Effect of Foliar Spraying with Different Sources of Potassium on Growth, Leaf Mineral Composition, Yield and Fruit quality of Picual Olive Trees.

Adel M. Gowda and Hassan A. M. Ali and Tarek Kh. El-Bolok

Horticulture Department, Faculty of Agriculture, Beni-Suef University, Beni Suef, Egypt.

Arid and Semi-Arid Zones and Olive Research Department, Horticulture Research Institute, Agriculture Research Center Giza, Egypt.

Introduction

Olives (Olea europaea L.) belongs to the family (Oleaceae) and is an old tree that has been cultivated for decades in the Mediterranean region producing more than 90% of the world production. The total acreage of olive in Egypt reached about 245142 feds. during the 2019 season producing about 981451 tons with an average of 4.7 tons / feddan according to the Ministry of Agriculture and Land Reclamation 2019. Olives comprise many cultivars that are used for both pickling and oil extraction. Olive fruits are commercially valuable for their edible flesh and their oil content. Fruit size, pulp to stone ratio, flesh texture, oil content and chemical composition are important features for evaluating table olives. Olive oil is an important source for fatty acids, vitamins and antioxidants. Its quality is evaluated according to flavor, color and aroma in addition to its chemical characteristics. Importance of olive oil is due to its beneficial effects on human health, dedicated primarily to the high content of monounsaturated fatty acids, such as oleic acid in addition to lower content of linoleic acid linoleic acid, improving the stability of oil oxidation (Simoes et al., 2002 and Morales-Sillero et al., 2007). Fruit components are formed during the growth and ripening and are influenced by cultivar, climate and horticultural practices as, fertilization (Thanaa Mahmoud et al., 2017).

Picual olive cultivar is one of the olive cvs. grown in Egypt and is used as oil and table olives, it has some production problems, especially in newly reclaimed soils, such as low productivity and poor fruit properties due to malnutrition in terms of doses and methods of application.
Mineral nutrition is one of the main tools for improving fruit yield and quality (Tagliavini and Marangoni, 2002). It is well known that spraying fruit trees with nutrients improved vegetative growth, flowering and correction of deficiency symptoms reflects on the quality of the fruits (Josan et al., 1995 and Dalal et al., 2017).

Potassium is an essential element in fruit trees because it is a mineral osmosis plays an important factor in osmotic and pressure regulator, so potassium plays an important role in cell enlargement, plant growth and finally the opening and closing of leaf stomata (Shabala, 2003). When irrigation water is scarce or in areas of low rainfall, foliar spraying of potassium is important to compensate for the lack of potassium absorption by roots from the soil (Elloumi et al., 2009). Potassium activates enzymes for photosynthetic, protein synthesis, oxidative metabolism and electrical charge balancing of plant cell membranes (Shabala, 2003). It is well known that Potassium has a positive effect on flowering (Fabbri and Benelli, 2000) and promotes the formation of amino acids that stimulate the formation of Indole Acetic Acid oxidase (IAA) which stimulates the induction of flowering (Gonzalez-Garcia et al., 1972 and Mazuelos et al., 1983). Potassium has an important role in the yield and quality of olives in addition to, it’s easy absorption and distribution through leaf tissues which improved growth (Arquero, et al., 2006). Using potassium nitrate as the foliar application has a positive effects on the growth, yield and fruit quality of olives (Gonzalez-Garcia et al., 1972 and Mazuelos et al., 1983). Olives are one of the fruit trees that require high amounts of potassium, their fruits are rich in potassium (Fernandez-Escobar, et al., 2004 and Hegazi et al.,2011) reported that foliar application of potassium nitrate on Picual olive trees, improved vegetative growth, nutritional status, yield, fruit quality and flesh oil content. Beneficial effects of potassium on growth, productivity and fruit quality are due to its vital role in stimulating cell division and elongation as well as biosynthesis and transport of organic compounds that promote tree growth and fruiting (Nijjar, 1985).

The effects of different potassium sources on yield and fruit quality of fruit trees varied according to methods, frequency of application and rates in addition to fruit species and phenological stages (Awad et al., 2014, El-rahman & Mohamed, Egypt. J. Hort. Vol. 49, No. 1 (2022) 2016 and Shen et al., 2016 ) However, there are no previous reports that compared effects of varies sources of potassium applied on different phenological stages to olives. Therefore, the current study was conducted to find out the effect of foliar applications of various potassium sources on the growth, yield and quality of fruits of Picual olive trees grown under the Western desert Minia Governorate conditions.

Materials and Methods

This study was conducted during two successive seasons 2018/2019 and 2019/2020 in a private orchard located 182 km. south of Cairo on the Western Desert Road in Minia Governorate, Egypt, trees used for the current investigation were on a 12 - years old olive trees cv. Picual. They were planted at 5 x 5 meters, in sandy soil and irrigated with a drip irrigation system (four dippers/tree). Well water of 2700 ppm was used for irrigation.

Experimental trees were selected at the beginning of the first season after harvesting in October 2018 to carried out the treatments during the two seasons. The selected trees were to be nearly uniform, in growth vigor, free from pathological and physiological disorders and all received the same farm management ( irrigation, weed, pests and disease control usually applied in the orchard except for the foliar application of potassium sources). The experiment was set in a complete randomized block design with three replicates, one tree each. Four sources of potassium K were used as foliar application at two application rates of 1.5 and 3 % each. Spraying was carried out three times immediately after harvesting (October), after the final fruit set (May) and after hardening of the pit (first week of August).

