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Importance of potassium and phosphorus in winter fertilization for olive trees

Elattar H. A.*
Pomology Dept., National Research Centre, El Behoos st., 12622 Dokki, Giza, Egypt
*Corresponding author

Saleh M. M. S.
Pomology Dept., National Research Centre, El Behoos st., 12622 Dokki, Giza, Egypt

Hassan H. S.
Pomology Dept., National Research Centre, El Behoos st., 12622 Dokki, Giza, Egypt

Sarrwy S. M. A.
Pomology Dept., National Research Centre, El Behoos st., 12622 Dokki, Giza, Egypt

Abstract---Background: This experiment was conducted in two successive seasons on Picual olive trees which planted in a private orchard located at El Khatatbah district belongs to El Behera governorate, Egypt, and that in order to study the effect of the potassium dihydrogen phosphate MKP (KH_2PO_4) addition on the olive fruit quality, yield and its oil content, trees were sprayed at two concentrations (2 and 4%). The treatments were applied on three dates as follows: (1) Once at mid-December. (2) Twice at mid-December + mid-January. (3) Once at mid-January. Results: Spraying MKP at 4% regardless the time of application had improved the tree yield (kg/tree), fruit characteristics and leaf nitrogen content compared to the control; however spraying MKP at 2% in the two seasons, had increased the oil content significantly. Conclusions: Winter applications of MKP at different times showed a positive effect on the studied parameters compared with the control.

Keywords---Picual, olive, MKP, yield, fruit quality, oil content.

Introduction

Olive (*Olea europaea* L.) is one of the important economic fruits in many countries including Egypt. Thus looking for treatments to improve trees yield, fruits and oil quality is necessary. Therefore, applying a material such as potassium dihydrogen phosphate (MKP) may be beneficial, since it can improve fruit quality. It is widely preferable as it's an available economic eco- friendly fertilizer and a fast efficient P and K source as a foliar spray when N fertilization should be limited. In 2001; Boman showed that, 'Valencia' orange trees that received MKP had 24- 29% more fruits per tree and larger fruit than the control trees. On tomatoes, Chapagain and Wiesman (2004) had sprayed MKP onto leaves at three dates and indicated that; K and P contents were significantly higher in sprayed plants than in the control. Also, the total marketable yield was significantly higher. MKP sprayed trees had higher fruit dry matter than the control. However, fruit total N was not affected by spraying treatments.

In addition, Kumar *et al.,* (2006) indicated that K has profound influence on fruit quality such as size; since it regulates many plant vital functions. They mentioned it as the most important nutrient regulating fruit quality and yield. Working on olive, Barranco *et al.,* (2010) applied foliar MKP at three different times on trees and revealed that MKP increased P contents and improved the K nutritional state. Also, Sarrwy *et al.,* (2010 and 2012) had sprayed different potassium forms as well as MKP onto Picual olive and citrus trees pre or post bloom. They noticed that, all treatments caused a remarked promotion of leaf mineral statues, yield and fruit quality compared to the control were (1.5% MKP gave the highest values). Hussein *et al.,* (2013) evaluated the influences of MKP and MKP+ urea on jatropha plants when sprayed in two dates. Fresh and dry weights of whole plant parts were significantly responded. A positive relationship was detected between MKP application and most of growth traits.

In this respect, Khan *et al.,* (2014) investigated the effect of various combinations from organic and inorganic K sources on growth, yield and fruit quality of tomato. All the combinations significantly affected growth, yield and fruit quality. Mikhail and Goargiuos (2014) indicated that foliar application of 0.3% MKP on "Picual" and "Manzanillo" had improved yield, fruit characters like: weight, flesh/ fruit weight, length, diameter, length/diameter and seed weight. Also, fruit oil content was increased. A study on mango held by Rania *et al.,* (2014), investigated different potassium forms applied at two rates effect. All applications had a positive effect on yield, fruit physical and chemical characteristics and mineral content compared to the control. Also, MKP was the best in increasing mineral content. Also, Baiea *et al.,* (2015) sprayed different K forms on mango at 1 and 2 % for four times. They showed that 2 % of MKP was very effective in increasing yield (fruits number and weight). In addition, MKP sprays at 2 % (in the same treatment) improved leaves NPK contents.

