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Influence of foliar application with putrescine, salicylic, and ascorbic acid on the productivity and physical and chemical fruit properties of Picual olive trees

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Abstract

Background and objective: Olive tree is very popular in the Mediterranean area because of its fruits and oil yields. Both of them are worldwide known by their beneficial health properties. Salicylic acid is naturally occurring as phenolic compound and endogenously synthesized as signaling molecule in plants and influences various physiological and biochemical functions in plants. Ascorbic acid is an antioxidant molecule and a key substrate for the detoxification of ROS. Putrescine participates in several processes of plant growth and development. Putrescine participates in several processes of plant growth and development. Therefore, the objective of this study is to determine the best concentrations of these substances to improve olive fruits yield and its chemical and physical properties.

Materials and methods: The field experiment was conducted during two seasons of 2017 and 2018 on adult olive trees of Picual cv. (8 years old) in a private orchard located in Ismailia Governorate, Egypt, to study the effect of foliar application with different concentrations of putrescine, salicylic, and ascorbic, in two dates of November and December. The effect of different concentrations and dates of spray under the conditions of the saline irrigation water (4.40 ds m^{-1}) were evaluated on the fruit yield, fruit physical characteristics and fruit chemical properties of olive trees of Picual cv.

Results: In this study, all treatments were able to improve all studied characters compared with the control treatment in both spraying dates of November and December in both seasons, respectively. Moreover, the best yield of olive fruits in this study was recorded with the application of putrescine at 15 ppm + salicylic at 200 ppm + ascorbic at 2000 ppm in the first and second seasons, respectively.

Conclusion: Spraying Picual olive trees with putrescine, salicylic, and ascorbic acid in this study under the conditions of the saline irrigation water (4.40 ds m^{-1}) was able to improve fruit yield and fruit physical and chemical properties of olive trees of Picual cv. compared with the control treatment in both spraying dates

Keywords: Olive trees, Picual, Putrescine, Salicylice acid, Ascorbic acid, Productivity, Physical properties, Chemical properties

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Introduction

Oleaceae family includes 30 genera of deciduous trees and shrubs including olive tree and its relatives numbering about 600 species (Grohmann 1981; Atta-ur-Rahman 1990). Oleaceae is best grown in Asia and Malaysia especially tropical and temperate regions of Asia (Pérez et al. 2005). The genus *Olea* comprises 30 species (Bracci et al. 2011), but *Olea europaea* L. is the most popular member of the genus *Olea* (Kaniewski et al. 2012). It is the only species of this genus which is used as food and is found in the Mediterranean region (Zohary et al. 2012; Sarwar 2013). The olive tree is a traditional symbol of abundance, glory, and peace, and its leafy branches were historically used to crown the victorious in friendly games. The olive fruit, oil, and the leaves of the tree have a rich history of nutritional, medicinal, and ceremonial uses (Soni et al. 2006). Olive tree is very popular in the Mediterranean area because of its fruits and oil. Both of them are worldwide known for their beneficial health properties (Kiritsakis 1998). Olive oil is produced at a level of around 2.6 million tonnes. It has a long history going back to pre-biblical times. It is produced and consumed mainly in Mediterranean countries, but demand is increasing in other countries in Northern Europe and in the USA as a consequence of strong marketing of this oil. Olive oil is considered to be an essential ingredient of the healthy Mediterranean lifestyle (Gunstone 2002).

Salicylic acid is naturally occurring as phenolic compound and endogenously synthesized as signaling molecule in plants and influences various physiological and biochemical functions in plants. It can act as an important signaling and competing various biotic and abiotic stresses. So it increases drought stress tolerance and salt stress tolerance (Arfan et al. 2007; Khan et al. 2015). Salicylic acid regulates important plant physiological processes such as nitrogen metabolism, photosynthesis, antioxidant defense system, proline metabolism, and plant-water relations, with concomitant protection in plants against abiotic stresses (Khan et al. 2012).

Ascorbic acid is an antioxidant molecule and a key substrate for the detoxification of reactive oxygen species (Foyer and Noctor 2011). Physiologically active form of ascorbic acid is the resonance stabilized anionic form, which is termed as ascorbate. Exogenous application of ascorbic acid can protect lipids and proteins against drought-induced oxidative adversaries (Naz et al. 2016). Ascorbic acid could improve tolerance against abiotic stresses by enhancing plant growth, rate of photosynthesis and photosynthetic pigments, transpiration, and oxidative defense potential. It is reported that ascorbic acid can effectively regulate anti-oxidative metabolism in plants (Noctor et al. 2014). Also, endogenous As levels could be improved by exogenous application of ascorbic acid (Athar et al. 2008).

Putrescine is one of the polyamines that are considered growth substances. Putrescine participates in several processes of plant growth and development, and its role as anti-senescence and anti-stress agent is previously reported by Ahmed et al. (2017). It works as an antioxidant and improves cell membrane stability (Li et al. 2015). It plays a role in modulating the defense response of plants to varied environmental stresses including drought stress (Ahmed et al. 2013; Khorshidi and Hamedi 2014).

Material and methods

This study was carried out during two successive seasons (2017 and 2018) at a private orchard located at Cairo-Ismailia Desert Road (about 80 km from Cairo), Ismailia Governorate, Egypt. The study was conducted on 8 years old olive trees of Picual cv., planted at 4 × 6 m apart grown in sandy soil, under drip irrigation system. The selected trees were uniformed in shape and received the common horticultural practices. The orchard soil analysis is given in Table 1, and the water irrigation analysis is given in Table 2 according to procedures which are outlined by Wild et al. (1985).