Treatments (T)

T1: Control ( spraying trees with water).
T2: Spraying trees with potassium sulphate K₂SO₄ at 1.5 %.
T3: Spraying trees with potassium sulphate K₂SO₄ at 3 %.
T4: Spraying trees with potassium nitrate KNO₃ at 1.5 %.
T5: Spraying trees with potassium nitrate KNO₃ at 3 %.
T6: Spraying trees with potassium citrate K₃C₆H₅O₇ at 1.5 %.
T7: Spraying trees with potassium citrate K₃C₆H₅O₇ at 3 %.
TABLE 1. Some physical and chemical properties of soil samples in the experimental orchard.

| Character                          | value  | Character                          | value  |
|------------------------------------|--------|------------------------------------|--------|
| Particle size distribution %       |        | EC (mm/cm)                         | 5.2    |
| Clay                               | 8.2    | pH                                 | 7.9    |
| Silt                               | 6.6    | organic matter %                   | 0.66   |
| Sand                               | 85.2   | CaCo3                              | 11.4   |
| Texture                            | sandy  | Soluble anions mq/100g soil        |        |
| Soluble cations mq/100g soil       |        | Co3                                | --     |
| Ca^{2+}                            | 0.43   | Hco3                               | 0.81   |
| Mg^{2+}                            | 0.19   | Cl                                 | 0.55   |
| Na^{+}                             | 0.20   | So4                                | 0.19   |
| K^{+}                              | 0.10   | Available micronutrients ppm       |        |
| Available macronutrients %         |        | Fe                                 | 1.02   |
| N                                  | 0.46   | Zn                                 | 1.10   |
| P                                  | 0.13   | Mn                                 | 1.59   |
| K                                  | 0.39   |                                    |        |

T8: Spraying trees with monopotassium phosphate KH$_2$PO$_4$ at 1.5 %.
T9: Spraying trees with monopotassium phosphate KH$_2$PO$_4$ at 3 %.

In early March of each study season, twenty shoots (one year old) were randomly selected and labelled, five shoots in each direction for the following measurement:

**Vegetative growth**

The following characteristics were measured at the end of each growing season during the first week of September:

- Shoots lengths (cm).
- Number of new shoots /twig
- Number of leaves /shoot
- Leaf area (cm$^2$) according to the following equilibration = 0.53 (length x width) $^{1/6}$.

(Ahmed and Morsy, 1999)

**Leaf mineral composition:**

At the end of each growing season during the first week of September of each season, leaf samples were taken from the middle of the shoot (Piper, 1950), washed and dried at 70°C to constant weight. The finely ground sample as the known weight of the dry weight of leaves was digested for determination of the nitrogen, potassium and phosphorus in percentage using an acid mixture consisting of perchloric and sulfuric acids in the ratio of 4:1 (v/v) as follows:

Nitrogen was determined by the Microkjeldahl method (Pregl, 1945).

Phosphorous was estimated by the method of Murphy and Riely (1962).

Potassium was determined by flame-photometer according to Brown and Lilleland (1946).

**Flowering characteristics**

Inflorescence length (cm): was estimated as the average of thirty inflorescences for each replicate.

Flowering Density (as the number of inflorescences per meter): the average number of inflorescences per shoot was recorded and calculated per meter.

Flowering density = No. of inflorescences X 100/shoot length (cm)

Total number of flowers /inflorescence: A sample of twenty inflorescences for each tree was used and the total number of flowers for each inflorescence was counted.

Percentage of perfect flowers / inflorescence: Twenty inflorescences from each tree were collected from the middle parts of shoots in the ballon stage. The number of perfect and total flowers on each inflorescence were recorded and % of perfect flowers was calculated (Mofeed, 2002).

The perfect flowers (%) = No. of perfect flowers/ No. of total flowers x 100

**Sex ratio**

The ratio of perfect flowers to male flowers was calculated for every replicate (El-Sharony, 2007).
Fruit set and yield

Fruit set Percentage: the percentage of the initial fruit set was calculated after 21 days from full bloom and the final fruit set percentage was calculated after 60 days from full bloom (Mofeed, 2002).

\[
\text{Fruit set} \,(\%) = \frac{\text{No. of fruits}}{\text{No. of total flowers}} \times 100
\]

Yield

Average yield per tree was calculated from each treatment as Kg/tree.

Fruit quality

Fifty fruits per tree were randomly harvested and used to determine the following physical characteristics: Fruit Dimensions (Fruit Length(cm), Fruit Diameter (cm) and Fruit Shape (L/D) - Fruit weight (g) – flesh weight and seed weight (g) – flesh / fruit weight ratio – fruit moisture content % according to A.O.A.C 1995.

\[
\text{Flesh/fruit weight} \,(\%) = \frac{\text{Flesh weight (g)}}{\text{Fruit weight}} \times 100
\]

Fruit oil content (%) as a dry weight was determined according to A.O.A.C. (1995) method by extracting the oil from the dried fruits with Soxhlet apparatus using petroleum ether at 60-80°C of boiling point.

Statistical Analysis

The obtained data were subjected to analysis of variance (ANOVA) using the MSTAT program according to (Snedecor and Cochran 1982). Differences between treatments were compared according to Duncan 1955 at a probability of 5%.

Results and Discussion

Vegetative growth measurements

Data in Table (2) show the effect of foliar applications of some potassium salts namely; potassium sulphate, potassium nitrate, potassium citrate and mono potassium phosphate on some growth parameters such as, shoot length, number of new laterals /shoot, number of leaves per shoot and leaf area of Picual olive trees in the 2018/2019 and 2019/2020 seasons. Compared with control, treated trees attained higher values of tested parameters. Highest values were recorded by foliar application of KNO₃ at 3% in both seasons. Hence, the highest values of shoot length (30.97 and 35.12 cm), number of new laterals /shoot (8.87 and 10.30), number of leaves/shoot (34.23 and 36.30) and leaf area (5.50 and 5.70 cm²) were obtained by trees that were sprayed potassium nitrate (KNO₃) at 3% in both seasons, respectively. Trees sprayed with potassium citrate and mono- potassium phosphate followed in this respect. The lowest values were recorded by the control trees. This increase in the resulting growth parameters can enhance the ability of the leaf photosynthetic capacity, as mentioned by Bongi and Palliotti (1994), which results in more assimilates for fruit growth. The promotion of vegetative growth of Picual olive trees can be