In China, Yang *et al.,* (2015) pointed out the effect of K/ N ratio on litchi; they reached the highest yield when the ratio ranged from 1.0 to 1.2. Moreover, Dorria *et al.,* (2016) had investigated MKP foliar spray effect on jatropha at full bloom and after fruit set. They recorded a remarked promotion in leaf mineral status with all sprays. MKP enhanced yield and seed characteristics compared to

control; definitely the mono spray of MKP 1% which greatly increase fruit yield, seed weight and oil proportion. Another study by Amira, Hegazi *et al.,* (2017), showed that P fertilization and foliar K effects on sweet pepper fruit quality. MKP recorded the highest yield compared to the control. Also, the K foliar spray enhanced fruits number and weight. Moreover, N, P and K contents were increased in parallel to P availability increase (MKP application). Thus, the aim of conducting this experiment is to study the important effect of phosphorous and potassium when used in winter fertilizers on all physical characteristics of fruits, the amount of the expected crop, the oil content of the fruits, and also the tree leaves elements percentages.

Methods

Plant material

This experiment was carried out during 2018 and 2019 seasons in a private orchard on 32 years old Picual olive trees that located in El Khatatbah district belongs to El Behera governorate, Egypt. The selected trees were almost similar in vigor and size also planted at 6 × 6 meters, in sandy soil under drip irrigation system. The experimental trees had received the same cultural practices that suitable for tree age and the area weather conditions according to Ministry of Agriculture and Land Reclamation recommendation.

Treatments

Foliar applications of potassium dihydrogen phosphate KH_2PO_4 (MKP) at 2 and 4 % were sprayed once in December (Dec) or twice in December + January (Dec + Jan) or once in January (Jan). Nine treatments were arranged in three replicates on one tree plot as follows:

- Water sprays only at Mid Dec (control)
- MKP 2 % at Mid Dec
- MKP 4% at Mid Dec
- Water sprays only at Mid Dec+ Mid Jan (control)
- MKP 2% at Mid Dec+ Mid Jan
- MKP 4% at Mid Dec+ Mid Jan
- Water sprays only at Mid Jan (control)
- MKP 2% at Mid Jan
- MKP 4% at Mid Jan

Measurements

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

Yield and fruit quality

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 (gm), fresh and dry flesh weight (gm), seed weight (gm), fruit length (cm), fruit diameter (cm), fruit shape index and fruit moisture (%) as described by A.O.A.C. (1995). Oil percentage in dried flesh were measured means of Soxhalt extraction apparatus using hexane at 60-80° boiling point, Banat *et al.,*(2013).

Leaf mineral content

Leaf samples were picked from each replicate tree then washed and dried at 70°C 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).

Statistical Analysis

The experimental layout was a randomized complete block design (RCBD) with three replicates for each treatment; one tree was represented as a replicate. The obtained data were subjected to analysis of variance (ANOVA) according to Snedecor and Cochran (1980) and the least significant differences (LSD) at probability of 5% were applied to separate the means using Co-Stat 4.11 software.

Results

Fruit physical characteristics
Fruit fresh weight (gm)

It is clear from the results in Table (1) that treating trees with MKP at 2 and 4% significantly affected fruit fresh weight in the two seasons. The highest fruit fresh weight was recorded when trees sprayed with 4% MKP since it gave 6.10 and 6.60 gm in both experimental seasons, respectively. The lowest fruit fresh weight was obtained from control where it was 4.72 and 5.03 gm in both seasons of the study, successively. This result goes with Hussein *et al.,* (2013) and Mikhail and Goargiuos (2014) results. Concerning time of application, weights were not affected significantly in both seasons since the heaviest fruits (5.55 and 5.90 gm) weighed when trees treated in January in both seasons by order. Whereas, the lightest fruits (5.49 and 5.67 gm) were weighed with December treatments. This result is on the contrary of Baiea *et al.,* (2015) results.

The interaction between spraying MKP and time of application showed a significant effect on fruit fresh weight in both experimental seasons. The highest fruit fresh weight was scored from spraying 4% MKP at (December+ January) since it was (6.25 gm) in the first season, while in the second season was obtained from spraying 4% MKP at (January) since it gave (6.76 gm). The lowest fruit fresh weight 4.65 gm was found in control application in (December+ January) or in (January) in the first season and 4.79 gm with the control sprayed in December in the second season. Similar findings were detected by Sarrwy *et al.,* (2010 and 2012).

Flesh weight (gm)

Results in Table (1) pointed out that, flesh weight was affected significantly by MKP sprays in the two seasons of the study. The highest flesh weight was obtained from foliar spray with MKP at 4% since it gave 4.39 and 4.42gm in the first and second seasons, respectively. The lowest flesh weight was found in control treatment which recorded 4.04 and 4.10 gm in the two seasons of the study, successively. This result is in harmony with Mikhail and Goargiuos (2014) findings.

