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Physiological and Biochemical Response of Olive (*Olea europaea* L.) Cultivars to Foliar Potassium Application

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ABSTRACT

This study was conducted under Ahvaz, Iran environmental condition during 2012 and 2013 growing seasons in order to investigate the influence of foliar application of potassium on some physiological and biochemical characteristics of three olive cultivars including 'Mission', 'Koroneiki' and 'Dezfuli'. Potassium sulfate in different concentrations of 0, 1, and 2 g l^{-1} was sprayed twice on selected mature 10 year old trees; at 50 and 65 days after full bloom. Potassium sprays increased leaf chlorophyll content of all cultivars, leaf potassium content in 'Mission' and 'Koroneiki' cvs., fruit anthocyanin concentration of 'Dezfuli' in two crop seasons. However, K treatments had no significant effect on leaf N and P content, fruit K and P content in all studied cultivars. Fruit soluble carbohydrates increased by foliar application of potassium in 'Koroneiki' and 'Dezfuli' cultivars in the second year of study. Stem water potential and leaf stomatal conductance were significantly affected by cultivar and K treatments during the two years. Our findings showed that foliar application of potassium resulted in the decrease of stomatal conductance of 'Koroneiki' and 'Dezfuli' in two crop seasons. Based on the results, it can be concluded that the studied cultivars differently respond to K treatments during the two crop seasons and foliar potassium application could have a positive impact on leaf chlorophyll, leaf potassium, fruit soluble carbohydrates and fruit anthocyanins in olive cultivars.

Keywords: Foliar application, Olive, Potassium, Soluble carbohydrates, Stomatal conductance.

INTRODUCTION

Olive (*Olea europaea* L.) tree is an evergreen native to the Mediterranean region. In recent years, due to high olive oil demand as well as to the olive oil and fruit nutritional value, the cultivation of olive has been expanded in various regions in Iran. However, the cultivation of olive tree is limited because of harsh environmental conditions and water scarcity in most of the new olive plantation areas (Arji and Arzani, 2008). The limitation of water as well as long hot summers in the regions lead to poor fruit and oil quality (Khaleghi *et al*., 2015; Saadati *et al*., 2013). In addition, low precipitation (200 mm) in the studied area has caused problems to supplying fertilizers during most of the year. To achieve optimal growing conditions in this region new strategies toward orchard management are required (Arzani *et al*., 2009). For this purpose applying an efficient nutritional management such as foliar nutrient application is one of the important practices. Since foliar feeding provides the stems, leaves or fruits directly with nutrients, it is a suitable method to reduce the environmental risks arising from the use of the soil-applied

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chemical fertilizers (Inglese *et al*., 2002). Meanwhile, potassium (K) is one of the most important and highly consumed nutrients in plants, which plays important roles in their growth, metabolism and survival. This element participates in the activity of enzymes, protein synthesis, photosynthesis, osmotic adjustment, stomatal movements, carbohydrate synthesis and translocation and stress tolerance (Marschner, 2012). Large amounts of plant potassium is removed through the harvested fruits (Fernandez-Escobar, 2004), while potassium plays an important role in regulating the water status in olive tree (Arquero *et al*., 2006). Potassium is especially compatible with foliar application method because it has been shown that after being sprayed on the leaves it is rapidly absorbed and translocated throughout the tree (Mengel, 2002). Thus, foliar application is a useful way of applying potassium to fruit trees, especially in arid and semi-arid regions, because in these areas, water scarcity due to low rainfall in summer, remarkably reduces the absorption of nutrients especially potassium from the soil, when trees are in higher potassium demand (Toscano *et al*., 2002). Therefore, the objective of the present study was to explore the physiological and biochemical response of three commercial olive cultivars to foliar application of potassium under Ahvaz, Iran environmental conditions.