| Treatments                      | (Shoot length (cm) 2018/2019) | Number of new laterals /shoot 2018/2019 | Number of leaves /shoot 2018/2019 | Leaf area (cm²) 2018/2019 |
|--------------------------------|-------------------------------|----------------------------------------|----------------------------------|--------------------------|
| Control                        | 25.30 E                       | D 4.93                                 | F 20.87                          | 4.10 E                   |
| % K- sulphate at 1.5           | E 26.13                       | BC 8.83                                | DE 23.60                         | 5.00 BCD                 |
| K- sulphate at 3%              | D 27.25                       | ABC 7.87                               | B 33.00                          | 5.23 AB                  |
| % K- nitrate at 1.5            | CD 28.19                      | AB 8.20                                | C 28.17                          | 5.33 ABC                 |
| K- nitrate at 3%               | A 30.97                       | A 35.12                                | A 34.23                          | 5.50 A                   |
| K- citrate at 1.5 %            | D 27.34                       | BC 6.97                                | C 34.81                          | 4.70 D                   |
| K- citrate at 3 %              | B 29.77                       | AB 34.81                               | B 28.60                          | 5.30 ABC                 |
| Mono K- phosphate at 1.5%      | CD 28.11                      | D 33.15                                | EF 20.60                         | 4.00 CD                  |
| Mono K- phosphate at 3%        | BC 29.00                      | BC 34.11                               | ABC 7.24                         | 4.90 BC                  |

Values within each column followed by different letters are significant at p < 0.05 according to Duncan’s multiple range tests.

Egypt. J. Hort. Vol. 49, No. 1 (2022)
attributed to the physiological role of potassium in carbohydrate formation which is translocation and accumulation within the plant organs and the turgor pressure of plant cells. (Meyer and Anderson, 1970). Potassium also contributes to the growth of meristematic cells, cell enlargement and the stimulation of the young tissue (Mengel and Kirkby, 1987). In addition to the synergistic affect between K and indole acetic acid (IAA) and the enhancement of K on the effect of gibberellic acid and cytokinins on plant growth Cocucci, and Rosa, 1980. The effect of K in increasing the growth of the olive tree was confirmed by Hussein (2008), Hegazi et al. (2011), Gowda et al. (2011) and Thanaa Mahmoud et al. (2017).

Leaf mineral composition
The results presented in Table (3) demonstrate the effect of K – forms on leaf N, P and K contents of Picual olive trees during the two seasons of study. Leaf nitrogen content was significantly affected with foliar application of various potassium sources in both studied seasons. Trees that were sprayed with potassium nitrate at 3 % had significantly the highest N content in leaves (1.157 and 1.260 %) in both seasons. Regarding leaf potassium content, results show significant effects for potassium foliar applications on leaf potassium content. The highest percentage of potassium in leaves was in trees sprayed with potassium nitrate at 3 % (0.760 and 0.753 ) in 2018/2019 and 2019/2020 seasons, respectively. Leaf phosphorus content wasn’t significant in both seasons by conducted treatments. The lowest values of leaf N and K contents were recorded by control trees in both seasons. These results are following with the results by Dikmelik et al. (1999) and Hegazi et al. (2011) on olives Also, Calvert (1969) and El-Darier (1991), suggested that spraying KNO₃ or K₂SO₄ is more effective in increasing potassium content of leaves in Balady Mandarin. In addition to Sarrwy et al. (2012) reported the highest K leaf content in Balady mandarin trees sprayed with KNO₃.

Flowering characteristics
Table (4) shows the effect of the studied treatments on the flowering characteristics of Picual olive trees in the 2018/2019 and 2019/2020 seasons. Significant variations were observed among all evaluated treatments. As a general trend, trees sprayed with any of the potassium treatments had a more pronounced effect than control with respect to the studied flowering parameters.

Regarding the length of inflorescences, data in Table (4) reveal that trees treated with foliar potassium nitrate at 3 % showed the longest of inflorescences (2.81 and 2.88 cm) followed by the potassium citrate treatment(2.76 and 2.83 cm) in both studied seasons, respectively with insignificant differences. Control trees showed the lowest values in this respect. Concerning

### Table 3 . Effect of foliar application with various potassium sources on leaf mineral composition (nitrogen, phosphorus and potassium) of Picual olive trees in 2018/2019 and 2019/2020 seasons.

| Treatments        | N % 2018/2019 | % 2018/2019 | % 2019/2020 | K % 2018/2019 | % 2019/2020 |
|-------------------|--------------|-------------|-------------|--------------|-------------|
| Control           | E 0.613      | C 0.737     | A 0.30      | 0.34A        | DE 0.603    | D 0.637     |
| % K- sulphate at 1.5 | D 0.887      | BC 0.803    | A 0.32      | 0.35A        | BC 0.667    | CD 0.660    |
| K- sulphate at 3% | B 1.027      | 1.137ABC    | A 0.34      | 0.37ABC      | ABC 0.70    | 0.72ABC     |
| % K- nitrate at 1.5 | AB 1.067     | AB 1.183    | 0.31A       | 0.34A        | CD 0.653    | 0.68BCD     |
| K- nitrate at 3%  | A 1.157      | A 1.260     | A 0.31      | A 0.37       | A 0.760     | 0.753A      |
| K- citrate at 1.5 % | D 0.833      | 1.10ABC     | 0.32A       | 0.34E        | 0.570       | 0.69ABC     |
| K- citrate at 3 % | BC 1.010     | A 1.254     | 0.33A       | 0.38A        | CD 0.660    | AB 0.727    |
| Mono K- phosphate at 1.5% | D 0.897 | 0.98ABC | 0.31A | 0.36A | CD 0.653 | D 0.637 |
| Mono K- phosphate at 3% | CD 0.923 | 1.14ABC | 0.36A | 0.39A | AB 0.727 | 0.717ABC |

Values within each column followed by different letters are significant at p < 0.05 according to Duncan’s multiple range tests.
the flowering density, the highest values were attained by trees treated with mono- potassium phosphate at 3 % (57.45 and 59.54) followed by trees applied with potassium nitrate at 3 % (54.05 and 57.63) with significant differences. Control trees had the lowest values (44.15 and 45.73) in 2018/2019 and 2019/2020 seasons, respectively.