Table 1
Effect of MKP foliar sprays on fruit fresh weight, flesh weight, fruit moisture, seed weight and fruit dry weight of Picual olive trees during 2018 and 2019 seasons

1st season					2nd season			
Treat.	Fruit fresh weight (g)							
	(Dec.)	(Dec.+Jan.)	(Jan.)	Means (A)	(Dec.)	(Dec.+Jan.)	(Jan.)	Means (A)
Control (0 %)	4.86	4.65	4.65	4.72	4.79	5.04	5.25	5.03
MKP (2 %)	5.78	5.67	5.79	5.75	5.53	5.95	5.69	5.72
MKP (4 %)	5.83	6.25	6.21	6.10	6.68	6.35	6.76	6.60
Means (B)	5.49	5.53	5.55		5.67	5.78	5.90	
LSD at 5 % (A)	0.27				LSD at 5 % (A)	0.40		
LSD at 5 % (B)	N.S				LSD at 5 % (B)	N.S		
LSD at 5 % (A*b)	0.46				LSD at 5 % (A*b)	0.70		
	Flesh weight (g)							
Control (0 %)	4.07	4.15	3.90	4.04	3.94	4.15	4.23	4.10
MKP (2 %)	4.05	4.07	4.24	4.12	4.23	4.29	4.01	4.18
MKP (4 %)	4.65	4.04	4.48	4.39	4.59	4.15	4.52	4.42
Means (B)	4.26	4.09	4.21		4.25	4.20	4.25	
LSD at 5 % (A)	0.27				LSD at 5 % (A)	0.24		
LSD at 5 % (B)	N.S				LSD at 5 %	N.S		

LSD at 5 % (A*b)	0.47				(B) LSD at 5 % (A*b)	0.42		
	Fruit moisture (%)							
Control (0 %)	73.63	75.77	76.85	75.42	74.99	75.50	77.25	75.91
MKP (2 %)	71.92	72.97	72.41	72.44	72.23	73.14	71.58	72.32
MKP (4 %)	72.31	74.38	73.20	73.29	71.52	74.76	71.87	72.72
Means (B)	72.62	74.37	74.15		72.91	74.46	73.57	
LSD at 5 % (A)	1.23				LSD at 5 % (A)	1.11		
LSD at 5 % (B)	1.23				LSD at 5 % (B)	1.11		
LSD at 5 % (A*b)	2.13				LSD at 5 % (A*b)	1.93		
	Seed weight (g)							
Control (0 %)	0.87	0.93	0.88	0.90	0.94	0.91	0.86	0.90
MKP (2 %)	0.85	1.02	0.85	0.90	0.95	1.09	0.71	0.91
MKP (4 %)	1.04	0.91	0.92	0.96	1.07	1.03	0.85	0.98
Means (B)	0.92	0.95	0.88		0.98	1.01	0.80	
LSD at 5 % (A)	N.S				LSD at 5 % (A)	N.S		
LSD at 5 % (B)	N.S				LSD at 5 % (B)	0.08		
LSD at 5 % (A*b)	0.16				LSD at 5 % (A*b)	0.15		
	Fruit dry weight (g)							
Control (0 %)	1.04	1.02	0.95	1.00	0.99	0.99	1.01	1.00
MKP (2 %)	1.14	1.10	1.17	1.13	1.17	1.15	1.14	1.16
MKP (4 %)	1.29	1.04	1.20	1.18	1.31	1.05	1.27	1.21
Means (B)	1.16	1.05	1.11		1.16	1.06	1.14	

LSD at 5 % (A)	0.09	LSD at 5 % (A)	0.07
LSD at 5 % (B)	0.09	LSD at 5 % (B)	0.07
LSD at 5 % (A*b)	0.15	LSD at 5 % (A*b)	0.12

Regarding the time of application, flesh weight was not affected significantly in the two seasons of the study where the heaviest weights (4.26 and 4.25 gm) weighed at December in the first season and at both treatments December and January in the second season by order. While, the lightest weights (4.09 and 4.20 gm) were found with December+ January application in both seasons, successively. The interaction between the two factors that shown in Table (1), clear a significant effect on flesh weight in both experimental seasons. The highest flesh weight was exhibited from foliar spray with MKP at 4% at December, since it gave 4.65 and 4.59 gm in the first and the second season, respectively. The lowest flesh weight was obtained from the control application in January which gave 3.90 gm in the first season. While in the second season, the lowest flesh weight was found with control treatment of December which gave 3.94 gm.

