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Enhancement Picual Olive Trees Productivity by Using Potassium Citrate with Gibberellic Acid

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ABSTRACT

This experiment was carried out during 2018 and 2019 seasons on 38 years old Picual olive trees which planted in a private orchard located at El Khatatbah district, El Monufia governorate, Egypt; and that in order to study the spraying effect of the Potassium citrate ($K_3C_6H_5O_7$) and Gibberellic acids – GA_3 ($C_{19}H_{22}O_6$) on the olive fruit quality, yield, oil content and its leaves mineral content. Olive trees were sprayed twice a year, once in February and the other in May, at two concentrations of each, 1 – 2 % of Potassium citrate and 10 – 20 ppm of GA_3. Generally, spraying both compounds, regardless the concentration, on olive trees recorded a significant effect on all studied parameters in this study. But the most important thing that can be noticed from the results obtained, is that the use of the highest concentration of Gibberellic acid had the strongest significant effect on increasing the yield of trees, while the use of the same concentration combined with the highest concentration of potassium citrate had the highest effect in increasing the oil accumulation percentage of the olive fruits.

Keywords: Picual, olive, Potassium, Gibberellic acid, yield, fruit quality, oil content.

1. Introduction

Olives (*Olea europaea* L.) is an old tree that has been cultivated in the Mediterranean region. Egypt is one of the North African countries where olive cultivation is widespread, as the cultivated area is about 250 thousand Feddans, producing about one million tons of olives annually, according to the statistics of the Egyptian Ministry of Agriculture (2019).

There are many various varieties of olives grown in Egypt, some of which are treasured for their edible flesh, some for the amount of oil they contain, and still others, like the Picual cultivar, which serve both edible and oil extraction functions. For assessing table olives, it's vital to consider the fruit's size, pulp, flesh texture, oil quantity, and chemical components. While the most crucial features of the oily cultivars are the ratio of oil and the bulb to seed, (Simoes *et al.*, 2002 and Morales-Sillero *et al.*, 2007). Picual olive cultivar has some production problems, especially in newly reclaimed soils, such as low productivity and poor fruit properties due to malnourishment in terms of doses and methods of application (Gowda *et al.*, 2011).

Potassium is an essential element in fruit trees. It is playing an important factor in osmotic and pressure regulator, so potassium plays an important role in cell enlargement, plant growth (Shabala, 2003). The effects of potassium on the yield, quality of fruits and the percentage of oil are due to potassium source, the method of addition, frequency of application, and rate of addition (El-rahman and Mohamed, 2016 and Shen *et al.*, 2016). Foliar spraying of potassium is considered one of the methods used to treat its deficiency, especially under conditions of irregular irrigation or drought (Elloumi *et al.*, 2009). Olive tree needs large amounts of potassium to improve the yield, the properties of the fruits and the percentage of oil (Sarrwy *et al.*, 2010 and Hegazi *et al.*, 2011).

Potassium citrate is a potassium salt of citric acid which considered one of the most important organic acids in the respiratory pathways into plant cell (Ibrahim *et al.*, 2015). Additionally, citric acid plays an important role in plant metabolism, it's as non-enzymatic antioxidant in chelating free radicals and protecting plant from injury could result in prolonging the shelf life of plant cells and improving

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growth characters (wang *et al.*, 2013). In this concern, Rania *et al.*, (2014) used a different potassium forms on mango, Potassium citrate included, most of the results praised the superiority of using potassium citrate over other potassium fertilizer sources, including the physical characteristics of fruits, yield and leaf content of elements.

Gibberellic acid (GA_3) is responsible for cell elongation, rather than cell division (Francis and Sorrell, 2001). Gibberellic acid treatments increase the weight, length, width of olive fruits, stone weight and flesh weight than untreated ones, (Rotundo and Gioffre, 1984), improvement fruit weight and flesh: seed ratio, (Ramezani and Shekafandeh, 2009; and Shabaq and Halala, 2014). On ten-year-old Shengeh olive trees, 0, 15, 30, and 45 ppm GA_3 and 0, 0.25, 0.50, and 0.75% $ZnSO_4$ in August were sprayed, it was found that the use of GA_3 as a growth regulator have complementary effects on fruit characteristics in terms of fruit weight and fruit oil percentage, (Ramezani *et al.,* 2010).

