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Effect of Foliar Application with Salicylic Acid, Benzyladenine and Gibberellic Acid on Flowering, Yield and Fruit Quality of Olive Trees (*Olea europaea* L.)

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Abstract: `Egazy Shami' olive trees (*Olea europaea* L.) were sprayed once at mid February (one month before beginning the flowering stage) with 7 treatments: salicylic acid at the concentration of 20 & 40µg/L, benzyladenine (20 & 30 mg/L), gibberellic acid (50 & 100 mg/L) and control (spraying with water only). The results indicated that foliar spray of salicylic acid at 40µg/L is recommended for improving yield and fruit quality of `Egazy Shami' olive trees. Improving productivity attributed to increase flowering percentage and density, as well as percentage of sex expression, pollen grains germination, fruit physical properties (fruit weight, length & diameter, seed weight, flesh weight & fruit dry weight) and fruit oil content. Application of 20 or 30 mg/L benzyladenine had the same effect of salicylic acid on improving yield and fruit quality, while it produced lower fruit oil content. On the other hand, GA_3 treatments produced lower yield than those of salicylic acid and benzyladenine.

Key words: Olive · Foliar spray · Antioxidants · Growth regulators · Yield · Fruit Quality

INTRODUCTION

Olive (*Olea europaea* L.) is traditionally important fruit crop grown extensively in the Mediterranean basin and parts of Asia Minor. It can be consumed either as the fully ripe black fruit or as the unripe green fruit that used for pickling or oil extracting. The production of olive oil became one of the important economical sectors in many countries due to its healthy benefits as non-saturated oil with fine aroma and pleasant taste. In 2011, the harvested area in Egypt reached approximately 64835 ha, while the production was about 1320800 tons [1]. However, productivity of olive trees is affected by some environmental factors, whereas, the trees must be exposed to a period of winter chilling temperatures (vernalization) in some countries that located under warm winter conditions such as Egypt in order to emerge the inflorescences in the spring. Considerable interest have been shown on other plants by using some materials that can make the same action such as salicylic acid, benzyladenine and gibberellic acid (GA_3), since they play an important role as an endogenous regulators and are consider as thermo genesis in plant for achieving the vernalization [2-7]. Till now, little information is known about how salicylic acid, benzyladenine and gibberellic acid (GA_3) have effect to recognize insufficient chilling requirements and consequently improve flowering parameters. In another word, this investigation was conducted to study if these materials have the same action of vernalization. Therefore, the aim of the present work was to study the effect of exogenously foliar applied of these materials on flowering, yield and fruit quality of olive trees to overcome the low productivity of olive trees under warm winter conditions.

MATERIALS AND METHODS

Plant Materials and Treatments: The present study was carried out during two successive seasons 2011 and 2012 on `Egazy Shami' olive trees (*Olea europaea* L.), at a private orchard of 'Writers & Thinkers Village' located on Regwa Road, Cairo-Alex desert Road, Egypt. The experimental trees were about 12 years old, spaced at 5 x 6 m, cultivated in sandy soil under drip irrigation

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system, similar in growth vigor and received the same horticultural practices. The trees were sprayed once at mid February (one month before beginning of the flowering) with 7 treatments: salicylic acid at 20 & 40µg/L, benzyladenine at 20 & 30 mg/L, gibberellic acid at 50 & 100 ml/L and control (spraying with water only). All trees were sprayed until the run off point with Triton B at 0.1% as a wetting agent.

Flowering Behaviour: Before beginning the flowering at mid March, twenty shoots per tree was labeled to record the following parameters at full bloom (mid April) according to Hassan [8]:

Flowering (%): Percentage of flower buds were calculated comparing with total buds per shoot.

Flowering Density: Number of inflorescences per shoot for each meter was counted.

Sex Expression (%): Samples of 30 inflorescences were taken from the middle portion of the shoots of every replicate tree and number of total flowers and perfect flowers per inflorescences were recorded then the percentage of perfect flowers to total flowers was calculated.