Fruit moisture (%)

Fruit moisture percentage was affected significantly by spraying MKP in both seasons as shown in Table (1). The highest fruit moisture was found in control which gave 75.42 and 75.91% in the first and the second season, respectively. The lowest moisture content (72.44 and 72.32%) was measured with MKP 2% in both seasons by order. Also, time of application significantly affected fruit moisture percentage in both seasons of the study. The highest fruit moisture percentage was recorded with December+ January application which gave 74.37 and 74.46% in the first and second seasons, respectively. Whereas, the lowest moisture values (72.62 and 72.91%) were measured in December application in the two seasons, successively. As for the interaction between MKP concentration and application time, there was a significant effect on fruit moisture percentage in the two seasons. The highest fruit moisture percentage (76.85 and 77.25%) was recorded with the control treatment of January in both seasons, respectively. Whereas, the lowest fruit moisture percentage (71.92%) was recorded with spraying 2% of MKP at December in the first season, and in the second season (71.52%) measured with spraying 4% of MKP at December.

Seed weight (gm)

Results in Table (1) show that seed weight was not affected significantly by spraying MKP at 2% or 4% in both seasons of the study. The highest weight (0.96 and 0.98 gm) weighed with 4% MKP and the lowest (0.90 gm) weighed with the control in both seasons and 2% MKP in the first season only. However, Mikhail and Goargiuos (2014) showed opposite results. Concerning time of application results in Table (1), clear that seed weight was not affected significantly in the

first season. While in the second season, seed weight was affected significantly. The highest seed weight (0.95 and 1.01 gm) was recorded from December+ January application in both seasons, successively. This result is in contradiction with those of Dorria *et al.,* (2016). But January sprays; recorded the lowest significant values (0.88 and 0.80 gm) in the two seasons, respectively. The results of the interaction between the two factors in Table (1) referred that seed weight was affected significantly in both seasons. The highest seed weight (1.04 gm) was recorded from spraying 4% of MKP at December. While in the second season, the highest seed weight (1.09 gm) was found with the foliar spray of 2% MKP at (December+ January). The lowest seeds weight (0.85 gm) measured with MKP 2% sprayed at December and January treatments in the first season, but (0.71 gm) with MKP 2% sprayed at January in the second season. Sarrwy *et al.*, (2010 and 2012) pointed out similar results.

Fruit dry weight (gm)

Results in Table (1) show that spraying MKP significantly affected fruit dry weight of Picual olive trees during the two seasons. The highest fruit dry weight was found in the trees sprayed with MKP at 4% which recorded 1.18 and 1.21 gm in the first and second seasons, respectively. The lowest fruit dry weight (1 gm) was recorded from control treatment in both experimental seasons. This result is similar to those found by Chapagain and Wiesman (2004). Regarding the time of application, results in Table (1) show that fruit dry weight was affected significantly in the two seasons. The highest fruit dry weight was obtained from December application which gave 1.16 gm in the two seasons of the study. The lowest fruit dry weight was recorded from December+ January application which gave 1.05 and 1.06 gm in the first and second seasons, respectively. The interaction between spraying MKP and application time was significant in the two seasons. The highest fruit dry weight was recorded from the foliar spray of MKP at 4% at December which gave 1.29 and 1.31 gm in both seasons, respectively. The lowest fruit dry weight was obtained from the control which gave 0.95 gm when application time was; January in the first season. While in the second season the lowest fruit dry weight (0.99 gm) was found also with the control when applied at December and December+ January.

Fruit length (cm)

The highest fruit length, as presented in Table (2), was recorded from spraying MKP at 2% since it gave 2.62 cm in the first season. While in the second season, the highest fruit length was obtained from spraying MKP at 4%, since it gave 2.66 cm. The lowest fruit length was obtained from the control treatment, since it was 2.36 and 2.43 cm in both experimental seasons, successively. Similar results were found by Mikhail and Goargiuos (2014). Considering the time of application, fruit length was not affected significantly in the two seasons. Were the tallest fruits (2.56 cm) measured in January treatment in both seasons also with Dec + Jan treatment in the second season; however the shortest fruits (2.51 cm) recorded in the first season with Dec and Dec + Jan, treatments. The interaction between the two tested factors was also significant in affecting fruit length in the first and second seasons. The highest fruit length (2.67 cm and 2.72 cm) was reported from trees sprayed with MKP 2% and 4% application at January in the

first and the second season, respectively. While the lowest fruit length (2.33 and 2.40 cm) recorded with the control spray at December in the first season and at January in the second season, respectively.