MATERIALS AND METHODS

Experimental Site

This experiment was carried out during 2012–2013 growing seasons in the research orchard, department of Horticultural Science, Shahid Chamran University, located at Ahvaz, Khuzestan province, Iran (Longitude: 48º 40´ E, Latitude: 31º 20´ N, Altitude: 22.5 m). According to the orchard soil analysis results, the soil texture was clay loam with 0.45% organic matter. The electrical conductivity of the soil was 4.05 dS m^{-1} with 7.9 soil pH. Note that, the highest amount of N (0.48%) and P (13.31 mg kg^{-1}) was observed in the top 30 cm of the soil. Although, data from soil analysis showed that the amount of K in the 30 cm top region of the soil was the lowest (132 mg kg^{-1}) compared to the deeper layer of 60 to 90 cm of soil depth (250 mg kg^{-1}). The average monthly climatic conditions of 2012 and 2013 growing seasons are presented in Table 1.

Plant Material and Treatments

This study was performed on 10-year-old mature olive trees of ‘Mission’, ‘Koroneiki’ and ‘Dezfuli’ cultivars. The experimental design was split plot, arranged based on Randomized Complete Block Design (RCBD) with three replications. Treatments were applied at 50 and 65 Days After Full Bloom (DAFB). Full Bloom (FB) occurred at 28th, 31st March and 4th of April for ‘Koroneiki’, ‘Mission’ and ‘Dezfuli’ respectively in the first year (2012) and at 1st, 5th and 7th of April for ‘Koroneiki’, ‘Mission’ and ‘Dezfuli’ respectively in the second year (2013), so FB was adopted on 1st of April in both growing seasons. All orchard agricultural practices and nutrition management were similar for all experimental trees. Annual application of fertilizers in the soil was 500 g N (urea), 250 g P (superphosphate) and 500 g K (potassium sulfate) per tree. The annual P and K fertilizers were applied in November and N fertilizer was applied three times in February, May and July. Foliar application of potassium was applied on trees with similar size and vigor. In addition, in order to avoid fast evaporation, trees were sprayed by a small automated sprayer in late afternoon one hour before sunset. Nutrient treatments included control (distilled water), K_2SO_4 (1 g l^{-}) and K_2SO_4 (2 g l^{-1}). About 20 liters per tree of K_2SO_4 solutions were applied, note that the wetting agent of Tween-20 (0.5%) was added into the solution before spray as a surfactant. The

Table 1. Climatic parameters of 2012 and 2013.

Months	Minimum temperature (ºC)	Maximum temperature (ºC)	Mean temperature (ºC)	Relative Humidity (% RH)	Rainfall (mm)	Evaporation (mm)
Jan	7.6	17.1	12.3	72	61.4	46.3
Feb	9.7	20.6	15.2	68	23.5	78.6
Mar	13.6	26.1	19.9	54	18.3	142.5
Apr	17.2	31.6	24.4	43	4.0	248.3
May	22.3	36.6	29.5	40	23.2	336.7
Jun	27.4	44.0	35.3	26	0.0	505.2
Jul	29.9	43.3	38.1	29	0.0	487.7
Aug	30.1	46.4	38.3	28	0.0	471.8
Sep	26.6	43.8	35.2	35	0.0	376.8
Oct	20.2	38.0	29.1	39	0.0	486.2
Nov	16.9	29.2	23.1	58	41.7	126.3
Dec	11.2	20.3	15.8	73	51.8	63.4
Mean	19.4	33.1	26.4	47.1		
Total					223.9	3369.8

nutrient concentration for applied treatments was determined in the experimental site based on the series of preliminary application of different concentrations (1 to 4 g l^{-1}) with visual observation of possible toxicity and damage of the leaves.