This experiment was designed to study the effect of spraying Picual olive trees with putrescine, salicylic acid, and ascorbic acid at different concentrations and dates, i.e., mid of November and mid of December (33 trees for each date) during two studied seasons as follows:

(Cont)—Control treatment (spray with distilled water only).

T1—Tree sprayed with putrescine (PUT) at 15 ppm.

T2—Tree sprayed with putrescine (PUT) at 30 ppm.

Table 1 Some physical and chemical properties of the orchard soil

Parameters	Surface sample	30 cm depth	60 cm depth
Depth of simple (cm)			
pH	8.02	8.70	8.11
EC(dSm−1)	3.80	0.80	1.70
Soluble cations (meq/l)			
Ca^{++}	6.00	2.50	3.00
Mg^{++}	4.00	1.50	1.50
Na^{+}	28.60	4.40	12.90
K^{+}	0.12	0.14	0.78
Soluble anions (meq/l)			
CO_3^{-}	–	–	–
HCO_3^{-}	4.40	2.40	2.00
Cl^{-}	27.20	5.00	13.00
$SO_4^{=}$	7.12	1.14	3.18

Table 2 Chemical characteristics of the used water well for the present study

Parameters	Values
pH	**7.49**
EC(ds m^{-1})	**4.40**
Soluble cations (meq/l)	
Ca++	**7.50**
Mg++	**5.00**
Na+	**33.1**
K+	**0.16**
Soluble anions (meq/l)	
CO_3^{-2}	**–**
HCO_3^{-}	**1.60**
Cl^{-}	**40.00**
SO_4^{-2}	**4.16**

T3—Tree sprayed with salicylic acid (SAL) at 200 ppm.

T4—Tree sprayed with salicylic acid (SAL) at 300 ppm.

T5—Tree sprayed with ascorbic acid (ASC) at 2000 ppm.

T6—Tree sprayed with ascorbic acid (ASC) at 3000 ppm.

T7—Tree sprayed with putrescine at 15 ppm + salicylic acid at 200 ppm.

T8—Tree sprayed with putrescine at 15 ppm + ascorbic acid at 2000 ppm.

T9—Tree sprayed with salicylic acid at 200 ppm + ascorbic acid at 2000 ppm.

T10—Tree sprayed with putrescine 15 ppm + salicylic acid 200 ppm + ascorbic acid 2000 ppm.

Both groups of trees which were sprayed in November or December received other two spraying dates, i.e., the first at full bloom (during April) and the second after fruit set (during May). Each treatment was represented by three replicates (one tree per replicate) which were chosen randomly, and on early October of each season, twenty healthy 1-year old shoots well distributed around the canopy were randomly selected and labeled (5 shoots for each direction) for carrying out the following measurements:

Fruit yield (kg/tree): Fruits were harvested at ripening stage on end of October in the years 2017 and 2018. Each individual tree was harvested manually, and weight of fruits/tree was measured. Average yield (kg)/tree was determined for each treatment.

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

1. Fruit weight (g): It was determined by weighing the samples (30 fruits) by ordinary balance with 0.01 g sensitivity, and average weight per fruit was calculated.
2. Pulp weight (g): It was determined by weighing the sample (30 fruits and their seeds), and average weight of pulp was calculated.
3. Pulp/seed ratio: Values were calculated by dividing the weight of the pulp over the weight of the seed.
4. Fruit length (cm): It was measured by digital caliper for the length of the sample (30 fruits), and the average weight of pulp was calculated.
5. Fruit diameter (cm): It was measured by a digital caliper for the diameter of the sample (30 fruits), and the average weight of pulp was calculated.

Chemical properties of fruit

Flesh fruit oil content (%)

Oil percentage was determined in the fruit flesh on dry weight basis using the Soxhlet oil extraction apparatus with hexane 60–80 °C boiling point, according to Banat et al. (2013).

Oil acidity (%)

It was determined according to the Dieffenbacker and Pocklington (1992), since 5 g of oil was accurately weighed in 250 ml dry conical flask with about 100 ml of neutralized 50% ethanol + 50% petroleum ether to dissolve the oily sample. Acidity of the sample was determined by titration with 0.1 N of potassium hydroxide solution in the presence of phenolphthalein as an indicator. The acid value was calculated according to the following equation.

$$\text{Acid percentage} = \frac{V \times N \times 5.61 \times 100}{\text{Weight of sample}}$$

where

V = volume of KOH solution

N = normality of potassium hydroxide solution

The peroxide value (meq/kg oil)

The peroxide value was determined according to Jacobs (1959) by dissolving 5 g of the oil in a mixture consisting of 60% glacial acetic acid + 40% chloroform. The solution was treated with approximately 0.5 ml of saturated solution of potassium iodide in glass stoppard flask. The flask was shacked in rotary for exactly 2 min, after which 30 ml of distilled water was added, and the liberated iodine was titrated with 0.01 N sodium thiosulfate using 1% of starch solution as external indicator.

The results were calculated in millimoles per kilogram oil according to the following equation.

$$\text{Peroxide value} = \frac{0.5 \times \text{N} \times \text{V} \times 100}{\text{Weight of sample}}$$

where

N = normality of sodium thiosulfate solution

V = volume in milliliters of sod. thiosulfate needed for titration

Iodine value (mg/kg oil)

The degree of instauration of oil was determined by measuring the amount of halogen absorbed by the oil as stated in Dieffenbacker and Pocklington (1992) since 0.1–0.5 g of oil was dissolved in 10 ml of chloroform and 25 ml of Hanus iodine solution was added. After 30 min, 10 ml of 15% potassium iodine solution and 100 ml of freshly boiled cooled distilled water were added. The liberated iodine was titrated with 0.1 N of sodium thiosulfate using starch indicator.

$$\text{Iodine value} = \frac{(V_1 - V_2) \times N \times 12.69}{\text{Weight of sample}}$$

where

N = normality of sodium thiosulfate solution

V_1 = volume in millliter of sod. thiosulfate needed for titration blank

V_2 = volume in milliliter. of sod. thiosulfate needed for titration sample

Experimental design and statistical analysis

This work was conducted as factorial experiment. Treatments were arranged in a completely randomized block design with three replicates for each treatment. This work was conducted as factorial experiment. Treatments were arranged in a completely randomized block design with three replicates for each treatment. All obtained data during both 2017 and 2018 experimental seasons were subjected to analysis of variances (ANOVA) according to Snedecor and Cochran (1980) using MSTAT program. Least significant ranges (LSR) were used to compare between means of treatments according to Duncan (1955) at probability of 5%.