As for the total number of flowers / inflorescences, Table (4) show also that in general K- sources application significantly increased the number of total flowers/inflorescences in both seasons compared with control trees. Whereas the highest number of total flowers / inflorescences of 13.58 and 14.87 were recorded with foliar application of mono potassium phosphate at 3 % in 2018/2019 and 2019/2020 seasons, respectively. The least value was attained by trees treated with mono- potassium phosphate at 3 % (57.45 and 59.54) followed by potassium nitrate at 3 % giving the highest perfect flower percentages (55.46 and 60.41) in comparison with the untreated trees which showed the lowest values in 2018/2019 and 2019/2020 seasons, respectively.

Concerning the perfect flowers percentage, data in Table (4) reveal that the perfect flowers percentage amounting to (11.98 and 12.61 & 0.71 & 0.82E respectively) was significantly increased with all K- forms foliar application in comparison with the untreated trees which showed the lowest values in both seasons. The trees treated with the potassium nitrate at 3 % gave the highest perfect flower percentages (55.46 and 60.41) followed by potassium citrate at 3 % (53.68 and 58.85) with insignificant differences. While the least value was detected in the control trees (45.98 and 46.77) in both seasons, respectively.

The effect of foliar spray treatments on the percentage of the sex expression ratio is illustrated in Table (4). It is observed that the trees treated with potassium nitrate at 3 % had the highest sex ratio of 2.93 and 3.94 % in the 2018/2019 and 2019/2020 seasons, respectively followed by trees treated with potassium citrate and monopotassium phosphate at 3% while the untreated trees gave the lowest values. The stimulation effect of the potassium nutrients caused an improvement in flowering parameters and photosynthesis which certainly reflected positively on both vegetative growth and flowering characteristics, and this effect may be attributed to the role of potassium which is important for carbon dioxide uptake and general photosynthetic capacity of olive trees (Erel et al., 2014 and Erel et al., 2015). Under higher K availability, higher levels of starch were found in growing olive trees (Erel et al., 2014). Fruit set and yield

Table (5) shows the effect of the K- sources foliar application treatments on fruit set and yield of Picual olive trees in the 2018/2019 and 2019/2020 seasons. Significant responses were among the studied treatments as compared with the control trees. Concerning initial and final percentage, presented data indicated that trees treated with potassium nitrate attained the highest percentages amounting to (11.98 and 12.61 & 0.71 & 0.82E & 3.94A & 3.21B respectively). Values within each column followed by different letters are significant at $p < 0.05$ according to Duncan’s multiple range tests.

**TABLE 4. Effect of foliar application with various potassium sources on some flowering parameters of Picual olive trees in 2018/2019 and 2019/2020 seasons.**

| Treatments          | Inflorescence | Length (cm) | Flowering density | Total Number of flowers/inflorescence | Perfect flowers (%) | Sex Ratio |
|---------------------|---------------|-------------|-------------------|--------------------------------------|---------------------|-----------|
| Control             |                |             |                   |                                      |                     |           |
| % K- sulphate at 1.5|               |             |                   |                                      |                     |           |
| K- sulphate at 3%   |               |             |                   |                                      |                     |           |
| % K- nitrate at 1.5 |               |             |                   |                                      |                     |           |
| K- nitrate at 3%    |               |             |                   |                                      |                     |           |
| K- citrate at 1.5%  |               |             |                   |                                      |                     |           |
| K- citrate at 3%    |               |             |                   |                                      |                     |           |
| Mono K- phosphate at 1.5% |           |             |                   |                                      |                     |           |
| Mono K- phosphate at 3% |            |             |                   |                                      |                     |           |

*Values within each column followed by different letters are significant at $p < 0.05$ according to Duncan’s multiple range tests.*

_Egypt. J. Hort. Vol. 49, No. 1 (2022)_
Our results may gain support from those obtained from the reactions inside the cell (Taiz, and Zeiger, 2002). Production is important (ATP synthesis) for all vital pathways of respiration and energy to increase fruit weight, or due to the role of potassium in photosynthesis and osmosis regulation, allowing the import of assimilates from the source into the fruits, which in turn leads to an increase in fruit weight as a result of potassium nitrate treatment at 1.5% with insignificant differences between them. Regarding yield (kg/tree) both potassium nitrate at 3% and potassium citrate at 3% resulted in significantly the highest yield was amounting to (18.11 and 29.92) and (17.72 and 29.47) respectively while the lowest yield was (14.08 and 23.91) for control trees in 2018/2019 & 2019/2020 seasons, respectively. The improvement in yield of Picual olive trees was associated with the increase in fruit weight as a result of applying potassium sources. The positive effect of the K- sources treatments on fruit set and yield was reported in the findings of Hegazi et al., 2011 and Amnon, et al., 2018/2019. Shen, et al., (2016) reported that a significant increase in pear yield was achieved by foliar application with the application of KNO3. In addition to the positive effect of potassium citrate is either due to the role of potassium in photosynthesis and osmosis regulation, allowing the import of the assimilates from the source into the fruits, which in turn leads to an increase in fruit weight, or due to the role of citric acid in pathways of respiration and energy production important (ATP synthesis) for all vital reactions inside the cell (Taiz, and Zeiger, 2002). Our results may gain support from those obtained by Arquero et al. (2006), Sarrwy et al. (2010), Hussein (2008), Abdel-Nasser and El-Shazly (2001), Amnon et al. (2018/2019) on olive trees. Moreover, (Vijay et al., 2017) found that foliar application of potassium nitrate and potassium sulphate significantly enhanced the yield of ‘Jaffa’ sweet oranges and potassium nitrate improved fruit yield of plum trees (Jawandha et al., 2017). On ‘Canino’ apricot trees, the yield was increased significantly with the application of potassium citrate (Haggag et al., 2016) and application of potassium nitrate and potassium citrate (Okba et al., 2021).