Germination of Pollen Grains (%): Pollen grains were collected from inflorescences samples taken before pollen dehiscence and kept for one night in the laboratory under room temperature. Germination of pollen grains was evaluated after incubation for 24 hrs at 25°C in Petri dishes with liquid medium of 10% sucrose, 0.01% boric acid and 10ppm tetracycline. Three drops of the medium containing pollens per each replicate were placed on a slide and number of germinated and non-germinated pollens was estimated then the germination percentage was calculated according to Escobar and Martin [9].

Yield and Fruit Quality: Yield was harvested at mid September and recorded as kg/tree, then 50 fruits were picked randomly from all sides of each tree at harvest to determine the following fruit quality: Fruit weight (g), fruit length and width (mm), shape index (L/W), seed weight (g), flesh weight (g), fruit dry weight (g) and fruit oil content in fresh weight (%) according A.O.A.C [10].

Statistical Analysis: Data were analyzed by analysis of variance (ANOVA) and means were compared using Duncan's test at $p < 0.05$ to determine the significance of differences between the conducted treatments [11].

RESULTS

Data presented in Table 1 showed the effect of foliar application of salicylic acid, benzyladenine and gibberellic acid (one month before beginning of flowering) on flowering behaviour of 'Egazy Shami' olive trees during the two studied seasons. Results revealed that all treatments increased percentage of flowering than the control in both seasons of this study. In this respect, salicylic acid at 20 & 40µg/L and benzyladenine at 20 & 30 mg/L gave higher percentage of flowering (3.22, 3.17, 3.14 and 3.11% in the first season & 3.52, 3.44, 3.41 and 3.53% in the second season, respectively) than gibberellic acid at 50 & 100 ml/L (2.56 and 2.43% in the first season & 2.51 and 2.33% in the second one, consequently). Meanwhile, the lowest percentage was obtained by control (1.86 and 1.83% in both seasons). This was true during the two studied seasons. Concerning flowering

Table 1: Effect of foliar application of salicylic acid, benzyladenine and gibberellic acid on flowering behaviour of 'Egazy Shami' olive trees during 2011 and 2012 seasons.

	Flowering (%) (percentage of flower buds per shot)		Flowering density (No. inflorescences per meter)		Sex expression (%)		Pollen grains germination (%)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1= Salicylic acid 20 µg/L	3.22 a	3.52 a	71.7 a	74.6 a	76.3 a	71.7 a	45.6 a	44.2 a
T2= Salicylic acid 40 µg/L	3.17 a	3.44 a	68.5 a	71.3 a	74.8 a	70.3 a	43.8 a	42.9 a
T3= Benzyladenine 20 mg/L	3.14 a	3.41 a	75.0 a	78.0 a	71.6 a	67.3 a	47.6 a	45.7 a
T4= Benzyladenine 30 mg/L	3.11 a	3.53 a	69.3 a	72.1 a	76.1 a	71.5 a	42.3 a	43.5 a
T5= Gibberelic acid 50 mg/L	2.56 b	2.51 b	57.7 b	60.0 b	75.3 a	70.8 a	46.5 a	47.4 a
T4=Gibberelic acid 100 mg/L	2.43 b	2.33 b	56.5 b	58.7 b	73.8 a	69.4 a	48.8 a	46.3 a
T5= Control	1.86 c	1.83 c	35.9 c	37.4 c	59.8 b	56.2 b	38.3 b	39.2 b

Means within a column followed by different letter (s) are statistically different at 5% level

Table 2: Effect of foliar application of salicylic acid, benzyladenine and gibberellic acid on yield and fruit physical properties of 'Egazy Shami' olive trees during 2011 and 2012 seasons