Plant Measurements

Determination of Nutrient Concentrations, Chlorophyll, Anthocyanin and Soluble Carbohydrate in Plant Tissues

Leaves from middle canopy position of one year old shoots and fruit from middle canopy zone were harvested in July and October in both years of study, respectively. All samples were washed with distilled water, dried at 70ºC for 48 hours, and then were ground into powder. N content was determined by Kjeldahl (1883) method. P and K contents were determined using colorimetry and flame photometer, respectively (Chapman and Pratt, 1961). The concentration of chlorophylls a and b in the leaves and fruit samples were determined by spectrophotometer (UV-1201, Shimadzu) at 645 and 663 nm (Lichtenthaler, 1987). The total chlorophyll contents are expressed in mg kg^{-1} fresh weight of leaf and fruit. Fruit anthocyanin content was determined by the pH differential method (Lee *et al.*, 2005) and expressed as mg g^{-1} cyanidin-3-glucoside equivalents. The soluble carbohydrates content was determined using the phenol sulphuric acid method (Hellebust and Graigie, 1978). The fruit samples were extracted with 80% ethanol, and then the absorbance of carbohydrate fraction was determined by spectrophotometer (UV-1201, Shimadzu) at 485 nm.

Measurement of Water Potential and Stomatal Conductance

The changes in Stem Water Potential (SWP) and stomatal conductance (g_s) were measured monthly from June to November in both years. Stem Water Potential (SWP) was measured by using a pressure chamber (Soil Moisture Equipment Corp, Model 3000). For this purpose, *SWP* was recorded immediately at midday on the detached one-year-old branches including leaves. Leaf stomatal conductance was measured at midday using a porometer (AP4, DELTA-T).

Statistical Analysis

The data were analyzed using the Analysis Of Variance (ANOVA) and Duncan`s multiple range test (P≤ 0.05) to evaluate the significance of differences between treatment means. A repeated measure ANOVA was used where the same measurement was performed at a different time.

RESULTS AND DISCUSSION

Nutrient Concentrations

There was no significant effect of K treatments on N and P content of leaves of the studied cultivars in two consequent years of this research (Table 2). These results are in agreement with the results of other researchers (Veberic *et al*., 2002) who reported a limited increase of leaf nutrient concentrations in response to foliar application of macronutrients and potassium (Weinbaum, 1988). They suggested that it is necessary to spray several times per crop season to achieve better results. In the case of leaf potassium, the effect of K treatments was significant in 'Mission' in both years. Foliar application of 1 g l^{-1} K had significantly increased leaf K content compared to control in 'Mission' *cv*. (Table 2). The K effect was also significant on fruit N content in 'Koroneiki' but not in 'Mission' and 'Dezfuli' cultivars. Insignificant differences were recorded among potassium treatments and olive cultivars concerning fruit P and K content, with the exception of 'Koroneiki' in the first

Table 2. Nitrogen, P and K concentrations (% ddry weight) in the leaves and fruit of the olive cultivars 'Mission', 'Koroneiki' and 'Dezfuli' at three rates of Foliar Application of Potassium (FAP) during 2012 and 2013 growing seasons.[a]

Treatments		2012 Growing season					
		Leaf			Fruit		
Cultivars	FAP[b]	N	P	K	N	P	K
Mission	T_1	1.45a	0.10ab	0.53d	1.06abc	0.16a	4.50ab
	T_2	1.44a	0.09ab	0.81c	1.22a	0.15a	4.71a
	T_3	1.56a	0.08b	0.61d	1.16ab	0.16a	4.93a
Koroneiki	T_1	1.31a	0.11a	0.93c	0.83e	0.16a	3.87b
	T_2	1.37a	0.11a	1.15b	1.11ab	0.15a	4.24ab
	T_3	1.63a	0.09ab	1.22ab	1.02bcd	0.18a	4.94a
Dezfuli	T_1	1.36a	0.09ab	1.25ab	0.91cde	0.17a	3.94b
	T_2	1.39a	0.10ab	1.28ab	0.88de	0.17a	4.50ab
	T_3	1.59a	0.09ab	1.34a	0.90cde	0.17a	4.51ab
		2013 Growing season					
		Leaf			Fruit		
		N	P	K	N	P	K
Mission	T_1	1.33d	0.09ab	0.53d	1.09ab	0.19bc	4.83a
	T_2	1.37cd	0.09ab	0.83bc	1.26a	0.25a	4.74a
	T_3	1.33d	0.08b	0.69cd	1.23a	0.21ab	4.80a
Koroneiki	T_1	1.64abc	0.13a	1.07ab	0.93bc	0.14d	4.83a
	T_2	1.76a	0.11ab	1.09ab	1.18a	0.15cd	4.54a
	T_3	1.69ab	0.10ab	1.05ab	1.09ab	0.17bcd	4.64a
Dezfuli	T_1	1.49abcd	0.10ab	1.29a	0.94bc	0.15cd	4.08b
	T_2	1.42bcd	0.12ab	1.14a	0.91c	0.16bcd	3.80b
	T_3	1.43bcd	0.09ab	1.21a	0.90c	0.15cd	3.84b