**Fruit quality**

**Fruit Dimensions (Fruit Length, Fruit Diameter and Fruit Shape)**

Data presented in Table (6) show the effect of spraying with various potassium sources on fruit length, fruit diameter and fruit shape ratio of Picual olive trees in 2018/2019 and 2019/2020 seasons. Significant variations were observed among the tested treatments as compared with control trees. It was observed that fruit length and diameter were significantly affected by different treatments in both seasons. K- supply as potassium nitrate at 3% resulted in significantly the highest values following by potassium citrate and potassium nitrate at 3%, but differences were statistically in the case of fruit diameter. Meanwhile control showed the lowest values in this respect. As for fruit shape ratio results showed significant differences obtained between treatments. Highest ratio was attributed to potassium nitrate treatment at 3%.

### Table 5. Effect of foliar application with various potassium sources on fruit set, fruit weight and yield of Picual olive trees in 2018/2019 and 2019/2020 seasons.

| Treatments                      | (%) Initial fruit set 2018/2019 | (%) Final fruit set 2018/2019 | Fruit weight (gm) 2018/2019 | Yield (kg/tree) 2018/2019 |
|--------------------------------|--------------------------------|------------------------------|----------------------------|--------------------------|
| Control                        | 8.85 G                         | 9.51 F                       | 1.66 G                     | E 6.11                   |
| % K- sulphate at 1.5           | 10.29 D                        | 10.83 DE                     | 2.26 DE                    | CD 7.09                  |
| K- sulphate at 3%              | 10.38 D                        | 11.63 BCD                    | 2.58 BC                    | AB 7.78                  |
| % K- nitrate at 1.5            | 10.76 C                        | 11.15 CDE                    | 2.35 D                     | 7.5ABC                   |
| K- nitrate at 3%               | 11.98 A                        | 12.61 A                      | 2.82 A                     | A 7.88                   |
| K- citrate at 1.5 %            | 9.60 F                         | 10.23 EF                     | 2.18 E                     | 7.42BCD                  |
| K- citrate at 3 %              | 11.59 B                        | 12.23 AB                     | 2.66 B                     | AB 7.68                  |
| Mono K- phosphate at 1.5 %     | 9.92 E                         | 10.58 E                      | 1.96 F                     | D 7.06                   |
| Mono K- phosphate at 3 %       | 10.71 C                        | 11.98 BC                     | 2.52 C                     | AB 7.64                  |

Values within each column followed by different letters are significant at p < 0.05 according to Duncan’s multiple range tests.
whereas, lowest ratio was due to control. The present findings are in line with those attained by Inglese et al. (2002), Elloumi et al. (2009), Hegazi et al. (2011) and Thanaa Mahmoud et al. (2017). The maximum size of apricot fruits were produced from trees treated with potassium nitrate, followed by potassium citrate (Okba et al., 2021).

The flesh weight, seed weight, flesh / fruit percentage

Data in Table (7) show that conducted treatments significantly increased the considered parameters. The highest flesh weight and seed weight (6.56 & 6.19 and 1.32 &1.28) were achieved with spraying trees K- supply as potassium nitrate KNO3 at 3% followed descending order by potassium citrate at 3% (6.38 & 6.03 and 1.30 &1.31) and the differences between them weren’t significant in 2018/2019 & 2019/2020 seasons, respectively. Control showed the least values in this respect in both seasons.

Regarding flesh/fruit weight percent, foliar application with potassium nitrate KNO3 at 3% was superior in this respect and resulted in the highest flesh/fruit of 83.25 and 82.85% as compared with control trees which showed the lowest values (80.03 and 79.40%) in the first and second seasons, respectively. These results are in harmony with those obtained by Hegazi et al. (2011), Thanaa Mahmoud et al. (2017). Foliar application of KNO3 during the second and third stages of olive growth improved fresh weight and flesh to pit ratio (Inglese et al. (2002). These results were achieved as a result of foliar fertilization with potassium which improved yield and quality as well as fruit weight and flesh to pit ratio of olives (Ben-Minoum et al., 2004).

Fruit moisture and oil content

Fruit moisture and oil content percentage in dry weight of Picual olive trees treated with K- forms under study were significantly affected and the differences among treatments were significant in both seasons. Data presented in Table (7) reveal that control treatment attained the highest fruit moisture content (69.43 and 70.12%) whereas the lowest fruit moisture was in fruits of treatment that applied with potassium nitrate at 3% (56.89 and 55.11%) in both seasons, respectively.

Concerning the oil percentage in fruit dry weight of Picual olive cv., it ranged from (29.89 to 37.41%) in the first season and from (31.00 to 41.88%) in the second season. Data in table (7) show that K- sources foliar application significantly affected fruit oil content and the highest content was in that trees treated with potassium citrate at 3% (37.41 and 41.88%) and potassium sulphate at 3% (35.26 and 41.19%) followed by that treatment applied with potassium nitrate at 3% (34.49 and 39.75%) while control treatment gave the lowest fruit oil content (29.89 and 31.00%) in 2018/2019 and 2019/2020 seasons, respectively. These observations agree with the findings of Hegazi et al. (2011), Sarrwy et al. (2010) concluded that foliar spraying with 3% potassium nitrate increases yield and fruit quality as well as fruit oil content of olive trees.

### TABLE 6. Effect of foliar application with various potassium sources on fruit dimensions, fruit length(cm), fruit diameter (cm) and fruit shape