Results

Yield (kg/tree)

With regard to olive yield per tree, results in the Table 3 cleared that most treatments significantly increased yield than the control in both seasons. In this concern, spraying trees with SAL at 200 ppm (T4) and PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) produced the highest yield (33.83 and 33.83 kg/tree) in the first season. Moreover, foliar spraying with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) recorded the highest value in this respect (26.31 kg/tree) in the second season. On the other hand, the control trees exhibited the lowest yield in this regard (25.33 and 17.03 kg/tree) in both seasons, respectively. On the other side, the other treatments were in between ranges. Concerning spraying dates in the first and second seasons, spraying

Table 3 Influence of foliar applications with putrescine, salicylic, and ascorbic acid on yield and fruit weight of Picual olives in 2017 and 2018 seasons

Treat.	Yield (kg/tree)						Fruit weight (g)					
	2017			2018			2017			2018		
	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean
	Nov.	Dec.		Nov.	Dec.		Nov.	Dec.		Nov.	Dec.	
Cont.	25.00 e	25.67 de	**25.33 C**	16.96 i	17.10 i	**17.03 G**	5.10 fg	4.93 g	**5.02 C**	5.60 k	5.64 jk	**5.62 K**
T1	30.00 a–e	28.00 cde	**29.00 B**	19.56 h	19.47 h	**19.51 F**	5.93 a–e	5.81 b–e	**5.87 AB**	5.60 k	5.80 ijk	**5.70 J**
T2	29.00 b–e	30.66 a–d	**29.83 B**	19.93 gh	20.90 g	**20.41 E**	5.60 def	5.70 c–f	**5.65 B**	5.63 jk	6.00 hi	**5.8 1I**
T3	32.00 abc	26.00 de	**29.00 B**	23.06 ef	20.59 gh	**21.83 D**	6.22 abc	5.63 c–f	**5.93 AB**	6.00 hi	6.16 gh	**6.08 H**
T4	34.67 a	33.00 abc	**33.83 A**	23.96 de	23.17 ef	**23.56 C**	5.97 a–e	6.41 ab	**6.19 A**	6.20 fgh	6.40 efg	**6.30 F**
T5	32.33 abc	28.00 cde	**30.17 B**	24.23 cde	22.30 f	**23.26 C**	5.91 a–e	5.86 a–e	**5.89 AB**	5.97 hij	6.44 efg	**6.20 G**
T6	33.66 ab	29.33 b–e	**31.50 AB**	23.26 ef	24.13 cde	**23.70 C**	6.39 ab	6.16 a–d	**6.28 A**	6.85 bcd	7.17 b	**7.01 B**
T7	30.33 a–d	26.00 de	**28.17 BC**	23.93 de	20.16 gh	**22.05 D**	6.17 a–d	5.85 a–e	**6.01 AB**	6.30 fgh	6.70 cde	**6.50 E**
T8	28.33 cde	30.00 a–e	**29.17 B**	24.66 bcd	23.10 ef	**23.88 C**	5.50 efg	6.39 ab	**5.95 AB**	6.55 def	7.00 bc	**6.77 D**
T9	32.33 abc	28.00 cde	**30.17 B**	25.26 bc	24.63 bcd	**24.95 B**	5.54 efg	4.94 g	**5.24 C**	6.66 cde	7.13 b	**6.89 C**
T10	33.00 abc	34.67 a	**33.83 A**	25.73 b	26.90 a	**26.31 A**	6.12 a–e	6.45 a	**6.28 A**	7.06 b	7.63 a	**7.34 A**
Mean	**30.97 A***	**29.03 B***		**22.78 A***	**22.04 B***		**5.86 A***	**5.83 A***		**6.22 B***	**6.55 A***	

*Mean in each column, row, or interaction with similar letter(s) are not significantly different at 5% level

T1 PUT at 15 ppm, *T2* PUT at 30 ppm, *T3* SAL at 200 ppm, *T4* SAL at 300 ppm, *T5* ASC at 2000 ppm, *T6* ASC at 3000 ppm, *T7* PUT at 15 ppm + SAL at 200 ppm, *T8* PUT at 15 ppm + ASC at 2000 ppm, *T9* SAL at 200 ppm + ASC at 2000 ppm, *T10* PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm

in November gave higher yield (30.97 and 22.78 kg/tree) as compared with spraying in December (29.03 and 22.04 kg/tree), respectively. Concerning interaction effect, spraying trees in December with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) gave the highest value (34.67 and 26.90 kg/tree) in both studied seasons, respectively.

Physical properties of olive fruit

Fruit weight

Regarding fruit weight, results in Table 3 cleared that all treatments except T9 in the first season significantly enhanced fruit weight than the control in both studied seasons. In this manner, spraying trees with ASC at 3000 ppm (T6) and PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) exhibited the highest fruit weight (6.28 and 6.28 g) in the first season. Meanwhile, trees sprayed with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) recorded the highest value in this respect (7.34 g) in the second one. On the other hand, control treatment recorded the least values (5.02 and 5.62 g) in both studied seasons, respectively. With regard to spraying dates, results showed no significant differences between spraying dates in the first season, while in the second one, spraying date of December recorded significantly higher value (6.55 g) than the November one (6.22 g) in this respect. Concerning the interaction effect, results showed that spraying with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) at December gave the highest values of fruit weight (6.45 and 7.63 g) in the both seasons of this study, respectively.