[a] The different letters in the same column symbolize statistically significant differences among three treatments and olive cultivars, according to the Duncan`s multiple range test (P≤ 0.05). [b] T_1= 0 g l^{-1} K_2SO_4 (control); T_2= 1 g l^{-1} K_2SO_4, T_3 = 2 g l^{-1} K_2SO_4.

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year, where significantly greater fruit K content (4.94 %) was recorded for the T_3 treatment (2 g l^{-1} K_2SO_4) than control treatment (T_1). These results are similar to other researches which showed that the application of potassium resulted in an increase in leaf potassium content in olive (Restrepo-Diaz *et al*., 2008; Saykhul *et al*., 2013), pecan (Diver *et al*., 1985) and prune (Robbins *et al*., 1982). However, no significant increase in the leaf potassium concentration of plants in response to K treatments has been reported (Smith *et al*., 1987). It is well known that leaf uptake is affected by several factors such as nutrient concentration, application rate, air temperature and internal factors such as leaf age, metabolic activity of plant, membrane and cuticle characteristics (Weinbaum, 1988). It has also been reported that cultivars may differently respond to nutrients (Chatzistathis *et al*., 2009; Loupassaki *et al*., 2002). In addition, it has been reported that in olive trees the tissue nutrient concentrations in the different plant parts is different. In this context, Rodrigues *et al.* (2012) showed different nutrient accumulation in different tree parts. Their results revealed that the higher K pool was in fruits followed by the leaves. They stated at harvest, 40.0% of total K in a tree appeared in the fruit. Leaves contained only 25.4% of total potassium.

Chlorophyll, Anthocyanin and Soluble Carbohydrates

Table 3. Leaf Chlorophyll (LCh), Fruit Chlorophyll (FCh), Fruit Soluble Carbohydrates (FSC) and Fruit Anthocyanin (FA) (based on fresh matter weight) of the olive cultivars 'Mission', 'Koroneiki' and 'Dezfuli' at three rates of foliar Application of Potassium Sulfate (FAP) during 2012-2013 crop seasons.[a]

Treatments		2012			
Cultivars	FAP[b]	LCh (mg kg^{-1})	FCh (mg kg^{-1})	FSC (mg g^{-1})	FA (mg g^{-1})
Mission	T_1	6.02c	1.45f	25.87a	0.016c
	T_2	9.79a	3.60ab	20.16ab	0.018c
	T_3	7.47bc	2.97cd	22.62ab	0.019c
Koroneiki	T_1	6.60c	3.39abc	14.66bc	0.025bc
	T_2	8.44ab	3.83a	8.19c	0.034ab
	T_3	9.25a	3.16bcd	16.64bc	0.034ab
Dezfuli	T_1	5.99c	2.85de	23.54ab	0.033b
	T_2	6.59c	2.39e	20.68ab	0.034ab
	T_3	8.63ab	2.95cd	28.43a	0.046a
		2013			
		LCh (mg kg^{-1})	FCh (mg kg^{-1})	FSC (mg g^{-1})	FA (mg g^{-1})
Mission	T_1	3.72e	1.25cde	17.51cd	0.020b
	T_2	5.19bcd	1.46bc	16.62cd	0.024ab
	T_3	4.32d	1.32bcd	12.51de	0.020b
Koroneiki	T_1	6.17b	1.32bcd	8.66e	0.018b
	T_2	5.47bcd	1.09de	17.92cd	0.021b
	T_3	8.10a	1.01e	13.44d	0.023ab
Dezfuli	T_1	4.88cd	1.55bc	21.29c	0.021b
	T_2	5.64bc	1.94a	29.00b	0.022ab
	T_3	5.20bcd	1.58b	43.37a	0.030a

[a] The different letters in the same column symbolize statistically significant differences among three treatments and olive cultivars, according to the Duncan`s multiple range test (P≤ 0.05). [b] T_1= 0 g l^{-1} K_2SO_4 (control); T_2= 1 g l^{-1} K_2SO_4, T_3 = 2 g l^{-1} K_2SO_4.