Through the previous studies that were presented, it is clear the positive effect of using each of the potassium fertilizers, especially Potassium citrate, as well as Gibberellic acid on the productivity of fruit trees, and from here the aim of this research dealing with study the effect of both compounds on the productivity and fruits' quality of the Picual olive trees, in the hope of reducing the bad effects that afflicted the olive crop due to climatic changes in the Mediterranean region.

2. Materials and Methods

2.1. Plant material

This study was conducted on 38-year-old Picual olive trees in the El Khatatbah region of El Monufia governorate, Egypt, during the 2018 and 2019 growing seasons. The chosen trees were planted at a spacing of 6×6 meters in sandy soil with drip watering system, and they were almost identical in size and vigour.

According to the Ministry of Agriculture and Land Reclamation's advice, the experimental trees got the same cultural practices appropriate for the trees' age and the local climate.

2.2. Treatments

Foliar applications of water (control), Gibberellic acids – GA_3 ($C_{19}H_{22}O_6$) at 10 and 20 ppm, Potassium citrate ($K_3C_6H_5O_7$) at 1 and 2 %, was sprayed each twice a year, once in February and once in May. Seven treatments were arranged in three replicates on one tree plot as follows:

1- (Control): Water sprays only.
2- (P1): Potassium citrate at 1%.
3- (P2): Potassium citrate at 2%.
4- (G1): GA_3 at 10 ppm.
5- (G2): GA_3 at 20 ppm.
6- (P1 + G1): Potassium citrate at 1% + GA_3 at 10 ppm.
7- (P2 + G2): Potassium citrate at 2% + GA_3 at 20 ppm.

2.3. Measurements

During November (harvest time), olive trees of the experiment were separately harvested, the following measurements were carried as follows:

2.3.1. Yield and fruit characteristics

Fruits of each replicate (tree) were separately harvested, weighed and yield as kg/tree was determined, then samples of 60 fruits from the sprayed trees (20 fruits from each replicate tree) were picked randomly around the tree to determine the following parameters: Average fruit weight (g), fruit length (cm), fruit diameter (cm), fruit shape index, fresh and dry flesh weight (g), and flesh moisture (%) as described by AOAC (2000).

2.3.2. Sex ratio

All developed inflorescences (panicles) on one-year-old shoots were assigned before the onset of flowering (at full bloom) to record the total number of flowers, perfect and male flowers /inflorescence. In addition, sex ratio was calculated as the percentage of perfect flowers to total flowers according to Rallo and Fernandez-Escobar (1985).

2.3.3. Oil percentage

Oil percentage in dried flesh were measured means of Soxhalt extraction apparatus using hexane at 60-80° boiling point, (Banat *et al.,*2013).

2.3.4. Leaf mineral content

Leaf samples were picked from each replicate tree then washed and dried at 70ºC till a constant weight to determine nitrogen (N), phosphorus (P), and potassium (K) as percentage of dry weight basis as the method described by Cottenie *et al.* (1982).

2.4. Statistical Analysis:

The experimental layout was a randomized complete block design (RCBD). The obtained data were subjected to analysis of variance (ANOVA) according to Snedecor and Cochran (1980) using COSTAT software (Alessandro and Guy, 2013).

3. Results

3.1. Fruit characteristics

Results of Table (1) showed the effect of Potassium citrate and GA_3 on fruit characteristics of olive fruits; considering fruit weight, the significant heaviest fruit weights (51.37 and 49.52 g) were recorded with Potassium citrate 2% (P2) at the first season and with potassium citrate 1% (P1) at the second one, respectively without significant difference between them. However, the lightest significant weights (40.29 and 35.06g) were weighted with control treatment at both seasons, successively.