	Yield (kg/tree)		Fruit weight (g)		Fruit length (L) (mm)		Fruit diameter (W) (mm)		Shape index (L/w)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1= Salicylic acid 20 µg/L	41.3 a	38.8 a	12.8 a	12.0 a	31.1 a	29.5 a	27.4 a	25.8 a	1.14 a	1.06 a
T2= Salicylic acid 40 µg/L	35.9 a	33.4 a	11.2 a	10.5 a	29.3 a	27.8 a	26.8 a	25.5 a	1.09 a	1.09 a
T3= Benzyladenine 20 mg/L	35.4 a	33.0 a	11.1 a	10.4 a	29.3 a	27.7 a	26.9 a	25.3 a	1.09 a	1.09 a
T4= Benzyladenine 30 mg/L	37.2 a	35.3 a	11.6 a	10.9 a	29.4 a	27.9 a	27.1 a	25.5 a	1.08 a	1.09 a
T5= Gibberelic acid 50 mg/L	27.3 b	25.6 b	8.5 b	8.0 b	27.7 b	26.1 b	24.8 b	23.3 b	1.12 a	1.12 a
T4=Gibberelic acid 100 mg/L	29.5 b	27.8 b	9.2 b	8.7 b	28.4 b	26.7 b	25.1 b	23.6 b	1.13 a	1.13 a
T5= Control	18.81 c	20.7 c	5.7 c	5.4 c	23.5 c	22.3 c	19.0 c	18.5 c	1.24 a	1.21 a

Means within a column followed by different letter (s) are statistically different at 5% level.

density (number of inflorescences per meter), the results took the same trend of flowering percentage. Salicylic acid at 20 & 40µg/L and benzyladenine at 20 & 30 mg/L gave higher percentage of flowering density (number of inflorescences per meter were 71.7, 68.5, 75.0 and 69.3 in the first year & 74.6, 71.3, 78.0 and 72.1 in the second season, respectively). While, the lowest value of flowering density was recorded by control (number of inflorescences per meter were 35.9 and 37.4). As for sex expression, all treatments increased the percentage than the control during the two seasons. Treatments increased sex expression percentage between 71.6 to 76.3% in the first season & between 67.3 to 71.7% in the second season, consequently. However, the sex expression percentage for control recorded 59.8 and 56.2% in both seasons. Regarding pollen grains germination%, all treatments increased it and the percentage was between 42.3 to 48.8% in the first year & between 42.9 to 47.4 in the second season compared with the control which achieved 38.3 and 39.2% in both seasons. The results in Table 2 cleared the effect of foliar application of salicylic acid, benzyladenine and gibberellic acid on yield and fruit physical properties (fruit weight, length, diameter and shape index) of 'Egazy Shami' olive trees during the two studied seasons. Data also cleared that, all treatments increased yield compared with the control treatment in the 1st and 2nd seasons. Moreover, salicylic acid at 20 & 40µg/L and benzyladenine at 20 & 30 mg/L achieved high yield (41.3, 35.9, 35.4 and 37.2 kg/tree in the first season & 38.8, 33.4, 33.0 and 35.3 in the second season, respectively) comparing with the gibberellic acid at 50 & 100 ml/L (27.3 and 29.5 kg/tree in the first year &. 25.6 and 27.8 kg/tree in the second year). Meanwhile, the control gave the lowest yield (18.81 and 20.7 kg/tree in both seasons). Regarding fruit physical properties (fruit weight, length and diameter), the results revealed that these fruit quality parameters were significantly affected by all applications. Foliar application of salicylic acid at 20 & 40µg/L and benzyladenine at 20 & 30 mg/L gave higher fruit weight (12.8, 11.2, 11.1 and 11.6 g in the first season and 12.0, 10.5, 10.4 and 10.9 g in the second season, consequently), fruit length (31.1, 29.3, 29.3 and 29.4 mm in the first year & 29.5, 27.8, 27.7 and 27.9 mm in the second year, consequently) and fruit diameter (27.4, 26.8, 26.9 and 27.1 mm in the first season & 25.8, 25.5, 25.3 and 25.5 mm in the second season, respectively). Meanwhile, the lowest value of these fruit quality parameters was recorded by the control (fruit weight was 5.7 and 5.4 g in the 1st and 2nd seasons, fruit length was 23.5 and 22.3 mm in both seasons, fruit diameter was 19.0 and 18.5 mm in both years). On the other hand, gibberellic acid at 50 & 100 ml/L was in between range (fruit weight was 8.5 and 9.2 g in the first season & 8.0 and 8.7 g in the second season, respectively as well as fruit length was 27.7 and 28.4 mm in the first season & 26.1 and 26.7 mm in the second season, consequently, while fruit diameter was 24.8 and 25.1 mm in the first year & 23.3 and 23.6 mm in the second year, respectively). As for fruit shape index (fruit length/diameter), there were no significant differences between treatments and control in the two seasons.