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The results showed in most cases, foliar application of potassium has led to a significant increase in leaf chlorophyll content of all cultivars compared to control treatments (Table 3). The highest concentrations of leaf chlorophyll was recorded in 'Mission' cultivar under 1 g l^{-1} K_2SO_4 (9.25 mg kg^{-1}) and 'Koroneiki' cultivar under 2 g l^{-1} K_2SO_4 (9.79 mg kg^{-1}) during 2012. Insignificant differences in fruit chlorophyll were recorded among K treatments and olive cultivars, with the exception of 'Mission' in the first year and 'Dezfuli' in the second year of this research where fruit chlorophyll was significantly increased by applying 1 g l^{-1} potassium sulfate (T_2). The maximum concentration of fruit chlorophyll was found in 'Koroneiki' (3.83 mg kg^{-1}) and 'Mission' (3.60 mg kg^{-1}) treated with 1 g l^{-1} potassium sulfate during 2012. In the first crop season, fruit chlorophyll concentration of 'Mission' cultivar was significantly increased by 1 g l^{-1} potassium sulfate compared to control; however in other olive cultivars, the similar effect was not observed (Table 3). It is well known that cultivars differently respond to nutrient application (Chatzistathis *et al*., 2009; Loupassaki *et al*., 2002). The increase in chlorophyll concentration might be due to the role of potassium as a precursor in the biosynthesis of photosynthetic pigments. Also, potassium plays an important role in preventing decomposition of newly formed Chlorophyll (Tanaka and Tsuji, 1980). In other studies also foliar spray of potassium sulfate increased the chlorophyll content in sunflower (Akram *et al*., 2009) and banana plants (Kumar and Kumar, 2008).

There was no significant effect of K treatments on Fruit Soluble Carbohydrates (FSC) in the studied olive cultivars in the first year of experiment (2012). However it was found that FSC increased by foliar application of potassium in 'Koroneiki' and 'Dezfuli' cultivars in the second year of research (Table 3). No significant statistical differences were detected for FSC of 'Koroneiki' trees treated with 1 g l^{-1} or 2 g l^{-1} potassium sulfate in 2013, but differences with untreated trees were significant. The maximum level of FSC (43.37 mg g^{-1}) was recorded in 'Dezfuli' trees treated with 2 g l^{-1} potassium sulfate. The higher carbohydrates content in fruit of 'Dezfuli' cultivar might be partly related to the fact that this is a native cultivar and therefore more adapted to environmental conditions of the experimental site. Therefore this cultivar was more efficient in using potassium and showed relatively higher photosynthetic activity. Other studies also showed that application of potassium increased total carbohydrates content in fruit of grape (Arshad *et al*., 2006) and prune trees (Southwick and Olson, 1996). It was reported that carbohydrate biosynthesis and translocation greatly depend on plant K content and the enzyme responsible for synthesis of carbohydrates is activated by potassium. Lower potassium levels result in accumulation of carbohydrates in plants and adequate levels of potassium is necessary for carbohydrate translocation in the sink organs (Amtmann *et al*., 2008; Amtmann and Armengaud, 2009; Geiger and Conti, 1983).

In this research, anthocyanin content of 'Dezfuli' cultivar was significantly increased by 2 g l^{-1} K in the first and second year of research (Table 3). The effect of potassium treatments on fruit anthocyanin was insignificant in 'Koroneiki' and 'Mission' cultivars in both years of experimentation (Table 3). The increase in the production of total anthocyanins with increasing potassium levels might be due to enhancement of Total Non-structural Carbohydrate (TNC). Present findings were also in agreement with the results of other researchers (Ghasemzadeh *et al*., 2010; Norhaiza et *al*., 2009; Wei *et al*., 1990), as they showed that total flavonoids such as anthocyanins production is increased under higher K levels. Potassium has distinct effects on photosynthesis and carbohydrate translocation in plants. This indirectly enhances the biosynthesis of total flavonoids under potassium application.