Fruit diameter (cm)

Results in Table (2) clear that fruit diameter was affected significantly by spraying MKP in both seasons. The highest fruit diameter (2.04 and 2.06 cm) was recorded from spraying 4% of MKP in both seasons, respectively. Whereas, the lowest fruit diameter (1.85 and 1.89 cm) was obtained from the control treatment in the first and second seasons, successively. In this respect, Mikhail and Goargiuos (2014) and Dalal and Beniwal (2017) recorded the same trend. As for the time of application, fruit diameter was not affected significantly in both seasons since the largest diameters (1.97 cm) was measured with both treatments Dec and Dec+ Jan sprays in the first season and (1.99 cm) with December spray in the second season. While, the smallest fruits (1.95 and 1.94 cm) were found with December spray in the first season and with January spray in the second season.

Table 2
Effect of MKP foliar sprays on fruit length, fruit diameter and fruit shape index of Picual olive trees during 2018 and 2019 seasons

1st season					2nd season			
Treat.	Fruit length (cm)							
	(Dec.)	(Dec.+Jan.)	(Jan.)	Means (A)	(Dec.)	(Dec.+Jan.)	(Jan.)	Means (A)
Control (0 %)	2.33	2.37	2.37	2.36	2.43	2.47	2.40	2.43
MKP (2 %)	2.57	2.63	2.67	2.62	2.57	2.60	2.57	2.58
MKP (4 %)	2.63	2.53	2.63	2.60	2.63	2.62	2.72	2.66
Means (B)	2.51	2.51	2.56		2.54	2.56	2.56	
LSD at 5 % (A)	0.08				LSD at 5 % (A)	0.08		
LSD at 5 % (B)	N.S				LSD at 5 % (B)	N.S		
LSD at 5 % (A*b)	0.15				LSD at 5 % (A*b)	0.14		
	Fruit diameter (cm)							
Control (0 %)	1.87	1.87	1.82	1.85	1.88	1.88	1.89	1.89
MKP (2 %)	1.99	1.97	2.03	2.00	2.00	1.99	1.87	1.95
MKP (4 %)	1.99	2.08	2.05	2.04	2.10	2.03	2.07	2.06
Means	1.95	1.97	1.97		1.99	1.97	1.94	

(B)								
LSD at 5 % (A)	0.06				LSD at 5 % (A)	0.07		
LSD at 5 % (B)	N.S				LSD at 5 % (B)	N.S		
LSD at 5 % (A*b)	0.10				LSD at 5 % (A*b)	0.11		
Shape index								
Control (0 %)	1.19	1.27	1.20	1.22	1.33	1.34	1.34	1.34
MKP (2 %)	1.29	1.34	1.31	1.31	1.28	1.31	1.38	1.32
MKP (4 %)	1.32	1.22	1.28	1.27	1.26	1.29	1.32	1.29
Means (B)	1.26	1.28	1.27		1.29	1.31	1.34	
LSD at 5 % (A)	0.07				LSD at 5 % (A)	N.S		
LSD at 5 % (B)	N.S				LSD at 5 % (B)	N.S		
LSD at 5 % (A*b)	0.11				LSD at 5 % (A*b)	N.S		

The interaction between the two tested factors had a significant effect on fruit diameter in both seasons. The highest fruit diameter (2.08 and 2.10 cm) was recorded from the trees sprayed with MKP at 4% at December+ January in the first season and at December in the second season. Whereas, the lowest fruit diameters (1.82 and 1.87 cm) obtained from control sprays at January in the first season and from MKP 2% sprays at January in the second season.

Shape index

Results in Table (2) show that length/ width ratio was affected significantly in the first season while it wasn't affected in the second season by MKP concentration. The highest ratio (1.31 and 1.32) was obtained from spraying MKP at 2% in both seasons, successively. However, the lowest ratio (1.22) recorded with control spray in the first season and (1.29) with 4% MKP in the second season. This result goes with Boman (2001), Kumar *et al.,* (2006) and Mikhail and Goargiuos (2014) findings. Concerning application time, length/ width ratio was not affected significantly in the two experimental seasons. Where the highest ratio (1.28) was found with December+ January date in the first season and (1.34) was calculated with January date in the second season. The lowest ratios (1.26 and 1.29) were calculated with December date in the two seasons, by order.