Data in Table 3 presented the effect of foliar application of salicylic acid, benzyladenine and gibberellic acid on seed weight, flesh weight, fruit dry weight and chemical properties (fruit oil% content in fresh weight) of 'Egazy Shami' olive trees during the two seasons of this study. With respect to seed weight, data indicated that all foliar applications gave heavy weight compared with the control, whereas salicylic acid treatment at 20 µg/L gave the heaviest seed weight in the 1st and 2nd seasons (2.27 and 2.13 g, respectively). On the other side, there was no significant variation in seed weight between

Table 3: Effect of foliar application of salicylic acid, benzyladenine and gibberellic acid on physical and chemical properties of 'Egazy Shami' olive trees during 2011 and 2012 seasons

	Seed weight (g)		Flesh weight (g)		Fruit dry weight (g)		Fruit oil content in fresh weight (%)	
Treatments	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
T1= Salicylic acid 20 µg/L	2.27 a	2.13 a	10.6 a	9.96 a	7.03 a	6.61 a	9.9 ab	10.4 ab
T2= Salicylic acid 40 µg/L	1.71 b	1.61 b	9.46 a	8.89 a	6.75 a	6.35 a	10.2 a	10.6 a
T3= Benzyladenine 20 mg/L	1.73 b	1.63 b	9.29 a	8.73 a	6.67 a	6.27 a	9.5 bc	9.3 b
T4= Benzyladenine 30 mg/L	1.76 b	1.67 b	9.48 a	8.91 a	6.78 a	6.38 a	9.6 bc	9.2 b
T5= Gibberelic acid 50 mg/L	1.92 ab	1.83 ab	6.59 b	5.25 b	4.97 b	4.67 b	9.5 bc	9.2 b
T4= Gibberelic acid 100 mg/L	1.71 b	1.62 b	7.48 b	7.03 b	5.09 b	4.79 b	9.2 c	9.3 b
T5= Control	1.12 c	1.07 c	4.56 c	4.29 c	3.20 c	3.04 c	7.8 d	8.0 c

Means within a column followed by different letter (s) are statistically different at 5% level.

salicylic acid at 20 µg/L and GA_3 at 50 mg/L. As for flesh and fruit dry weight, higher value in both seasons was obtained by salicylic acid at 20 & 40 µg/L (flesh weight was 10.6 and 9.46 g in the first year & 9.96 and 8.89 g in the second year, respectively & fruit dry weight was 7.03 and 6.75 g in the first season & 6.61 and 6.35 in the second season, respectively) and benzyladenine at 20 & 30 mg/L (flesh weight was 9.29 and 9.48 g in first year & 8.73 and 8.91 g in the second year, consequently). Fruit oil percentage was significantly affected by different treatments in comparison with the control during the 1st and 2nd seasons. Salicylic acid at 40 µg/L recorded higher percentage (10.2 and 10.6% in the 1st and 2nd seasons, respectively) than benzyladenine at 20 µg/L (9.5 and 9.3%), benzyladenine at 30 µg/L (9.6 and 9.2%), gibberellic acid at 50 mg/L (9.5 and 9.2%) and gibberellic acid at 100 mg/L (9.2 and 9.3%). Therefore, salicylic acid at 40 µg/L is considering the recommended treatment; since it achieved higher fruit quality especially fruit oil percentage than the other treatments including the control.