Water Potential and Stomatal Conductance

Stem Water Potential (SWP) was significantly affected by cultivar in both years, and by K treatments in the second year of this research (Figures 1-A and -B). It was found that the highest stem water potential (-0.5 MPa) in the first year (2012) was recorded in 'Koroneiki' (in October), while the lowest one (-2.9 MPa) was recorded in 'Dezfuli' (in July) (Figure 1-A).

Stem Water Potential (SWP) in all treatments increased from June to November and reached maximum level in October (Figure 1-A). Subsequently, there was a decrease of stem water potential in November which was higher than the *SWP* values in summer. It was found that stem water potential of 'Koroneiki' was greater than that of 'Mission' and 'Dezfuli' during the summer. Similar results were obtained by other researchers, who showed that the water potential values were different among olive cultivars and during different times of season (Bacelar *et al.,* 2009) and it is normally higher in late summer (Burma, 2011; Giorio *et al*., 1999).

As shown in Figure 1-B, the highest stem water potential was observed in the T_3 treatment of 'Koroneiki' (-0.23 MPa) in November, and the lowest was observed in the T_1 treatment of 'Dezfuli' (-2.96 MPa) in July. It was observed that in the measurements from July to November, stem water potential levels of 'Mission' cultivar were higher in treated trees (T_2 and T_3) compared to control (T_1). In fact, the SWP of 'Mission' cultivar increased with foliar potassium applications. The maximum level of SWP in 'Mission' was observed in T_3 (-0.46 MPa) in September and its minimum in T_1 (-2.83 MPa) in August. During the summer (from July to September), stem water potential decreased in 'Koroneiki' in the T_2 and T_3 treatments compared to T_1 (control), while during October and November, stem water potential increased in 'Koroneiki' *cv*. in the T_2 and T_3 treatments compared to control. Stem water potential of 'Dezfuli' cultivar increased by applying K treatment (T_2 and T_3) compared to control during the experiment. The maximum values of stem water potential in 'Dezfuli' cultivar were observed in T_2 treatment in September (-0.5 MPa) and October (-0.6 MPa) and in T_3 treatment in November (-0.6 MPa). It has been suggested that potassium is one of the osmolytes and its accumulation in plant cell might facilitate the occurrence of osmotic adjustment or activate the enzymes involved (Chartzoulakis *et al*., 2006). In the present research such mechanism might have happened due to reduction of water potential in the treated 'Koroneiki' cultivar during the hot summer period. Our finding of stem water potential in untreated 'Mission' and 'Dezfuli' trees was in agreement with a previously reported research in which stated