The interaction between the two factors had significantly affected length/ width ratio in the first season, where the highest length/ width ratio (1.34) was obtained from 2% MKP spray at December+ January. While in the second season, length/

width ratio was not affected significantly since the highest ratio (1.38) found with 2% MKP sprayed at January. The lowest ratio (1.19) in the first season was measured when control sprays applied in December, whereas in the second season (1.26) was found with MKP 4% sprayed at December also. These results are in contradiction with those of Sarrwy *et al.,* (2010 and 2012).

Yield and oil percentage
Yield/ tree (kg)

Results in Table (3) clearly show that yield/ tree of Picual olive trees was significantly affected by the tested treatments in both seasons. The highest yield/ tree was obtained from spraying MKP at 4%, since it was 64.44 and 65.56 kg in the first and the second seasons, respectively. Whereas, the lowest yield/ tree found in control treatment which recorded 39.78 and 40.33 kg in both experimental seasons, successively. These results are in harmony with those of Boman (2001), Chapagain and Wiesman (2004) and Kumar *et al.,* (2006). Regarding time of application effect, results showed that yield/ tree was affected significantly in both seasons. The highest yield/ tree were obtained from January application which recorded 56.89 and 57.56 kg in both seasons, successively. While the lowest yield/ tree was exhibited from December application which gave 52.56 and 53.11 kg in both seasons, by order. Similar results were mentioned by Baiea *et al.,* (2015). The interaction between the two tested factors was also significant in the two seasons. The highest yield/ tree (70 and 68.33 kg) were recorded for trees sprayed with 4% of MKP at January in both seasons, respectively. But, the lowest yield/ tree (39.33 kg) was found in control treatment when applied at December or December+ January in the first season. Meanwhile, in the second season the lowest yield/ tree (39 kg) was recorded from the control when sprayed at December+ January. These results are in harmony with those of Sarrwy *et al.,* (2010 and 2012).

Oil percentage in dried flesh (%)

Data tabulated in Table (3) clear that oil content percentage was affected significantly by foliar spray with MKP in both seasons. The highest oil content was recorded from spraying MKP at 2%, since it was 35.33 and 34.51% in the two seasons, successively. The lowest oil content was obtained from the control treatment which recorded 26.33 and 26.17% in both experimental seasons, successively. This result goes with those of Mikhail and Goargiuos (2014).

Table 3
Effect of MKP foliar sprays on yield and oil percentage in dried flesh of Picual olive trees during 2018 and 2019 seasons

1st season					2nd season			
Treat.	Yield /tree (kg)							
	(Dec.)	(Dec.+Jan.)	(Jan.)	Means A	(Dec.)	(Dec.+Jan.)	(Jan.)	Means A
Control (0 %)	39.33	39.33	40.67	39.78	41.00	39.00	41.00	40.33

MKP (2 %)	56.67	63.33	60.00	60.00	55.00	61.67	63.33	60.00
MKP (4 %)	61.67	61.67	70.00	64.44	63.33	65.00	68.33	65.56
Means (B)	52.56	54.78	56.89		53.11	55.22	57.56	
LSD at 5 % (A)	3.73				LSD at 5 % (A)	2.91		
LSD at 5 % (B)	3.73				LSD at 5 % (B)	2.91		
LSD at 5 % (A*b)	6.46				LSD at 5 % (A*b)	5.04		
Oil percentage in dried flesh (%)								
Control (0 %)	26.67	26.17	26.19	26.33	26.01	26.50	26.00	26.17
MKP (2 %)	35.96	35.04	35.00	35.33	35.58	33.88	34.08	34.51
MKP (4 %)	34.38	30.92	35.06	33.45	33.68	31.70	34.54	33.31
Means (B)	32.34	30.71	32.08		31.75	30.69	31.54	
LSD at 5 % (A)	0.55				LSD at 5 % (A)	0.48		
LSD at 5 % (B)	0.55				LSD at 5 % (B)	0.48		
LSD at 5 % (A*b)	0.95				LSD at 5 % (A*b)	0.84		

Concerning oil content percentage, it was significantly affected by time of application in both seasons. The highest oil content was obtained from application time at December which gave 32.34 and 31.75% in the first and the second seasons, respectively. The lowest oil content was recorded from December+ January application time which gave 30.71 and 30.69% in both experimental seasons, respectively. The interaction between spraying MKP treatment and time of application significantly affected the oil content in the two seasons. The highest oil content (35.96 and 35.58%) was exhibited from foliar spray with MKP at 2% applied at December in the first and the second seasons, respectively. The lowest oil content (26.17%) was recorded from the control spray at December+ January in the first season. However, the lowest oil content (26%) was found from the control sprayed at January in the second season. Moreover, Sarrwy *et al.,* (2010 and 2012) and Dorria *et al.,* (2016) showed such results.