Pulp weight

Data in Table 4 indicated that pulp weight was significantly affected by different spraying treatments as compared with control in both studied seasons except T9 in the first season. Application of PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) recorded the maximum values in this respect since there were (5.51 and 6.40 g) in both studied seasons, respectively. However, the minimum values were shown with the control (4.14 and 4.77 g) in the first and second seasons, respectively. Moreover, the time of foliar spraying shows that no significant differences between spraying dates in the first season, but December application date was significantly higher (5.67 g) than November (5.27 g) in the second season. Concerning the interaction effect, trees sprayed with PUT at 15 ppm + ASC at 2000 ppm (T8) at December recorded the highest significant value (5.71 g) in the first season. However, trees sprayed with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) in December presented the highest value in this respect (6.67 g) in the second season.

Pulp to seed ratio

Regard to pulp to seed ratio, results in the Table 4 illustrated that all spraying treatments except T1 in the second season significantly increased pulp to seed ratio than the control in the first and second seasons, respectively. In this concern, spraying trees with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) produced the largest values (7.11) in this regard during the

Table 4 Influence of foliar applications with putrescine, salicylic, and ascorbic acid on fruit weight, pulp weight, and pulp/seed ratio of Picual olives in 2017 and 2018 seasons

Treat.	Pulp weight (g)						Pulp/seed ratio					
	2017			2018			2017			2018		
	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean
	Nov.	Dec.		Nov.	Dec.		Nov.	Dec.		Nov.	Dec.	
Cont.	4.22 gh	4.07 h	**4.14 E**	4.74 fg	4.80 efg	**4.77 K**	4.79 gh	4.72 h	**4.76 F**	5.56 gh	5.71 fg	**5.64 F**
T1	5.07 c–f	4.93 def	**5.00 CD**	4.71 g	4.94 efg	**4.82 J**	5.86 d–h	5.64 e–h	**5.75 DE**	5.29 h	5.77 fg	**5.52 F**
T2	4.82 ef	4.93 def	**4.87 D**	4.80 fg	5.18 d–g	**4.99 I**	6.18 def	6.37 b–f	**6.27 BCD**	5.85 fg	6.35 cde	**6.10 E**
T3	5.49 a–d	4.84 ef	**5.16 AD**	5.19 c–g	5.34 c–g	**5.27 G**	7.50 ab	6.09 def	**6.79 ABC**	6.46 cde	6.54 cd	**6.51 CD**
T4	5.18 a–f	5.61 abc	**5.39ABC**	5.39 b–f	5.56 b–f	**5.47 E**	6.53 b–f	7.01 bcd	**6.77 ABC**	6.71 bc	6.65 bcd	**6.68 BC**
T5	5.09 b–f	4.97 def	**5.03 BCD**	5.19 c–g	5.53 b–f	**5.36 F**	6.22 c–f	5.61 e–h	**5.91 DE**	6.65 bcd	6.09 ef	**6.37 D**
T6	5.45 a–d	5.37 a–e	**5.41 AB**	6.03 abc	6.23 ab	**6.13 B**	5.90 d–h	6.74 b–e	**6.32 BCD**	7.42 a	6.62 bcd	**7.02 A**
T7	5.33 a–e	5.00 def	**5.16 A–D**	5.43 b–f	5.82 a–d	**5.12 H**	6.30 c–f	5.93 d–g	**6.11 CDE**	6.27 de	6.67 bcd	**6.47 CD**
T8	4.65 fg	5.71 a	**5.18 A–D**	5.67 b–e	6.09 ab	**5.88 D**	5.52 fgh	8.41 a	**6.96 AB**	6.44 cde	6.74 bc	**6.59BCD**
T9	4.67 fg	4.18 gh	**4.42 E**	5.78 a–d	6.20 ab	**5.99 C**	5.48 fgh	5.48 fgh	**5.48 E**	6.60 bcd	6.66 bcd	**6.63 BCD**
T10	5.34 a–e	5.68 ab	**5.51 A**	6.13 ab	6.67 a	**6.40 A**	6.84 bcd	7.37 abc	**7.11 A**	6.64 bcd	6.97 b	**6.81 AB**
Mean	**5.03 A***	**5.02 A***		**5.27 B***	**5.67 A***		**6.10 A***	**6.31 A***		**6.35 A***	**6.44 A***	

*Mean in each column, row, or interaction with similar letter(s) are not significantly different at 5% level

T1 PUT at 15 ppm, *T2* PUT at 30 ppm, *T3* SAL at 200 ppm, *T4* SAL at 300 ppm, *T5* ASC at 2000 ppm, *T6* ASC at 3000 ppm, *T7* PUT at 15 ppm + SAL at 200 ppm, *T8* PUT at 15 ppm + ASC at 2000 ppm, *T9* SAL at 200 ppm + ASC at 2000 ppm, *T10* PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm

first season; moreover, spraying trees with ASC at 3000 ppm (T6) showed the highest value (7.02) in the second season, respectively. Concerning spraying dates, no significant differences between spraying dates were found in the first and second seasons, respectively. Concerning interaction influence, spraying trees in December with PUT at 15 ppm + ASC at 2000 ppm (T8) gave the highest value (8.41) in the first season. On the other hand, spraying trees with ASC at 3000 ppm (T6) at November gave the largest value (7.42) in this regard in the second season compared with other treatments.