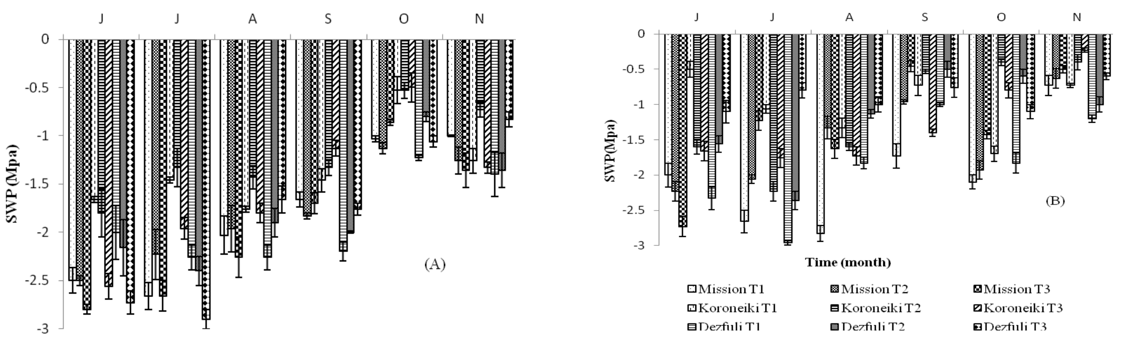

Figure 1. Effect of foliar application of potassium sulfate on stem water potential (SWP) of three olive cultivars in 2012 (A) and 2013 (B). T_1= 0 g l^{-1} K_2SO_4 (control); Months from June (J) to November (N). T_2= 1 g l^{-1} K_2SO_4; T_3= 2 g l^{-1} K_2SO_4. Data are means±*SE*, n= 3 Replicate plants.

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that olive trees are able to reduce the water potential of their tissue and thus create a higher potential difference between their leaves and roots, therefore being able to increase the amount of water absorption from the soil under hot and dry weather conditions (Xiloyannis *et al*., 1999).

Stomatal conductance (g_s) was significantly affected by cultivar and K treatments in both crop seasons (Figures 2-A and -B). 'Koroneiki' trees were more affected than the other two cultivars by the foliar application of potassium in the two studied growing seasons as the level of g_s was remarkably reduced by application of potassium. In fact, a similar response in the stomatal conductance of 'Koroneiki' and 'Dezfuli' cultivars was found. During the first crop season, the maximum levels of g_s were 367.78 mmol m^{-2} s^{-1} in untreated 'Koroneiki' trees in June and 366.39 mmol m^{-2} s^{-1} in untreated 'Dezfuli' trees in October. The minimum levels of g_s were observed in T_2 (54.07 mmol m^{-2} s^{-1}) and T_3 (47.21 mmol m^{-2} s^{-1}) of 'Koroneiki' cultivar in August (Figure 2-A). During the second crop season, the maximum levels of g_s were observed in untreated 'Dezfuli' trees recording 321.2 mmol m^{-2} s^{-1} in July and 349.53 mmol m^{-2} s^{-1} in November (Figure 2-B). 'Mission' cultivar showed different response to foliar application of potassium between the two years of the study. In the first year of experiment, g_s of 'Mission' cultivar decreased by applying T_2 (1 g l^{-1} potassium sulfate) and increased with T_3 (2 g l^{-1} potassium sulfate) compared to T_1 (control). In the second year of experiment, g_s in the T_2 treatment of 'Mission' increased during the season until the end of October compared with control treatment. Treated 'Mission' trees (T_3) showed an increase in g_s in June to July, and then g_s decreased from August to September. Stomatal conductance increased during the next measurements from October until the end of November in all treatments.

Stomatal regulation is an important mechanism in balancing plants water relations (Athar and Ashraf, 2005; Dubey, 2005) and it depends on the distribution of potassium into epidermal cells, guard cells and leaf apoplast (Shabala *et al*., 2002). In apple it was shown that foliar application of potassium reduced stomatal conductance (Swietlik *et al*., 1982). In another study (Arquero *et al*., 2006) on olive trees, higher potassium nutrition led to less stomatal conductance during the whole day compared to low-fed potassium plants. These results are in agreement with those of the present research. However, Akram *et al*. (2009) found that stomatal conductance in sunflower increased significantly with the application of potassium sulfate. In the present study different amounts of potassium sulfate reduced stomatal conductance in 'Koroneiki' and 'Dezfuli' cultivars. This

