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Full Length Research Paper

Roles of gibberellic acid and zinc sulphate in increasing size and weight of olive fruit

Sadrollah Ramezani* and Akhtar Shekafandeh

Department of Horticulture Science, College of Agriculture, Shiraz University, Shiraz, Iran.

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Olive trees (*Olea europaea* L. cv. Shengeh) were treated with gibberellic acid (GA_3) at 0, 15, 30 and 45 ppm and zinc sulphate at 0, 0.25, 0.5 and 0.75% when fruit were at 70% of their final size in experiments carried out in 2007 season. The effect of GA_3 and $ZnSO_4$ treatments on yield and some variables related to fruit characteristics (fruit, pit and pulp weight, pulp/pit weight ratio, fruit length and diameter, pit length and diameter, fruit L/D ratio, pit L/D ratio fruit volume) was analyzed. Fruit weight was significantly increased most by concentrations of GA_3 and $ZnSO_4$ treatments with respect to control trees, due to an increase in fruit size. GA_3 spray at the 30 ppm concentration was more effective in improving yield than spraying GA_3 at other concentrations and control. Thus, these treatments accelerated fruit growth of olive, and also increased both fruit size and total yield per tree, allowing for an increase in its economic value. Use of 0.5% $ZnSO_4$ + 30 ppm GA_3 treatments was optimum for improvement of olive fruit yield.

Key words: Fruit size, gibberellic acid, growth, olive, yield, zinc sulphate.

INTRODUCTION

Olive tree (*Olea europaea* L.) of the *Oleaceae* family has a high economic value and many countries such as Iran and Mediterranean countries use its oil and conserved fruits (Payvandi et al., 2001; Mitrakos et al., 1991). Olive is very well adapted to the high temperature; tolerate dry weather, high soil salinity levels and infertile soil. The size of the fruit is important, not only because it is a component of productive yield, but also determines the acceptance by the consumer as conserved fruits.

Gibberellins are known for their ability to increase cell enlargement (Arteca, 1996; Davis, 2004; Pharis and King, 1995), thus enhancing fruit growth in certain species such as citrus (Eman et al., 2007; El-Sese, 2005), litchi (Stern and Gazit, 2000; Chang and Lin, 2006), guava (El-Sharkawy et al., 2005), and pear (Zhang et al., 2007). In all species so far studied, gibberellins had the potential for increasing fruit size.

The beneficial effects of Gibberellic acid (GA_3) and nutrient elements sprays specially zinc on yield and fruit quality of different fruit crops were mentioned by many investigators including Swietlik (2002). Also, the use of GA_3 as a growth regulator to promote size and to control fruit drop was reported by Arteca (1996). Swietlik (2002) was stated that soil applications of zinc are not very effective because the roots of fruit crops occupy deep soil layers and zinc does not easily move in the soil. Therefore foliar sprays of zinc are more effective.

Since no report has been published as to the effect of gibberellic acid on fruit size of olive, and a few report about zinc effect on olive fruit characteristics was available, the aim of this work was to study the possibility of increasing fruit size, yield and improvement of fruit characteristics in 'Shengeh' olive cultivar fruit by treatment with gibberellic acid and zinc sulphate applied in third stage of fruit growth.

MATERIALS AND METHODS

Plant material

Olive (*Olea europaea* L. cv. Shengeh) trees of similar vigour, age (ten years old) and size were selected for sprays treatments during 2007 season. For each replication of treatment, same shoot with regard to height, thickness, vigor and number of fruit and orientation was selected.

Trees were grown in sandy loam soil, 4 × 5 m apart under drip irrigation system (consisted of two lateral lines per row, separated by 1.0 m, with 1.6 l h^{-1} pressure compensated in-line drippers space at 0.5 m) at the experimental farm of olive research station (29°49'N, 51°37'E, 920 m, 400 mm, high temperatures; 42°C max., low temperatures; -3°C min. and low humidity; < 40% RH during the

*Corresponding author. E-mail: sramezani@shirazu.ac.ir.

Table 1. Effect of GA_3 and $ZnSO_4$ sprays on fruit weight of 'Shengeh' olive trees.

Treatment		Mean fruit weight (g)	Mean pulp weight (g)	Mean pit weight (g)	Pulp /pit weight
$ZnSO_4$ (%)	GA_3 (ppm)				
0	0	2.20 d[†]	1.45cd	0.75d	1.93b
0	15	2.45 c	1.65b	0.80d	2.06a
0	30	2.60bc	1.75b	0.85d	2.05a
0	45	2.40 c	1.45cd	0.95cd	1.52c
0.25	0	2.15d	1.30d	0.85d	1.52c
0.25	15	2.35cd	1.30d	1.05c	1.23d
0.25	30	2.40c	1.20e	1.20c	1.00f
0.25	45	2.45c	1.10e	1.35b	0.81h
0.5	0	2.35cd	1.30d	1.05c	1.23d
0.5	15	2.80b	1.50c	1.30b	1.15e
0.5	30	2.85b	1.35d	1.50a	0.90g
0.5	45	3.00b	1.45cd	1.55a	0.93g
0.75	0	2.90b	1.75b	1.15c	1.52c
0.75	15	3.05b	1.70b	1.35b	1.26d
0.75	30	3.25a	1.65b	1.60a	1.03f
0.75	45	3.25a	1.80a	1.50a	1.20de

[†]Means having the same letters within a column significantly different for p = 0.05 (Tukey's multiple test).

summer) in Kazeroon (Fars province, southwest of Islamic Republic of Iran).