| Treatments                  | (Fruit shape index (L/D) F 2.49 F 2.52 F 2.18 F 2.16 1.14E 1.17E | Fruit diameter (cm) E 2.64 E 2.67 F 2.23 E 2.25 1.18 C 1.19 E | Fruit length (cm) BC 2.86 BC 2.90 C 2.36 AB 2.41 1.21 AB 1.22 DE |
|-----------------------------|----------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------|
| Control                     | F 2.49 F 2.52 F 2.18 F 2.16 1.14E 1.17E                          | E 2.64 E 2.67 F 2.23 E 2.25 1.18 C 1.19 E                        | BC 2.86 BC 2.90 C 2.36 AB 2.41 1.21 AB 1.22 DE                     |
| % K- sulphate at 1.5        | E 2.64 E 2.67 F 2.23 E 2.25 1.18 C 1.19 E                        | BC 2.86 BC 2.90 C 2.36 AB 2.41 1.21 AB 1.22 DE                     |
| % K- sulphate at 3          | BC 2.86 BC 2.90 C 2.36 AB 2.41 1.21 AB 1.22 DE                     |
| % K- nitrate at 1.5         | 2.72D BC 2.89 2.41AB CD 2.34 1.20 B 1.24 BC                      |
| K- nitrate at 3 %           | 2.72D BC 2.89 2.41AB CD 2.34 1.20 B 1.24 BC                      |
| K- citrate at 1.5 %         | 2.72D BC 2.89 2.41AB CD 2.34 1.20 B 1.24 BC                      |
| K- citrate at 3 %           | 2.72D BC 2.89 2.41AB CD 2.34 1.20 B 1.24 BC                      |
| Mono K- phosphate at 1.5 %  | DE 2.67 D 2.74 2.31CD DE 2.30 1.16 CD 1.19 CD                   |
| Mono K- phosphate at 3%     | DE 2.67 D 2.74 2.31CD DE 2.30 1.16 CD 1.19 CD                   |

index (L/D) of Picual olive trees in 2018/2019 and 2019/2020 seasons.
Values within each column followed by different letters are significant at $p < 0.05$ according to Duncan’s multiple range tests.

*Egypt. J. Hort. Vol. 49, No. 1 (2022)*
TABLE 7. Effect of foliar application with potassium sources on fruit quality of Picual olive trees in 2018/2019 and 2019/2020 seasons

| Treatments                  | Flesh weight(gm) | Flesh/fruits % | Seed weight (gm) | Fruit moisture content % | Oil content % |
|-----------------------------|------------------|----------------|------------------|--------------------------|--------------|
|                             | 2018/2019        | 2019/2020      | 2018/2019        | 2019/2020                | 2018/2019    |
| Control                     | 4.89F            | 4.66E          | 80.03E           | 79.40E                   | 69.43A       |
| % K- sulphate at 1.5        | 5.82E            | 5.49D          | 82.09D           | 81.82D                   | 61.02B       |
| % K- sulphate at 3          | 6.45AB           | 6.02AB         | 82.91A           | 82.92A                   | 61.39B       |
| % K- nitrate at 1.5         | 6.18CD           | 5.88BC         | 82.40C           | 82.12C                   | 60.01 BC     |
| K- nitrate at 3 %           | 6.56A            | 6.19A          | 83.25A           | 82.85A                   | 56.89 C      |
| K- citrate at 1.5 %         | 6.12D            | 5.82C          | 82.50C           | 81.74D                   | 60.87 B      |
| K- citrate at 3 %           | 6.38AB           | 6.03AB         | 83.07AB          | 82.15C                   | 56.99 A      |
| Mono K- phosphate at 1.5 %  | 5.83E            | 5.59D          | 82.5            | 81.73D                   | 66.94 A      |
| Mono K- phosphate at 3 %    | 6.34BC           | 5.88BC         | 82.98B           | 82.24C                   | 67.87A       |

Values within each column followed by different letters are significant at $p < 0.05$ according to Duncan’s multiple range tests.

**Conclusion**

Under similar conditions, it may be recommended that spraying potassium nitrate or potassium citrate at 3% three times immediately after harvesting (October), after the final fruit set (May), after hardening of the pit (first week of August) improving growth, leaf mineral composition, yield, fruit quality and fruit oil content of Picual olive trees.

**Acknowledgment**

The authors would like to thank all members of Arid and Semi-Arid Zones and Olive Research Department, Horticultural Research Institute, Agricultural Research Centre, for their support.

**Funding statements**

The authors declare that they do not receive any funding for this experiment.

**Conflicts of interest**

The authors declares that there are no conflicts of interest related to the publication of this study.

**References**

Abdel-Nasser, G. and El-Shazly, S.M. (2001) Response of Picual olive trees to potassium and boron fertigation. 1-Vegetative growth and leaf constituents. *J. Adv. Agric. Res.*, 6, 631-649.

Ahmed, F.F. and Morsy, M.H. (1999) A new method for measuring leaf area in different fruit species. *Minia J. of Agric. & Develop.* 19, 97-105.

Haberman, A., Dag, A., Shtern, N., Zipori, I., Erel, R., Ben-Gal, A. and Yermiyahu, U. (2019) Long-Term Impact of Potassium Fertilization on Soil and Productivity in Intensive Olive Cultivation. *Agronomy* 9 (9), 525; [https://doi.org/10.3390/agronomy9090525](https://doi.org/10.3390/agronomy9090525)

A.O.A.C. (1995) *Official Methods of Analysis*. 15th ed. Association of Official Analytical Chemists. Washington, D.C., USA.

Arquero, O., Barranco, D. and Benlloch, M. (2006) Potassium starvation increases stomatal conductance in olive trees. *Hort. Sci.* 41, 433-436.

Awad, M.A., Ismail, S.M. and Al-Qurashi, A.D. (2014) Effect of potassium soil and foliar spray fertilization on yield, fruit quality and nutrient uptake of “Seweda” date palm grown in sandy loam soil. *J. Food Agric. Environ.*, 12, 305–311.

Ben Mimoun, M. and Marchand, M. (2013) Effects of potassium foliar fertilization on different fruit tree crops over five years of experiments. *Acta Hortic.*, 984, 211–218. [CrossRef]

Brown, J. D. and Lilleland, D. (1946) Rapid determination of potassium and sodium in plant material and soil extract by flame photometer. *Proc. Amer. Soc. Hort. Sci.*, 48, P. 341.

Calvert, D.V. (1969) Spray applications of potassium nitrate for citrus on calcareous soils. *Proc. 1st Int’l Citrus Symposium*, 3, 1587-1597.

*Egypt. J. Hort. Vol. 49*, No. 1 (2022)
Cocucci, M.C. and S.D. Rosa (1980) Effects of canavanine on IAA- and fuscoiccin-stimulated cell enlargement, proton extrusion and potassium uptake in maize coleoptiles. *Physiol. Plant.*, **48**, 239-242.