DISCUSSION

Flowering of olive trees is affected by some environmental factors. Under warm winter conditions such as Egypt, trees must be exposed to a period of winter chilling temperatures (vernalization) in order to emerge inflorescences in the spring which reflect on the productivity. The obtained data indicated that foliar spray of salicylic acid (20 & 40 µg/L) and benzyladenine (20 & 30 mg/L) increased flowering percentage and density than GA_3 (50 & 100 mg/L) compared to the control (spraying water only). This could be attributing to the role of these materials as thermo genesis in plant [2-7]. Therefore, these materials recognized insufficient chilling temperatures as thermo genesis in plant and induced flowering, consequently improved flowering parameters. Generally, the studied substances had the same action of vernalization on flowering behaviour. Improving flowering percentage and density could be also interpreted to salicylic acid as endogenous growth regulator which plays an important role in increasing antioxidants [3]. This interpretation confirmed by Srivastava and Dwivedi [12] who noticed that salicylic acid treatment decreased catalase and peroxidase with concomitant increase in glutathione reductase which play a role in antioxidant action. The mechanism of salicylic acid was reported by Oota [13] and Pieterrse &Muller [14] who concluded that salicylic acid induced flowering by acting as a chelating agent. This view was supported by Raskin [2] who confirmed that salicylic acid functioned as endogenous growth regulators of flowering and florigenic effects. Regarding, benzyiladenine, Reda *et al*. [15] reported that foliar application of benzyiladenine caused stimulatory effects on flowering. As for GA_3, Reda *et al*. [7] confirmed that GA_3 has the potential control on growth and flowering process. In addition, spraying trees with salicylic acid (20 & 40 µg/L), benzyladenine (20 & 30 mg/L) and GA_3 (50 & 100 mg/L) increased significantly the percentage of sex expression and pollen grains germination than the untreated trees due to their role as growth regulators in development of different plant organs [16].

From the above-mentioned results, it was noticed that salicylic acid (20 & 40 µg/L), benzyladenine (20 & 30 mg/L) recorded high yield than gibberellic acid GA_3 (50 & 100 mg/L) comparing with the control. This could be attributed to the positive effect of these materials on improving flowering percentage and density as well as percentage of sex expression and pollen grains germination than the untreated trees. Meanwhile, salicylic acid (20 & 40 µg/L), benzyladenine (20 & 30 mg/L) increased flowering percentage and density than

gibberelic acid GA_3 (50 & 100 mg/L). Therefore, the treatment of salicylic acid and benzyladenine had higher yield than GA_3. Regarding fruit physical properties (fruit weight, length and diameter, flesh weight and fruit dry weight), salicylic acid (20 & 40 µg/L), benzyladenine (20 & 30 mg/L) improved these parameters than GA_3 (50 & 100 mg/L) compared with the control due to the positive effect of antioxidants on fruit physical properties especially fruit weight that reflected also on increasing yield. Similar results were obtained by Yousef *et al*. [17] and Maksoud *et al*. [18] found that spraying Picaul and Chemlali olive trees with some antioxidant increased fruit weight and yield. The essential oil percent increased by all treatments compared to the control. However, salicylic acid at 40µg/L produced the highest percentage. Therefore, it could be suggested that growth regulators which were used in this study controlled the biosynthesis of essential oil through the main metabolic pathway. In this respect, salicylic acid at 40µg/L was effective one [6, 7]. In support of this suggestion, Cseke and Kaufmann [19] concluded that the control of biosynthetic pathways leading to the production of specific metabolites as essential oils are controlled by enzymes, which in turn are mainly effected by growth regulators. In addition, Heldt [20] mentioned that auxins regulated the physiological processes through enzymatic reactions, cell structure, nucleic acids synthesis and consequently other metabolic pathways. However, it could be pointed out that exogenous application of antioxidant had a regulating effect on essential oil production of olive [17]. Moreover, the results are in harmony with those obtained by Yousef *et al*. [17] on Picual olive and Maksoud *et al*. [18] on Chemlali olive, who reported that fruit oil content increasing by some antioxidant treatments. Moreover, foliar spray of antioxidants improved essential oil content of many oil crops [15, 21- 24].

CONCLOSION

For improving yield and fruit quality of `Egazy Shami' olive trees, foliar spray of salicylic acid at 40µg/L is recommended by application at one month before beginning of flowering stage (mid February). Improving productivity attributed to increase flowering percentage and density, as well as percentage of sex expression, pollen grains germination, fruit physical properties (fruit weight, length & diameter, seed weight, flesh weight & fruit dry weight) and fruit oil content. Concerning the treatment of benzyladenine (20 &30 mg/L), it had the same effect of salicylic acid on improving yield and fruit quality but produced lower fruit oil content. On the other hand, GA_3 (50 & 100 mg/L) produced lower yield than salicylic acid (20 & 40 µg/L) and benzyladenine (20 & 30 mg/L).

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