. حجم میوه، حجم گوشت میوه و نسبت حجم گوشت به هسته با افزایش غلظت سولفات روی (۰،۰/۲۵،۰/۵، ۰/۷۵٪) افزایش یافت. هم چنین بیشترین حجم میوه، حجم گوشت میوه و نسبت حجم گوشت به هسته در غلظت ۰/۵٪ سولفات روی و ۰/۵٪ نیترات پتاسیم بدست آمد. نتایج بدست آمده تاکید بر اهمیت یک مدیریت کودی مناسب بویژه در زیتون کنسروی که در آن اندازه میوه و نسبت گوشت به هسته حائز اهمیت است دارد.

واژه های کلیدی: اندازه میوه، زیتون، سولفات پتاسیم، نیترات پتاسیم

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*به ترتیب دانشجوی پیشین کارشناسی ارشد و دانشیار

** مکاتبه کننده