Desouky, I.M., Haggag, L.F., Abd El-Migeed, M.M.M., Kishk, Y.F.M. and El-Hady, E.S. (2009) Effect of boron and calcium nutrients sprays on fruit set, oil content and oil quality of some olive oil cultivars. *World J. Agric. Sci.*, **5**, 180-185.

Dikmelik, U., Püskülcü, G., Altu, M. and Irget, M.E. (1999) The effect of KNO application on the yield and fruit quality of olive. *Developments in Plant and Soil Sci.*, **86**(2), 77-80.

Duncan, D.B. (1955) *Multiple Range and Multiple F tests*. *Biometrics*, **11**, 1-24.

El-Darier, S.M. (1991) Mineral composition in the ecosystem of fruit trees in Egypt, Citrus reticulata, Blanco and *Citrus aurantium* L. *J. Islamic Academy of Sci.*, **4**(3), 211-220.

Elloumi, O., Ghrab, M. and Ben Mimoun, M. (2009) Responses of olive trees (cv. Chemlali) after five years of experiment to potassium mineral nutrition under rainfed conditions. The Proceedings of the International Plant Nutrition Colloquium XVI, Plant Sciences, UC Davis, UC Davis.

El-Rahman, A. and Mohamed, M. (2016) Physiological studies on improving fruit quality of Valencia Orange fruits. *Glob. J. Biol. Agri. Health Sci.*, **5**, 93–101.

El-Sharony, T.A.M. (2007) Effect of organic and biofertilization on growth and productivity of olive trees. *MSc. Thesis*, Fac. Agric. Cairo Univ., Egypt

Erel, R., Ben-Gal, A., Dag, A., Schwartz, A. and Yermiyahu, U. (2014) Sodium replacement of potassium in physiological processes of olive trees (var. Barnea) as affected by drought. *Tree Physiol.*, **34**, 1102–1117. [Google Scholar] [CrossRef]

Erel, R., Yermiyahu, U., Ben-Gal, A., Dag, A., Shapira, O. and Schwartz, A. (2015) Modification of non-stomatal limitation and photoprotection due to K and Na nutrition of olive trees. *J. Plant. Physiol.*, **177**, 1–10. DOI: 10.1016/j.jplph.2015.01.005

Fabbrri, A. and Benelli, C. (2000) Review article flower bud induction and differentiation in olive. *J. Hortic. Sci. Biotechnol.*, **75**, 131-141. Fernandez-Escobar, R., Moreno, R. and Sanchez-Zamora, M.A. (2004) Nitrogen dynamics in the olive bearing shoot. *HortScience*, **39**, 1406-1411.

Gonzalez-Garcia, F., Chaves, M., Mazuelos, C. and Troncoso, A. (1972) Physiological aspects of the nutrition of the olive tree, ‘Manzanillo’ table variety. Cycle of nutrients in leaves and in growth of reproduction organs. *Physiol. Biochem. Hortic. Crops*, **32**, 614-634.

Gowda, A.M., El-Taweel, A.A. and Eassa, K.B. (2011) Studies on reducing the harmful effect of saline water irrigation on Picual olive trees. *Minufiya J. Agric. Res.*, **36**(3), 623 – 645.

Haggag, L.F., Fawzi, M.I.F., Shahin, M.F.M. and El-Hady, E.S. (2016) Effect of yeast, humic acid, fulvic acid, citric acid, potassium citrate and some chelated micro-elements on yield, fruit quality and leaf minerals content of ‘Canino’ apricot trees. *Int. J. Chem. Tech. Res.*, **9**, 7–15.

Hegazi, E.S., Mohamed, S.M., El-Sonbaty, M.R., Abd El-Naby, S.K.M. and El-Sharony, T.F. (2011) Effect of potassium nitrate on vegetative growth, nutritional status, yield and fruit quality of olive cv. Picual. *J. Hort. Sci. Ornament. Plants*, **3**, 252-258.

Hussein, A.H.A. (2008) Response of Manzanillo olive (*Olea europaea* L.) cultivar to irrigation regime and potassium fertigation under Tabouk conditions, Saudi Arabia. *J. Agronomy* **7**(4), 285-296.

Inglese, P., Gullo, G. and Pace, L.S. (2002) Fruit growth and olive oil quality in relation to foliar nutrition and time of application. *Acta. Hort.*, **586**, 507-509.

Jawandha, S.K., Gill, P.P.S., Singh, H. and Thakur, A. (2017). Effect of potassium nitrate on fruit yield, quality and leaf nutrients content of plum. *Vegetos*, **30**, 325–328. [CrossRef]

Josan, J.S., Sandhu, A.S., Singh, R. and Monga, P.K. (1995) Effect of various nutrient sprays on fruit quality of lemon. *Indian Journal of Horticulture*, **52**, 288-290.

Mazuelos, C., Romero, R., Valpuesta, V., Sarmiento, R. and Catalina, L. (1983) Pyruvate kinase activity, levels of potassium and reducing sugars in vegetative and productive buds of Olea europaea L. trees. *Anales de Edafologia Agrobiologia*, **42**, 279-284.

Mengel, K. and Kirkby, E.A. (1987) *Principle of Plant Nutrition*. 4th ed., International Potash Institute, Berne, Switzerland.

Meyer, B.S. and Anderson, D.B.I. (1970) Plant Physiology. 2nd ed., East West Press Pvt. Ltd., New Delhi, India, Pages: 473.
Ministry of Agriculture and Land Reclamation (2019) *Agricultural Statistics*, 349p.

Mofeed, A.S. (2002) Effect of picking date on flowering and fruiting of olive trees. M.Sc. Thesis, Faculty of Agriculture, Cairo University, Egypt.

Morales-Sillero, A., Jimenez, R., Fernandez, J.E., Troncoso, A. and Beltran, G. (2007) Influence of fertigation in ‘Manzanilla de Sevilla’ olive oil quality. *HortScience*, 42, 1157-1162.