Leaf mineral contents
Nitrogen percentage (%)

Table (4) data show that spraying MKP significantly affected nitrogen percentage of Picual leaves in the two seasons. Water sprayed trees (control treatment)

showed the lowest nitrogen percentage (1.74 and 1.76%) compared to those sprayed with MKP at 4% (1.90 and 1.88%) which scored the highest nitrogen percentage in both seasons, respectively. This result is on contradiction of Chapagain and Wiesman (2004) findings. Whereas, the results in harmony with Amira, Hegazi *et al.,* (2017) results.

Table 4
Effect of MKP foliar sprays on nitrogen, phosphorus and potassium of Picual olive trees during 2018 and 2019 seasons

1st season					2nd season			
Nitrogen (%)								
	(Dec.)	(Dec.+Jan.)	(Jan.)	Means A	(Dec.)	(Dec.+Jan.)	(Jan.)	Means A
Control (0 %)	1.74	1.74	1.75	1.74	1.76	1.78	1.75	1.76
MKP (2 %)	1.75	1.97	1.81	1.85	1.79	1.91	1.82	1.84
MKP (4 %)	2.09	1.70	1.90	1.90	1.94	1.84	1.87	1.88
Means (B)	1.86	1.80	1.82		1.83	1.84	1.81	
LSD at 5 % (A)	0.06				LSD at 5 % (A)	0.07		
LSD at 5 % (B)	N.S				LSD at 5 % (B)	N.S		
LSD at 5 % (A*b)	0.10				LSD at 5 % (A*b)	0.12		
Phosphorus (%)								
Control (0 %)	0.146	0.145	0.146	0.146	0.145	0.144	0.144	0.144
MKP (2 %)	0.151	0.133	0.137	0.140	0.151	0.137	0.136	0.141
MKP (4 %)	0.147	0.144	0.135	0.142	0.149	0.143	0.142	0.145
Means (B)	0.148	0.141	0.139		0.149	0.141	0.140	
LSD at 5 % (A)	0.002				LSD at 5 % (A)	0.002		
LSD at 5 % (B)	0.002				LSD at 5 % (B)	0.002		
LSD at 5 % (A*b)	0.003				LSD at 5 % (A*b)	0.004		
Potassium (%)								
Control	1.75	1.77	1.82	1.78	1.82	1.80	1.79	1.81

(0 %)								
MKP (2 %)	1.86	1.64	1.82	1.77	1.87	1.64	1.82	1.77
MKP (4 %)	1.66	2.07	1.67	1.80	1.66	2.06	1.67	1.80
Means (B)	1.76	1.83	1.77		1.78	1.83	1.76	
LSD at 5 % (A)	N.S				LSD at 5 % (A)	0.03		
LSD at 5 % (B)	0.04				LSD at 5 % (B)	0.03		
LSD at 5 % (A*b)	0.06				LSD at 5 % (A*b)	0.05		

Considering the effect of application time, results clear that nitrogen percentage was not affected significantly by it in the two experimental seasons. Since the highest percentage measured (1.86%) when trees sprayed at December in the first season, and (1.84%) when trees sprayed at December+ January in the second season. However, the lowest percentage (1.80%) in the first season was detected with December+ January spray; meanwhile the lowest value (1.81%) was detected with January spray in the second season. The interaction between spraying treatments with MKP and application time was significant in the two seasons. Higher nitrogen percentage (2.09 and 1.94%) was obtained from trees sprayed with 4% of MKP at December in both seasons, respectively. Low nitrogen percentage (1.70%) was measured in trees sprayed with 4% MKP at December+ January in the first season. Meanwhile, in the second season the lowest nitrogen percentage (1.75%) was obtained from control treatment applied at January. Similarly, Sarrwy *et al.,* (2010 and 2012) and Baiea *et al.,* (2015) showed significant effects of such treatments

Phosphorus percentage (%)

Data presented in Table (4) clear that spraying MKP significantly affected phosphorus percentage in Picual olive leaf in the two seasons. The highest phosphorus percentage (0.146%) was recorded from the control treatment in the first season. While in the second season, the highest phosphorus percentage (0.145%) was obtained from MKP foliar spray at 4%. The lowest phosphorus percentage (0.140 and 0.141%) was measured with MKP at 2% in the first and second seasons, respectively. Similar results were mentioned by Chapagain and Wiesman (2004) and Barranco *et al.,* (2010). Time of application significantly effected phosphorus percentage in both seasons. Where, the highest phosphorus percentage (0.148 and 0.149%) was gained from December application in the two seasons of the experiment, respectively. While the lowest phosphorus percentage (0.139 and 0.140%) was recorded from spraying trees at January in both seasons, successively. In this respect, Baiea *et al.,* (2015) showed similar trend.