Fruit length

Data in Table 5 indicated that fruit length was significantly affected by different treatments compared with control in both studied seasons. In the first season, application of ASC at 2000 ppm (T5) gave the highest values in this respect since (2.69 cm). But in the second season, application of PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) recorded the highest value of fruit length (2.86 cm) in this respect, while the least significant values were shown with untreated trees (control) (2.44 and 2.42 cm) in both studied seasons, respectively. Moreover, the time of foliar spraying showed that November application date had more significant higher value (2.62 cm) than December (2.60 cm) in the first season, but in the second season, results showed that December application date recoded more significant higher (2.70 cm) than November (2.60 cm) in this regard. Concerning interaction effect, trees sprayed with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) and ASC at 2000 ppm (T5) in December recorded the largest significant values (2.70 and 2.70 cm) in the first season. But trees sprayed with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) in December presented the highest fruit length (2.90 cm) in the second season.

Fruit diameter

Data in Table 5 indicated that fruit diameter was significantly affected by different treatments compared with control in both studied seasons. In the first season, application of SAL at 300 ppm (T4) gave the maximum fruit diameter (2.13 cm). Moreover, in the second one, spraying with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) recorded the maximum value (2.17 cm) in this respect, while the significant lowest values were shown with control treatment (1.95 and 1.93 cm) in the first and second seasons, respectively. Moreover, the time of spraying shows that there was no significant difference found between the two spraying dates in the first season, while in the second one, December spraying date had significant higher value (2.07 cm) than the November one (2.03 cm) in this respect. Regarding interaction effect, trees sprayed with SAL at 300 ppm (T4) at December and PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) at December recorded the largest significant fruit diameter (2.19 and 2.20 cm) in the first and second seasons, sequently.

Table 5 Influence of foliar applications with putrescine, salicylic, and ascorbic acid on fruit length and diameter of Picual olives in 2017 and 2018 seasons

Treat.	Fruit length (cm)						Fruit diameter (cm)					
	2017			2018			2017			2018		
	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean
	Nov.	Dec.		Nov.	Dec.		Nov.	Dec.		Nov.	Dec.	
Cont.	2.42 g	2.46 fg	**2.44 C**	2.40 c	2.44 bc	**2.42 I**	1.93 j	1.98 hij	**1.95 F**	1.88 d	1.98 bcd	**1.93 J**
T1	2.69 a	2.46 fg	**2.57 B**	2.42 c	2.54 abc	**2.48 H**	2.05 d–g	2.11 bcd	**2.08 BC**	1.92 cd	1.96 bcd	**1.94 I**
T2	2.60 a–e	2.66 abc	**2.63AB**	2.48 abc	2.60 abc	**2.54 G**	2.02 e–h	2.00 ghi	**2.01 DE**	2.00 a–d	2.02 a–d	**2.01 H**
T3	2.64 a–d	2.56 c–f	**2.61 B**	2.54 abc	2.62 abc	**2.58 F**	2.12 bc	2.07 c–f	**2.09ABC**	2.04 a–d	2.06 a–d	**2.05 G**
T4	2.64 a–d	2.51 efg	**2.58 B**	2.70 abc	2.66 abc	**2.68 D**	2.08 cde	2.19 a	**2.13 A**	2.06 a–d	2.08 a–d	**2.07 E**
T5	2.68 ab	2.70 a	**2.69 A**	2.62 abc	2.68 abc	**2.65 E**	2.08 cde	2.01 f–i	**2.04 CD**	2.02 a–d	2.14 ab	**2.08 D**
T6	2.66 abc	2.69 a	**2.68 A**	2.72 abc	2.84 abc	**2.78 B**	2.12 bc	2.06 d–g	**2.09 ABC**	2.12 abc	2.14 ab	**2.13 B**
T7	2.67 abc	2.59 a–e	**2.63 AB**	2.62 abc	2.74 abc	**2.68 D**	2.11 bcd	2.08 cde	**2.10 AB**	2.02 a–d	2.10 abc	**2.06 F**
T8	2.57 b–e	2.62 a–d	**2.60 B**	2.66 abc	2.80 abc	**2.73 C**	2.03 e–h	2.17 ab	**2.10 AB**	2.10 abc	2.02 a–d	**2.06 F**
T9	2.63 a–d	2.54 def	**2.58 B**	2.67 abc	2.88 ab	**2.77 B**	2.01 f–i	1.95 ij	**1.98 EF**	2.10 abc	2.12 abc	**2.11 C**
T10	2.66 abc	2.70 a	**2.68 A**	2.82 abc	2.90 a	**2.86 A**	2.06 d–g	2.08 cde	**2.07 BC**	2.14 ab	2.20 a	**2.17 A**
Mean	**2.62 A***	**2.59 B***		**2.60 B***	**2.70 A***		**2.05 A***	**2.06 A***		**2.03 B***	**2.07 A***	

*Mean in each column, row, or interaction with similar letter(s) are not significantly different at 5% level

T1 PUT at 15 ppm, *T2* PUT at 30 ppm, *T3* SAL at 200 ppm, *T4* SAL at 300 ppm, *T5* ASC at 2000 ppm, *T6* ASC at 3000 ppm, *T7* PUT at 15 ppm + SAL at 200 ppm, *T8* PUT at 15 ppm + ASC at 2000 ppm, *T9* SAL at 200 ppm + ASC at 2000 ppm, *T10* PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm

Fruit oil content

Results presented in Table 6 revealed that the most different spraying treatments in the first season and all treatments in the second one significantly increased fruit oil percentage on dry weight basis than the control during both seasons. Trees sprayed with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) gave the maximum fruit oil percentages (39.92 and 40.49%) in the first and second seasons, respectively. On the other side, the control trees recorded the lowest oil percentage (33.25 and 35.45%) in both studied seasons, respectively. Meanwhile, the other treatments were in between ranges. Concerning spraying dates, there were no significant differences in fruit oil percentage between the two spraying dates in the first season, but in the second season, December spray recorded the higher value (38.47%) as compared with November spraying date (37.62%) in this respect. As for interaction effect between different foliar application treatments and spraying dates, it could be concluded that there were no significant differences in fruit oil content between different treatments and spraying dates in the first season; however, trees sprayed with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) in December recorded the highest oil content (40.73%) in the second season.