Similarly, the significant tallest fruits (2.50 and 2.87 cm) were measured with P2 at the first season and with GA_3 20 ppm (G2) at the second season, sequentially. Whereas, the shortest significant fruits values (2.32 and 1.74 cm) were measured with P2+G2 treatment at the first season with no significance with control, but with P2 at the second one, by order.

Regarding fruit diameter, P2 at the first season but P1 at the second season scored the highest fruits diameter (2.057 and 1.963 cm), while the control and G2 treatments in the first and the second seasons had recorded the lowest diameter (1.787 and 1.777 cm), respectively.

Following the fruit shape index indicated that, the highest value (1.307) at the first season was measured with the control, but (1.323) at the second season with P2+G2. However, the lowest value (1.220) at the first season was recorded with P2, whereas (1.240) at the second season was recorded with P1.

Table 1: Effect of Potassium citrate and GA_3 on fruit characteristics of Picual olive trees in 2018 and 2019 seasons

Treatments	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)		Fruit shape index	
	2018	2019	2018	2019	2018	2019	2018	2019
Control	40.29 C	35.06 E	2.33 D	2.27 A	1.787 C	1.788 F	1.307 A	1.273 E
***P1**	48.42 A	49.52 A	2.44 B	2.43 A	1.923 B	1.963 A	1.270 AB	1.240 G
P2	51.37 A	45.06 BC	2.50 A	1.74 B	2.057 A	1.867 C	1.220 B	1.290 C
G1	44.81 B	47.34 AB	2.41 BC	2.39 A	1.900 BC	1.900 B	1.273 AB	1.260 F
G2	43.83 B	37.48 D	2.37 CD	2.87 A	1.880 BC	1.777 G	1.260 AB	1.277 D
P1 + G1	42.30 BC	45.43 BC	2.33 D	2.39 A	1.817 BC	1.857 D	1.280 A	1.293 B
P2 + G2	42.07 BC	43.52 C	2.32 D	2.41 A	1.810 BC	1.840 E	1.283 A	1.323 A

*P1: Potassium citrate 1% P2: Potassium citrate 2% G1: GA_3 10ppm G2: GA_3 20ppm

Table 1: Cont.

Treatments	Flesh weight (g)		Flesh dry weight (g)		Flesh moisture (%)	
	2018	2019	2018	2019	2018	2019
Control	30.37 E	28.18 C	8.22 B	8.10 C	74.98 AB	71.28 D
***P1**	37.28 AB	38.68 A	10.03 A	9.84 A	73.09 BC	74.58 C
P2	40.27 A	38.17 A	9.97 A	9.32 AB	75.09 AB	75.60 C
G1	36.07 BC	37.53 A	8.58 B	8.61 BC	76.14 A	76.98 AB
G2	33.23 CDE	35.49 B	8.65 B	8.22 C	73.99 AB	75.90 BC
P1 + G1	35.74 BCD	38.21 A	8.58 B	8.57 BC	75.48 AB	77.49 A
P2 + G2	32.58 DE	34.14 B	9.54 A	9.77 A	70.75 C	71.38 D

*P1: Potassium citrate 1% P2: Potassium citrate 2% G1: GA_3 10ppm G2: GA_3 20ppm

As for flesh weight, the highest significant values (40.27 and 38.68 g) were weighed with P2 at the first season and with P1 at the second one, by order. While, the lightest significant weights (30.37 and 28.18 g) were weighed with the control at both seasons, sequentially.

Considering flesh dry weight, results evidenced that P1 had increased it to the highest significant values (10.03 and 9.84 g) at both seasons, by order; whereas the control treatment recorded the lightest significant weights (8.22 and 8.10 g) at the two experimental seasons, respectively.

Concerning flesh moisture, the highest values (76.14 and 77.49 %) were measured in G1 at the first season and in P1+G1 at the second season, by order. However, the least values (70.75 and 71.28 %) were detected in P2+G2 at the first season and in control at the second season, successively.