Looking to the interaction between the two tested factors was also significant in the two seasons. The highest phosphorus percentage (0.151%) was recorded twice

with spraying 2% of MKP at December in both seasons. The lowest phosphorus percentage (0.133%) was recorded from spraying 2% MKP at December+ January in the first season. Meanwhile, the lowest phosphorus percentage (0.136%) was obtained from spraying 2% of MKP at January in the second season. These results go with those of Barranco *et al.,* (2010) and Sarrwy *et al.,* (2010 and 2012).

Potassium percentage (%)

Results in table (4) reveal that spraying MKP lacked for significance in the first season. Where, MKP 4% spray resulted in the highest potassium percentage (1.80%), while the control trees recorded the highest potassium percentage (1.81%) in the second season. However, spraying MKP at 2% showed the lowest potassium percentage (1.77%) in both seasons. On the contrary, Chapagain and Wiesman (2004) and Barranco *et al.,* (2010) noticed a significant increase in potassium percentage with MKP treatments. Potassium percentage of Picual olive trees was significantly affected by the time of application in the two seasons. Trees sprayed at December+ January showed the highest potassium percentage (1.83%) in both seasons. The lowest potassium percentage (1.76%) was found when application time was December in the first season, but in the second one it was recorded with January treatment. Baiea *et al.,* (2015) pointed out similar results. The interaction was also significant in the two seasons. The highest potassium percentage (2.07 and 2.06%) was valued from the trees treated with MKP 4% at December + January in both experimental seasons, respectively. The lowest potassium percentages (1.64%) were recorded from trees sprayed with MKP at 2% when applied at December + January in the two seasons, respectively. These results are in harmony with those of Sarrwy *et al.,* (2010 and 2012).

Discussion

The previous results showed that the use of MKP at both concentrations and spraying dates had a positive impact on fruits quality characteristics also the fruits elements' content and the crop quantity and oil, compared to control. Because there is a link between vegetative development and reproductive phases, flowering and fruit set are the essential factors that impact fruit tree yield, notably in olive (Lavee 2006). This was explained by the dates of addition of the pre-flowering period in the olive trees (December and January) which reflected positively on all the studied characters. However, the date of addition in January was the highest in the trees yield (Kg). This may be due to the need of trees at this time for the elements of phosphorus and potassium. Potassium deficiency can reduce potential yield and quality a long time before visible symptoms appearance "hidden hunger". Subsequently, that robs profits due to low soil K levels needed at all times during the season. Short deficiency periods, especially during critical development stages, cause serious losses. Also potassium plays significant roles in enhancing crop quality. High levels of available potassium improve the fruit physical quality (Kalavati and Modi, 2012). It is also known, because of the high concentrations of potassium that found in the fruit, that potassium fertilization is considered essential particularly in olive (López-Villalta 1996).

But it was noticeable that in most measurements of this experiment like: fruit fresh and dry weight, fruit flesh weight, seed weight, fruit diameter and yield/

tree, an upward significant increase was observed associated with an increase in the MKP spray concentration compared to the control. This indicates that by increasing the concentration of potassium and phosphorus fertilizers used, there is an increase in the quality characteristics of fruit and yield quantity. This result is consistent with what found by Erel *et al.,* (2011), since leaf P higher than 0.09% resulted in high stable flowering intensity, also there is a significant linear fruit set and total fruits number response to leaf P content was detected.

Conclusions

The previous results presented in this work proved that the use of MKP sprayed on trees in winter had a positive effect on all the characteristics of the fruits under study and the resulting yield, which increased by approximately 50-60 % in both seasons of the study compared to the unsprayed trees, and it also had the same positive effect on the increase in the fruits' oil accumulation, which also increased by no less than 25 % compared to untreated trees.
These percentages, which are represented in an increase in both the yield and the percentage of oil in the fruits, can be considered as large percentages in the profits of olive growers compared to the cost of fertilizers used to spray olive trees in winter.

List of Abbreviations

MKP: Monopotassium phosphate (KH_2PO_4), RCBD: Randomized complete block design, A.O.A.C.: Association of Official Agricultural Chemists, ANOVA: analysis of variance, N: Nitrogen, P: Phosphorus and K: Potassium

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