Chemical properties of fruit oil

Oil acidity

Data in Table 6 indicated that oil acidity was significantly affected by different treatments and spraying dates and it range from 0.16 to 0.51% in the first season, while in the second one, it ranged between 0.20 and 0.49%. However, the lowest oil acidity was found with trees sprayed by ASC at 2000 ppm (T5) (0.21 and 0.24%) in both studied seasons, respectively. Meanwhile, the highest oil acidity was recorded with PUT at 15 ppm (T1) (0.39 and 0.42%) in the first and second seasons, respectively. As for spraying dates, results clear that spraying dates in December (0.26 and 0.26%) significantly decreased oil acidity compared with November (0.39 and 0.39%) in both studied seasons, respectively. Regarding interaction effect in between the different concentrations treatments and spraying dates, spraying by ASC at 2000 ppm (T5) in December presented the lowest oil acidity percentages (0.16 and 0.20%) in the first and second seasons, respectively. On the other side, trees sprayed with SAL at 300 ppm (T4) in November and PUT at 15 ppm (T1) in November recorded the highest values (0.51 and 0.49%) in this respect in both seasons of the study, respectively.

Peroxide value

Results in Table 7 reported that peroxide value was significantly affected with different foliar application treatments and spraying dates in both seasons. However, peroxide values ranged from 3.36 to 5.05 meq/kg and 3.48 to 5.11 meq/kg in the first and second seasons, respectively. On the other hand, the lowest peroxide values (3.61 and 3.66 meq/kg) were obtained with trees sprayed with PUT at 15 ppm + ASC at 2000 ppm (T8) in the first

Table 6 Influence of foliar applications with putrescine, salicylic, and ascorbic acid on flesh oil content and oil acidity of Picual olives in 2017 and 2018 seasons

Treat.	Flesh oil content (%)						Oil acidity (%)					
	2017			2018			2017			2018		
	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean
	Nov.	Dec.		Nov.	Dec.		Nov.	Dec.		Nov.	Dec.	
Cont.	33.18 ab	33.32 ab	**33.25 B**	35.60 lm	35.30 m	**35.45 H**	0.38 a–f	0.37 a–f	**0.37 B**	0.39 a–d	0.38 a–d	**0.38 B**
T1	33.63 ab	37.87 a	**35.75 AB**	36.03 kl	38.34 h	**37.18 F**	0.47 a–d	0.32 b–g	**0.39 A**	0.49 a	0.36 a–e	**0.42 A**
T2	33.73 ab	39.39 a	**36.56 AB**	36.56 j	39.83 cde	**38.20 C**	0.49 ab	0.23 efg	**0.36 C**	0.48 a	0.31 b–f	**0.39 B**
T3	35.62 ab	37.87 a	**36.74 AB**	35.78 l	39.39 ef	**37.58 E**	0.48 abc	0.29 d–g	**0.38 AB**	0.47 a	0.25 def	**0.36 C**
T4	38.98 a	38.93 a	**38.95 AB**	40.10 cd	40.63 ab	**40.37 A**	0.51 a	0.27 efg	**0.39 A**	0.46 ab	0.24 def	**0.35 D**
T5	39.13 a	38.35 a	**38.74 AB**	38.99 fg	38.50 h	**38.75 B**	0.27 efg	0.16 g	**0.21 G**	0.29 c–f	0.20 f	**0.24 H**
T6	40.00 a	28.98 b	**34.49 AB**	39.69 de	41.01 a	**40.35 A**	0.41 a–e	0.22 fg	**0.31 D**	0.42 abc	0.22 ef	**0.32 E**
T7	35.50 ab	35.61 ab	**35.55 AB**	36.34 jk	36.06 kl	**36.20 G**	0.32 a–g	0.25 efg	**0.28 E**	0.35 a–f	0.27 c–f	**0.31 F**
T8	34.84 ab	35.80 ab	**35.32 AB**	35.80 l	36.28 jk	**36.20 G**	0.31 b–g	0.25 efg	**0.28 E**	0.36 a–e	0.21 ef	**0.28 G**
T9	37.80 ab	36.28 ab	**37.04 AB**	38.72 gh	37.12 i	**37.92 D**	0.35 a–g	0.26 efg	**0.30 D**	0.35 a–f	0.24 def	**0.29 G**
T10	40.60 a	39.24 a	**39.92 A**	40.24 bc	40.73 a	**40.49 A**	0.29 c–g	0.21 fg	**0.25 F**	0.30 c–f	0.21 ef	**0.25 H**
Mean	**36.63 A***	**36.51 A***		**37.62 B***	**38.47 A***		**0.39 A***	**0.26 B***		**0.39 A***	**0.26 B***	

*Mean in each column, row, or interaction with similar letter(s) are not significantly different at 5% level

T1 PUT at 15 ppm, *T2* PUT at 30 ppm, *T3* SAL at 200 ppm, *T4* SAL at 300 ppm, *T5* ASC at 2000 ppm, *T6* ASC at 3000 ppm, *T7* PUT at 15 ppm + SAL at 200 ppm, *T8* PUT at 15 ppm + ASC at 2000 ppm, *T9* SAL at 200 ppm + ASC at 2000 ppm, *T10* PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm

Table 7 Influence of foliar applications with putrescine, salicylic, and ascorbic acid on peroxide value and iodine value of Picual olive oil in 2017 and 2018 seasons

Treat.	Peroxide value (meq/kg oil)						Iodine value (mg/kg oil)					
	2017			2018			2017			2018		
	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean	Spraying date		Mean
	Nov.	Dec.		Nov.	Dec.		Nov.	Dec.		Nov.	Dec.	
Cont.	5.05 a	5.04 a	**5.05 A**	5.11 a	5.09 a	**5.10 A**	81.14 ab	81.14 ab	**81.14 J**	78.57 c	78.57 c	**78.57 K**
T1	5.00 ab	3.80 cd	**4.40 C**	4.95 ab	3.87 cd	**4.41 C**	82.74 ab	83.37 ab	**83.05 F**	83.05 bc	84.33 abc	**83.69 E**
T2	3.72 cd	3.71 cd	**3.71 H**	3.61 d	3.80 cd	**3.71 H**	82.19 ab	82.05 ab	**82.12 I**	82.90 bc	81.85 bc	**82.37 H**
T3	3.76 cd	4.31 a–d	**4.03 E**	3.81 d	4.33 a–d	**4.04 E**	85.37 ab	81.58 ab	**83.56 E**	83.02 bc	81.23 bc	**82.12 J**
T4	3.90 bcd	3.67 cd	**3.78 G**	4.00 bcd	3.61 d	**3.80 F**	83.37 ab	81.51 ab	**82.44 H**	82.74 bc	85.28 ab	**84.01 D**
T5	4.66 abc	4.32 a–d	**4.49 B**	4.66 abc	4.33 a–d	**4.49 B**	85.49 ab	83.66 ab	**84.57 C**	84.85 ab	86.83 ab	**85.84 B**
T6	3.67 cd	3.73 cd	**3.70 I**	3.80 cd	3.75 cd	**3.77 G**	80.50 b	81.75 ab	**81.12 K**	82.40 bc	83.05 bc	**82.72 G**
T7	4.19 a–d	4.20 a–d	**4.19 D**	4.26 a–d	4.17 a–d	**4.22 D**	86.26 ab	83.61 ab	**84.93 B**	89.65 a	84.84 ab	**87.24 A**
T8	3.62 cd	3.6 cd	**3.61 K**	3.70 cd	3.63 d	**3.66 I**	84.69 ab	84.16 ab	**84.42 D**	82.11 bc	82.35 bc	**82.23 I**
T9	3.92 bcd	3.36 d	**3.65 J**	3.94 bcd	3.48 d	**3.71 H**	81.42 ab	84.06 ab	**82.74 G**	85.22 ab	85.68 ab	**85.45 C**
T10	3.96 a–d	4.04 a–d	**4.00 F**	4.04 bcd	4.10 a–d	**4.07 E**	87.28 a	84.34 ab	**85.81 A**	83.56 abc	83.66 abc	**83.61 F**
Mean	**4.13 A***	**3.98 B***		**4.17 A***	**4.01 B***		**83.69 A***	**82.84 B***		**83.46 A***	**83.42 B***	

*Mean in each column, row, or interaction with similar letter(s) are not significantly different at 5% level

T1 PUT at 15 ppm, *T2* PUT at 30 ppm, *T3* SAL at 200 ppm, *T4* SAL at 300 ppm, *T5* ASC at 2000 ppm, *T6* ASC at 3000 ppm, *T7* PUT at 15 ppm + SAL at 200 ppm, *T8* PUT at 15 ppm + ASC at 2000 ppm, *T9* SAL at 200 ppm + ASC at 2000 ppm, *T10* PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm

and second seasons, respectively. In this manner, the control trees exhibited the highest peroxide value (5.05 and 5.10 meq/kg) in the first and second seasons. As for spraying dates, results clear that spraying in November gave higher peroxide values (4.13 and 4.17 meq/kg) as compared with spraying in December (3.98 and 4.01 meq/kg) in the first and second seasons, respectively. Regarding, interaction effect, trees sprayed in December with SAL at 200 ppm + ASC at 2000 ppm (T9) recorded the minimum values (3.36 and 3.48 meq/kg) in both studied seasons, respectively. Meanwhile, the control trees at November and December dates exhibited the maximum values in this respect in the first (5.05 and 5.04 meq/kg) and second one (5.11 and 5.09 meq/kg) seasons, respectively.

Iodine value

Concerning iodine value, in Table 7, results cleared that spraying different treatments led to significant increase in iodine value in both seasons. Spraying PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) and PUT at 15 ppm + SAL at 200 ppm (T7) produced the highest values (85.81 and 87.24 mg/kg) in the first and second seasons, respectively, while the control treatment recorded the lowest values (81.14 and 78.57 mg/kg) in this regard in both studied seasons, respectively. As for spraying dates, November spray recorded higher values (83.69 and 83.46 mg/kg) as compared with December (82.84 and 83.42 mg/kg) in both studied seasons, respectively. Regarding interaction effect, spraying trees with PUT at 15 ppm + SAL at 200 ppm + ASC at 2000 ppm (T10) at November gave the highest value (87.28 mg/kg) in this respect in the first season, but in the second one, trees sprayed with PUT at 15 ppm + SAL at 200 ppm (T7) at November exhibited the maximum value (89.65 mg/kg) in this regard.