Murphy, J. and Riely, J.P. (1962) A modified single dilution method for determination of phosphate in natural water. *Ann. Chem. Acta*, 27, 31-36.

Nijjar, G.S. (1985) Nutrition of Fruit Trees. USHA Raji Kumar, Kalyani, New Delhi, India, pp: 10-12.

Okba, S.K., Mazrou, Y., Elmenofy, H.M., Ezzat, A. and Salama, A. (2021) New insights of potassium sources impacts as foliar application on ‘Canino’ apricot fruit yield, fruit anatomy, quality and storability. *Plants* 10(6), 1163. https://doi.org/10.3390/plants10061163

Piper, C.S. (1950) *Soil and Plant Analysis*. Int.Sci. Publ., New York, 368p.

Pregl, F. (1945) *Quantitative Organic Micro-Analysis*. 4th ed., and A. Churchill. LTD. London. pp:126-129.

Sarrwy, S.M.A., El-Sheikh, M.H., Sanna Kabeil, S. and Shamseldin, A. (2012) Effect of foliar application of different potassium forms supported by zinc on leaf mineral contents, yield and fruit quality of “Balady” mandarin trees. *Middle-East Journal of Scientific Research*, 12 (4), 490-498.

Sarrwy, S.M.A., Mohamed, Enas A. and Hassan, H.S.A. (2010) Effect of foliar spray with potassium nitrate and mono-potassium phosphate on leaf mineral contents, fruit set, yield and fruit quality (*Olea europaea* L.) of Picual olive trees grown under sandy soil conditions. *American-Eurasian J. Agric and Environ. Sci.*, 8(4), 420-430.

Shabala, S. (2003) Regulation of potassium transport in leaves: From molecular to tissue level. *Ann. Bot.*, 92, 627-634.

Shen, C., Ding, Y., Lei, X., Zhao, P., Wang, S., Xu, Y. and Dong, C. (2016) Effects of foliar potassium fertilization on fruit growth rate, potassium accumulation, yield, and quality of ‘Kousui’ Japanese pear. *Horttechnology*, 26, 270–277. [CrossRef]

Simoes, P., Pinheiro-Alves, C., Cordeiro, A.M. and Marcelo, M.E. (2002) Effect of the nitrogen and potassium fertilization on fatty acids composition and oxidative stability for Carrasqueinha cultivar olive oil at different harvest periods-preliminary study. *Acta Hortic.*, 586, 337-340.

Snedecor, G.A. and Cochran, W.G. (1982) *Statistical Methods*, 7th ed., The Iowa State Univ. Press, Ames, Iowa, USA. pp: 365-372.

Tagliavini, M. and Marangoni, B. (2002) Major nutritional issues in deciduous fruit orchards of Northern Italy. *Hort. Technology*, 12, 26-31.

Taiz, L. and Zeiger, E. (2002) Respiration and Lipid Metabolism. In Plant Physiology, 3rd ed.; Sinauer Associates: Sunderland, MA, USA, 2002, pp: 223-258. [CrossRef]

Thanaa Sh. M. Mahmoud, Enaam Sh. A. Mohamed and T.F. El-Sharony (2017) Influence of foliar application with potassium and magnesium on growth, yield and oil quality of “Coroneiki” olive trees. *Am. J. Food Technol.*, 12 (3), 209-220.

Vijay, V., Dalal, R.P.S., Beniwal, B.S. and Saini, H. (2017) Effect of foliar application of potassium and its spray schedule on yield and yield parameters of sweet orange (*Citrus sinensis* Osbeck) cv. Jaffa. *J. Appl. Nat. Sci.*, 9, 786–790. [CrossRef]
تأثير الرش الورقي بمصادر مختلفة من البوتاسيوم على النمو والمحتوى المعدني للاوراق والمحصول وجودة الثمار لأشجار الزيتون صنف البيكوال

عادل محمد جودة، حسن محمد علي، طارق خلف البلك، حسن أحمد محمد علي، عادل محمد جودة

قسم البساتين - كلية الزراعة - جامعة بني سويف - مصر.
قسم بحوث الزيتون وفاكهة المناطق شبه الجافة - معهد بحوث البساتين - مركز البحوث الزراعية - الجيزة - مصر.

أجريت هذه الدراسة خلال موسمين متتاليين 2019/2020 و 2018/2019 على أشجار زيتون صنف البيكوال وعمرها 12 سنة مزروعة في بستان خاص يقع على بعد 182 كيلومتر جنوب القاهرة على الطريق الصحراوي الغربي بمحافظة المنيا، وهدفت الدراسة إلى معرفة تأثير الرش الورقي بمصادر البوتاسيوم المختلفة على النمو الخضري والمحصول وجودة الثمار. وكانت مصادر البوتاسيوم المستخدمة في الرش الورقي هي: كبريتات البوتاسيوم، نترات البوتاسيوم، سترات البوتاسيوم، فوسفات البوتاسيوم الأحادي، وتم استخدامها رشًا على الأشجار بعند الثمار مباشرة (مايو) وبعدها (الأسبوع الأول من أغسطس) وبعد الحصاد (أكتوبر) بعد تحليل النتائج. وقد أظهرت النتائج أن استخدام الرش الورقي بمصادر البوتاسيوم تحت الدراسة أدى إلى تحسين عملي في النمو الخضري، والمحصول، وجودة الثمار، وعدد زيتون الزيتون المكملة بالأشجار الغير معالجة. وقد حققت أقصى نتائج في النمو الخضري (طول الأفرع وعدد الفروع) بعد الفروع الحديقة/ فروع - عدد الأوراق/ فروع - مساحة الورقة) ثم قليلاً تأخر في نتائج البتونات الورقيات بنسبة 3%. أما بالنسبة للمحتوى المعدني للأوراق فقد زاد محتوى النتائج بنسبة 4% مقارنة بالأوراق التي تم زراعتها في الأوراق. كما أن ازدادت نسبة أقصى النتائج في المحصول، وتمترزاز النتائج وكيفية الرش الورقي بنترات البوتاسيوم، وترشة البوتاسيوم بمعدل 3% خلال موسمين التجاري.