'Shengeh' is an early maturing olive cultivar with its small fruit and superior quality and recent decades has become one of the major cultivar in south of Iran.

During the course of the experiment, the normal cultural practices with regard to nutrition, irrigation, weed control, pests, and diseases were utilized.

Soil was analyzed by using the methods described by Chapman and Pratt (1961) that included sand (55%), silt (15%) and clay (30%). The texture of experimented soil is sandy loam and have pH = 7.8 and EC = 1.4 dsm^{-1}.

Application of spray treatments

GA_3 and $ZnSO_4$ were applied when the fruits were in the stages PS 77 (at 70% of their final size, mid august) of the BBCH scale (Sanz-Cortés et al., 2002).

For the gibberellic acid (GA_3) treatment, doses of 0, 15, 30 and 45 mg l^{-1} were used in the 2007 season. Zinc sulphate ($ZnSO_4$) treatments were prepared with $ZnSO_4.7H_2O$ (Merck company, Germany) at doses of 0, 0.25, 0.5 and 0.75%. Treatments were performed by spraying 4 liter per shoots of the GA_3 and $ZnSO_4$ alone and their combination solutions with a hand-pump knapsack sprayer, and 1 ml l^{-1} of Rica (A commercial detergent) was used as wetting agent. Control trees were sprayed with water and the same wetting agent.

Analytical determinations

The olive fruit were harvested at commercial maturity in the late of October. In the harvest date, the variables evaluated related to fruit size characteristics were recorded in a sample of twenty fruits / shoot and they include fruit weight (g), pit weight (g), pulp weight (g), pulp/fruit weight ratio, pulp/pit ratio, fruit length (mm), fruit diameter (mm), pit length (mm), pit diameter (mm), Fruit L/D ratio, pit L/D ratio and fruit volume (cm^3).

Statistical analysis

Factorial experimental 4 × 4 × 4 was arranged in completely randomized block design (CRBD) with sixteen treatments and four replications. An ANOVA was made to determine the effects of each treatment on fruit, pit and pulp weight, pulp/pit ratio, fruit length and diameter, pit length and diameter, fruit L/D ratio, pit L/D ratio and fruit volume. All analyses were performed with a statistical software package (SPSS version 13) and the means were compared by Tukey's multiple tests at 5% level of probability to differentiate means.

RESULTS AND DISCUSSION

Weight (g) of fruits per shoot as shown in Table 1 increased in treatments than in the control. In this respect, a particular trend was noticed that GA_3 sprays at the 30 ppm concentration was more effective in improving yield than spraying GA_3 at other concentrations and control. Highest fruit weight was obtained from trees sprayed with 0.75% zinc sulphate + 30 ppm gibberellic acid, while fruits taken from the control trees recorded the lowest fruit weight values. The highest pulp weight was obtained from trees sprayed with 0.75% $ZnSO_4$ + 45 ppm GA_3 concentration.

Table 2. Effect of GA_3 and $ZnSO_4$ sprays on fruit dimension of 'Shengeh' olive trees.

Treatment		Mean fruit length mm)	Mean fruit diameter (mm)	Mean pit length (mm)	Mean pit diameter (mm)	Mean fruit volume (cm^3)	Fruit L/D	Pit L/D
$ZnSO_4$ (%)	GA_3 (ppm)							
0	0	9.15f	6.70f	7.55d	4.15c	5.55a	1.36de	1.81ef
0	15	9.60e	6.95f	7.65d	4.25c	5.46ab	1.38de	1.80fg
0	30	10.05d	7.25e	7.85d	4.30c	5.40b	1.38de	1.82de
0	45	10.20d	7.55d	8.00c	4.40b	5.60a	1.35 e	1.81ef
0.25	0	9.65e	6.90f	7.70d	4.25c	5.37b	1.39de	1.81ef
0.25	15	10.90c	7.30e	7.85d	4.35c	4.95d	1.49 a	1.80fg
0.25	30	11.30b	7.50d	8.00c	4.40b	5.01d	1.50 a	1.81ef
0.25	45	11.45b	7.60d	8.20c	4.40b	4.82e	1.50 a	1.86b
0.50	0	10.35d	7.10ef	7.85d	4.45b	5.35b	1.46ab	1.76h
0.50	15	11.35b	7.95c	8.15c	4.50b	4.89e	1.43bc	1.81ef
0.50	30	11.80a	8.10c	8.35cb	4.65ab	5.08d	1.46ab	1.79g
0.50	45	11.90a	8.35b	8.55b	4.65ab	5.19c	1.42bc	1.83cd
0.75	0	10.75c	7.65d	8.20c	4.50b	5.16c	1.41bc	1.82de
0.75	15	11.20b	8.30b	8.45b	4.60ab	4.79e	1.35 e	1.84c
0.75	30	11.75a	8.60a	8.85a	4.60ab	5.10d	1.36de	1.92a
0.75	45	11.80a	8.70a	8.70ab	4.55b	5.23 c	1.36de	1.91a