3.2. Inflorescence sex ratio, yield and oil percentage

Table (2) claimed that, the maximum significant sex ratios (84.67 and 75.67 %) were calculated with G2 treatment at the first season and with P1 at the second one, by order. However, the minimum significant ratios (43.33 and 27.33 %) were recorded with G1 at the first season, while with P2+G2 at the second one, sequentially.

Table 2: Effect of Potassium citrate and GA_3 on flowers sex ratio, yield and fruits oil content of Picual olive trees in 2018 and 2019 seasons

Treatments	Sex ratio (%)		Yield (Kg/ tree)		Oil (%)	
	2018	2019	2018	2019	2018	2019
Control	60.33 BC	39.67 C	51.52 D	48.48 D	13.77 D	14.43 D
***P1**	71.00 B	75.67 A	80.75 AB	80.73 Ab	15.33 B	14.87 CD
P2	49.67 CD	22.67 E	70.67 C	78.99 B	16.67 A	16.47 B
G1	43.33 D	29.67 D	66.67 C	72.59 C	14.63 C	15.07 CD
G2	84.67 A	62.67 B	84.09 A	84.00 A	14.37 C	15.17 C
P1 + G1	59.67 C	19.67 F	80.73 AB	82.41 AB	15.77 B	16.40 B
P2 + G2	57.00 C	27.33 D	77.36 B	78.88 B	16.93 A	17.10 A

*P1: Potassium citrate 1% P2: Potassium citrate 2% G1: GA_3 10ppm G2: GA_3 20ppm

As for trees yield, the biggest significant values (84.09 and 84.00 kg/ tree) were yielded with G2 at both seasons, by order, whereas the less significant values were reached by control (51.52 and 48.48 kg/ tree) at the two seasons, successively.

Concerning oil content, the highest values (16.93 and 17.10 %) were measured in P2+G2 samples at both seasons, respectively. Whereas, the lowest values (13.77 and 14.43 %) were detected in control samples at both studied seasons, by order.

3.3. Leaf mineral content

Results tabulated in Table (3) clear that; the highest significant N values (1.902 and 1.857 %) were measured with P2+G2 at the first season, meanwhile with P1+G1 at the second season. However, the lowest significant N values (1.681 and 1.637 %) were recorded in control samples in the two seasons, successively.

Regarding P content, the highest significant values (0.142 and 0.144 %) were measured in G2 samples at the first season and with P1 treatment at the second season, respectively. Whereas, the lowest values (0.119 and 0.120 %) were found in the control samples at both seasons, by order.

Considering K content, the highest significant values (2.171 and 2.137 %) were detected in P2+G2 samples at the first season, but with P2 treatment at the second season, successively. While the least significant values (1.660 and 1.667 %) were recorded in the control samples at the two seasons, sequentially.

Table 3: Effect of Potassium citrate and GA_3 on leaves mineral content of Picual olive trees in 2018 and 2019 seasons

Treatments	N (%)		P (%)		K (%)	
	2018	2019	2018	2019	2018	2019
Control	1.681 D	1.637 C	0.119 D	0.120 F	1.660 F	1.667 D
***P1**	1.790 C	1.797 B	0.135 C	0.144 A	1.911 C	1.880 C
P2	1.810 BC	1.793 B	0.136 BC	0.127 E	2.032 B	2.137 A
G1	1.861 AB	1.780 B	0.134 C	0.133 D	1.791 D	1.677 D
G2	1.820 BC	1.783 B	0.142 A	0.139 B	1.720 E	1.687 D
P1 + G1	1.800 C	1.857 A	0.137 B	0.131 D	1.871 C	1.870 C
P2 + G2	1.902 A	1.803 AB	0.134 C	0.135 C	2.171 A	2.010 B