Discussion

From the abovementioned results, it is clear that all treatments were able to improve all studied characters compared with the control treatment in both spraying dates of November and December in both seasons, respectively. These results agree with those obtained by Maksoud et al. (2009) who found that foliar application with ascorbic acid 1000 ppm improved yield kg/tree on Chemlali olive trees. Also, foliar spraying with putrescine, ascorbic acid, and salicylic acid increased yield of Flame seedless grapevine grown under arid condition (Kassem et al. 2011). In addition, Abd El-Razek et al. (2013) cleared that foliar application with 20 μg/L salicylic acid at mid-February gave the highest yield of EgazyShami olive trees. Thus, Omima et al. (2014) indicated that foliar application with 3000 ppm ascorbic acid at full bloom, 1 month later, and 1 month later after the second spray was effective in improving yield values of Manzanillo olive trees. However, Abd-El-Rhman and Attia (2016) found that maximum yield (kg/tree) of

Manzanillo olive trees verified with spraying by salicylic acid at 1000 ppm compared with the control.

All foliar treatments in both studied date could improve physical properties of olive fruit compared with control treatments; it may be due to the role of putrescine in modulating the defense response of plants to varied environmental stresses including drought stress (Ahmed et al. 2013; Khorshidi and Hamedi 2014), as well as the ability of **s**alicylic acid on maintaining fruit firmness, reduced chilling injury incidence, delayed membrane lipid peroxidation (Khademi and Ershadi 2013), and delayed fruit senescence through inhibiting ethylene biosynthesis which finally maintains pre- and post-harvest fruit quality (Srivastava and Dwivedi 2000). Also, ascorbic acid is considered as a natural and organic antioxidant compound (Hafez et al. 2010). It is also considered as an essential compound for plant tissues since it has antioxidant functions and acts as co-enzyme in an enzymatic cofactor and plant growth regulator (Gomez and Lajolo 2008). In addition, the positive action of antioxidants in catching or chelating the free radicals which could result in extending the shelf life of plant cells and stimulating growth aspects is reported (Rao et al. 2000). The present results regarding the influence of different foliar treatments on fruit physical properties of Picual olives in several studies are in agreement with those found by Ali et al. (2010) who cleared that fruit weight, fruit breadth, and fruit length enhanced with putrecine at 10^{-5} and 10^{-4} mM. Also, they observed the highest fruit properties with putrecine 10^{-4} mM on Canino apricot trees. In addition, Abd El-Razek et al. (2013) found that application of salicylic acid at 20 μg/L improved fruit physical properties (i.e., fruit weight, length and diameter, seed, flesh, and fruit dry weight) and fruit oil content of EgazyShami olive trees. In other investigation on Amhat date palm, Abd El-Migeed et al. (2013) found that foliar spraying with putrescine at 0.45 mM treatments gave the highest flesh weight, fruit length, and diameter and pulp/seed ratio. Also, on Manzanillo olive trees, Omima et al. (2014) reported that spraying with ascorbic acid gave the highest fruit quality compared with other treatments and (Ahmed et al. 2011) on grapevines. In this manner, on mango trees, Hanan (2015) showed that spraying with ascorbic acid at 1 Mm + salicylic acid at 2 Mm presented the highest fruit weight, thickness, and pulp percentage.

As a result of the role of the foliar spraying to improve fruit yield and physical parameters, the oil yield also was improved as a consequence to that. The previous results are in harmony with Maksoud et al. (2009) who showed that spraying with ascorbic acid 1000 ppm on the 1st of April, May, and June combined with soil application of phosphorine increased the flesh oil content of Chemlali olive trees compared with other treatments. Additionally, Abd El-Razek et al. (2013) found that application of salicylic acid at 20 μg/L improved fruit oil content of EgazyShami olive trees. Therefore, Abd-El-Rhman and Attia (2016) clearly showed that foliar spraying with salicylic acid at 1000 ppm led to improving the flesh oil content percentage of Manzanillo olive fruits. In the same respect, Brito et al. (2018) mentioned that flesh oil content increased in the first year and decreased in the second one with salicylic acid at 100 μM on olive trees.

Chemical properties of fruit oil in this study were improved as a result of foliar spraying compared with control treatment. These observations are in accordance with those obtained by Malik and Singh (2006) who showed that application with putrescine at 0.1 mM decreased acidity of fruit juice, while Abd-El-Rhman and Attia (2016) clearly showed that foliar spraying by salicylic acid at 1000 ppm led to reduction total acidity percentage of Manzanillo olive fruits. On the other hand, these results disagree with Brito et al. (2018) who mentioned that foliar sprays with salicylic acid did not significantly affect the olive oil properties such as oil acidity percentage and peroxide value of olive oil.

Conclusion

Spraying Picual olive trees with putrescine and salicylic and ascorbic acid in this study under the conditions of the saline irrigation water (4.40 ds m^{-1}) was able to improve fruit yield and fruit physical and chemical properties of olive trees of Picual cv. compared with the control treatment in both spraying dates of November and December in both seasons, respectively. Moreover, the best yield of olive fruits in this study was recorded with the application of putrescine at 15 ppm + salicylic at 200 ppm + ascorbic at 2000 ppm in the first and second seasons, respectively.

Abbreviation

SAL: Salicylic acid; ASC: Ascorbic acid; PUT: Putrescine

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Significance statement

The study represented useful treatments to increase the quality and quantity of olive fruits and oil yields under the condition of salinity

Authors' contributions

EAEG contributed to the design and performance of the experiment and also to the data analysis, writing of the manuscript, and following up the publication with the journal (correspondence). NAA contributed to the design and performance of the experiment and also to the data analysis and writing of the manuscript. HSAH contributed to the design and performance of the experiment and also to the data analysis and writing of the manuscript. AMH contributed to the design and performance of the experiment and also to the data analysis and writing of the manuscript. LFH contributed to the design and performance of the experiment and also to the data analysis and writing of the manuscript. All authors read and approved the final version.

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