† Means having the same letters within a column significantly different for p = 0.05 (Tukey's multiple test).

Spraying zinc alone or with GA_3 at any concentration markedly increased fruit diameter comparing with the control. The results are shown that use of $ZnSO_4$ at 0.5% with GA3 resulted in improvement of fruit length compared to the control (Table 2). Moreover, spraying zinc alone or in combination with GA_3 at any concentration significantly increased yield comparing with the control. Although highest yield was obtained from trees sprayed with 30 ppm GA_3 + 0.75% $ZnSO_4$.

The obtained results of GA_3 sprays are in line with those reported by El-Sese (2005) who found that Balady mandarin trees sprayed with GA_3 resulted in increased yield as number or weight (Kg) of fruits/ tree. The obtained results are also supported by Agusti et al. (1982) on Sweet orange, Mostafa et al. (2001) on pear, Abd El-Migeed (2002) on Washington navel and El-Sharkawy and Mehaisen (2005) on guava.

Kuiper (1993) suggested that sink strength is established and regulated by plant growth regulators. That is, certain plant hormones can increase mobilization of assimilates to fruit and modulate many of the rate-limiting components in carbon partitioning (Ozga and Dennis, 2003). These hormones may stimulate transport of nutrients through the phloem, modify the strength of the sink by stimulating its growth and increase the ability for sugar unloading from the phloem. Or, they may act on metabolism and compartmentalization of sugar and its metabolites (Brenner and Cheikh, 1995).

The increase in fruit weight and diameter with zinc sprays might be due to important component for fruit growth and development which have been influenced via tryptophan by zinc sprays (Sahota and Arora, 1981). The improvement occurred in fruit quality and quantity due to supplying trees with zinc could be attributed to its effects on enhancing formation and translocation of carbohydrates and carbohydrate enzymes (Yogeratnam and Greenham, 1982).

Increasing yield due to GA or zinc sprays may be attributed to their effects on increasing levels of IAA. Enhancement of yield may be attributed to the improvement in the nutritional status specially zinc. The role of GA in improving fruit quantity namely, fruit weight and fruit size may be due to its role in increasing cell elongation (Eman et al., 2007). Marschner (1986) indicated that application of GA_3 and/or IAA on higher plants caused elongation in the primary cells in the young tissues and growth centers. The present results may be attributed to stimulative influence of this bioregulator on cell extension and /or on cell division.

Sucrose synthase (SS) and invertase may be important in determining sink activity and could play critical roles in both phloem transport and in photosynthetic partitioning in sucrose-translocating plants. Fruit size increases in response to exogenously applied GA_3 and this has been associated with an increase in cell size of the mesocarp and increased sink demand (Zhang et al., 2007; Brenner and Cheikh, 1995). GAs increase sink demand by the enhancement of phloem unloading or/and metabolism of carbon assimilates in fruit. GA treatment significantly increased fruit size and fruit fresh weight. A larger fruit size and increased sink demand were closely correlated with changes in activities of sugar metabolizing enzymes induced by GA application. Also, Zhang et al. (2007) expressed that increased sink demand by induced application of GA is closely related to the activation of invertase cell wall-bound (Inv-CW) in the core and invertase neutral (Inv-N) and NAD-dependent sorbitol dehydrogenase (NAD-SDH) in the pulp during rapid fruit growth in fruit.

From the results it seems that physical fruit properties in terms of fruit weight, pulp weight, fruit diameter and fruit length were improved by most treatments especially those including zinc sprays. The role of GA_3 in improving fruit quantity namely, fruit and pulp weight and fruit diameter may be explained due to its role in increasing cell elongation (Pharis and King, 1995).

Conclusions

The improvement that occurred in the fruit yield and quality could be attributed to effects of nutrients on carbohydrate influx or plant growth regulators synthesis in growing fruits. Our results have revealed that nutrient spray applications can also cause yield and fruit size improvement. In conclusion, our results shown that application of 30 ppm GA_3 along with 0.5% $ZnSO_4$ at third stage of fruit growth stimulated cell enlargement in the mesocarp of ‘Shengeh’ olive fruit, which in turn, caused a significant improvement in fruit size, weight and total yield.

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