*P1: Potassium citrate 1% P2: Potassium citrate 2% G1: GA_3 10ppm G2: GA_3 20ppm

4. Discussion

It was clear from the obtained results that potassium citrate treatments separately had the highest effect in improving the characteristics of the fruit as fruit weight, flesh weight, as well as the percentage of dry matter in flesh compared to the control. On the other hand, gibberellic treatments, whether alone or with potassium citrate, were the most influential treatments on the shape of the fruit, as well as the fruit moisture content. The results obtained are consistent with those reported by Gowda *et al.,* (2022); Sarrwy *et al.,* (2010); Hussein (2008); Arquero *et al.,* (2006); Abdel-Nasser and EL-Shazly (2001). The positive effects of potassium citrate on the photosynthesis process, as well as the osmotic effect of potassium salts in transferring the compounds manufactured in the leaves to the fruits, have been acknowledged by Taiz and Zeiger (2002). On the other hand, citric acid plays a significant role in the process of respiration and the synthesis of an energy compound (ATP) has a positive impact on the weight of the fruit as well as the flesh and dry weight. On the other hand, Pharis and King (1995) reported that the role of GA_3 in improving the fruit as fruit diameter may be due to its role in increasing cell elongation. Our results are agree with that obtained by Ramezani and Shekafandeh, 2009; Ramezani *et al.,* 2010; and Shabaq and Halala, 2014.

The results showed a difference in the effect of treatments on the sex ratio of trees during the two seasons, where the GA_3 at 20 ppm were the highest in the sex ratio during the first season, except that, the treatment with potassium citrate at 1% was significantly higher in the second season. Potassium plays an important role in improving flowering properties as a result of increasing the ability to absorb carbon dioxide, as well as improving the photosynthesis rate of olive trees (Erel *et al.,* 2014 and Erel *et al.,* 2015). In addition, sufficient levels of potassium increase the level of starch stored in olive trees (Erel *et al.,* 2014). This result is agreed with studies carried by Gowda *et al.,* (2022). Sex ratio was significantly affected by different times and concentrations of GA_3 (Abd El-Naby *et al.,* 2012). The average percentage of perfect flowers increased when GA_3 was sprayed on olive trees at various doses and times, although the percentage of opened flower buds per shoot and the number of flowers per inflorescence decreased, (El-Iraqy, 2001 and El-Sharkawy, 1999). Gowda *et al.,* (2022) reported that fruit moisture of Picual olive trees treated with K- forms were significantly affected and the differences among treatments were significant in both seasons.

Results cleared that GA_3 at 20 ppm or potassium citrate at 1% recorded the highest yield of the trees in both seasons. Gowda *et al.,* (2022) reported that treating olive trees cultivar Picual with different sources of potassium, including potassium citrate, led to an increase in the yield of the tree compared to the control, due to the increase in the weight of the fruit. These results are agreed with that obtained by Hegazi *et al.*, (2011). Additionally, the role citric acid plays in respiration and the synthesis of an energy compound (ATP), as well as the positive effects of potassium citrate on the photosynthesis process and the osmotic effect of potassium in transferring nutrients to the fruits, all have a positive impact on the weight of the fruit as well as the flesh and dry weight (Taiz, and Zeiger, 2002). However, as compared to other treatments, spraying olive trees with (GA_3 100 $mg.l^{-1}$ + NAA 100 $mg.l^{-1}$) greatly enhanced the yield of both seasons, while the control produced a lower yield. (Shabaq and Halala, 2014; and Abdrabboh, 2013). On the contrary spraying olive trees with GA_3 significantly reduced yield per tree, (Abd El-Naby *et al.,* 2012).

The data presented that the higher percentage of oil was obtained by mix GA_3 at 20 ppm with potassium citrate 2% in two seasons. According to Gowda *et al.,* (2022), potassium sources applied as foliar application, significantly affected fruit oil content and the highest content was in that trees treated with potassium citrate at 3 %. These comments agree with the findings of Hegazi *et al.*, (2011), Sarrwy *et al.,* (2010) concluded that foliar spraying with 3 % potassium nitrate increases fruit oil content of olive trees. On the other hand, Ramezani *et al.,* (2010) decided that spraying GA_3 significantly increased total fruit oil per tree increases as a result of increasing oil percentage and fruit weight of Shengeh olive trees.

According to the leaves' content of the elements, the results showed a high content of the leaves nitrogen and potassium was found at the mixing treatments between potassium citrate and Gibberellic acid as well as potassium citrate separately compared to the control. As for the phosphorous content of the leaves, the Gibberellin 20 treatment was the highest in the first season and the potassium citrate 1% treatment in the second season. Gowda *et al.*, (2022) established the effect of K forms on leaf N, P and K contents of Picual olive trees. Since, Leaf nitrogen and potassium content was significantly affected with foliar application of various potassium sources in both, while leaf phosphorus content was not affected. Also, Hegazi *et al.* (2011) was agreement with the results obtained at this study. On the other hand, Al-Rawi *et al*. (2016) on peach trees reported that GA_3 spray significantly increased and gave the highest leaf nitrogen content and the highest leaf potassium content.

4. Conclusion

Through this study, it was found that the use of any of the treatments under study had a significant positive effect on the yield of fruits, and this was represented in the physical properties of the fruits, as well as the percentage of oil inside the fruits and the content of the leaves of nutrients.
As shown in Fig. (1), we find that the treatments that led to a high increase in the yield were accompanied by a slight decrease in the oil content of the fruits, and the treatments that led to a significant increase in the yield maintained at the same time a higher oil content of the fruits than the control trees.

When calculating the percentages of crop increase resulting from the different treatments, we find that it ranges between 40 and 68%, compared to the untreated trees (control), and this increase is significant compared to the prices and quantities of fertilizers used in the process of spraying trees, which is positively reflected on the income of olive farmers to meet the general shortage of most crops resulting from climate changes, which in turn also affected most olive growers in the Mediterranean region, which led to a decrease in olive productivity globally.

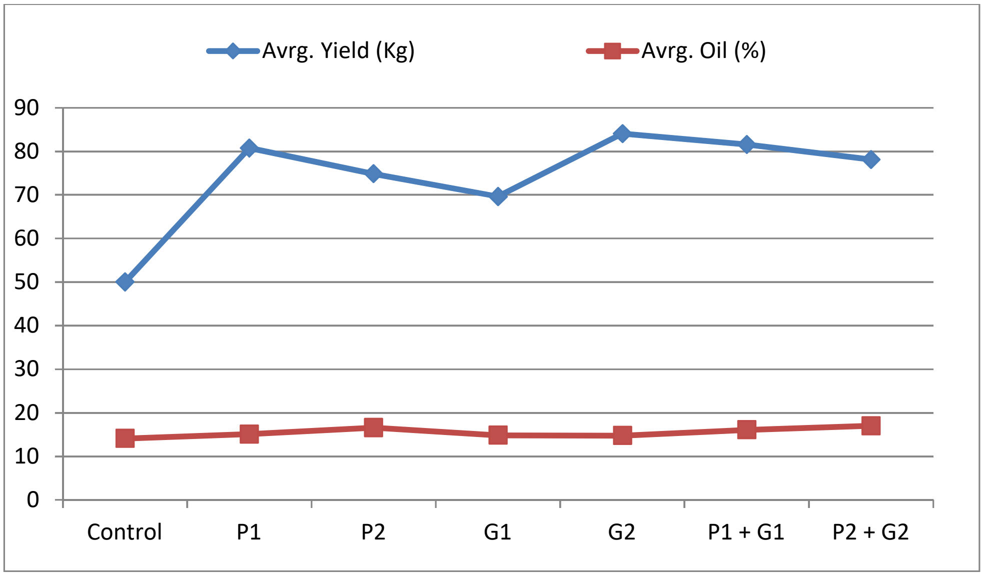

Fig. 1: Average olive yield (Kg/ tree) and fruit oil content (%) calculated during 2018 and 2019 seasons

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