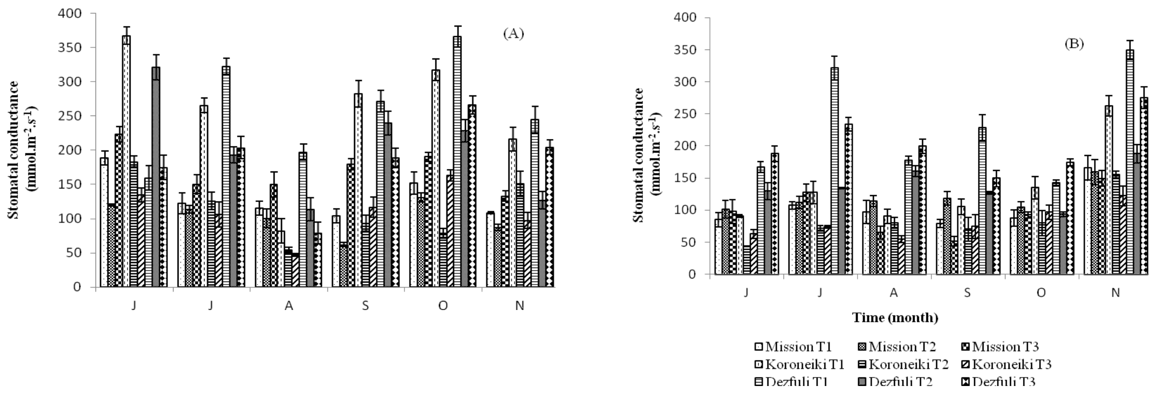

Figure 2. Effect of foliar application of potassium sulfate on stomatal conductance (g_s) of three olive cultivars in 2012 (A) and 2013 (B). T_1= 0 g l^{-1} K_2SO_4 (control); T_2= 1 g l^{-1} K_2SO_4, T_3= 2 g l^{-1} K_2SO_4. Data are means±*SE*, n= 3 Replicate plants. Months from June (J) to November (N).

unexpected result of K nutrition on stomatal regulation of plants was also described by Benlloch-Gonzalez *et al.* (2008). Since potassium is important in the stomatal opening, the application of potassium is expected to increase stomatal conductivity. It has been suggested that the interactions between abscisic acid and ethylene could possibly explain this unexpected response (Benlloch-Gonzalez *et al*., 2010a, b).

Moreover, stomatal conductance decreased during the summer (Figures 2-A and -B). In August, in most cases (Figure 2-A), g_s in all treatments reached to lower values than at the start of the experiment (June). Stomatal conductance increased from August to early autumn (October and November), but in the first crop season, reduction in g_s was observed in November. It seems that in mid-summer, the increase in air temperature and evaporation (Table 1) is associated to low stomatal conductance, then in late summer the decreased evaporation and air temperature resulted in higher g_s than the mid-summer. These finding are similar to those obtained by Burma (2011), who stated that g_s in olive trees grown in Iran, decreased during the summer and increased in the late summer. These results were not similar to those of Giorio *et al.* (1999) in southern Italy which showed that in late summer low evaporative atmospheric demand resulted from low air temperature, *VPD* (Vapor Pressure Deficit) and radiation was associated to low stomatal conductance in olive trees of 'Kalamon' cultivar.

Our data indicated that the pattern of water potential and stomatal conductance were not exactly similar between the two crop seasons. The differences are probably due to changes in environmental conditions and internal plant conditions. Other researchers have also expressed that physiological and environmental variables as well as other plant internal factors can affect the stomatal conductance and water status parameters (Moriana *et al*., 2002). Factors such as time of the day (Mencuccini *et al*., 2000) and the amount of crop load (Palmer *et al*., 1997) seem to play an important role in regulating water status and the chemical signals to control stomatal conductance. In general it can be stated that although the technique of foliar application of potassium has been widely accepted (Swietlik and Faust, 1984; Tagliavini and Marangoni, 2002), however little is known about its effectiveness in various specific environmental conditions. Researchers have examined the effect of foliar application of potassium on different species, but the reported results were different. Such variation in the results is probably due to the fact that this technique is affected by many factors such as plant species, leaf age, type and concentration of the nutrients, number of foliar application, weather condition and plant nutrition status (Swietlik and Faust, 1984).

In the present study, although the differences among the cultivars in their physiological and biochemical responses to the application of potassium should not be ignored, it is important to note that the environmental conditions during the year might have a strong influence on olive trees response. In this research it was inferred that foliar application of potassium on olive cultivars affects the studied physiological and biochemical parameters in different ways and possibly several mechanisms such as gene activation or expression, may be involved in these responses. If such mechanisms exist, more precise studies such as molecular and genetic experiments are required.

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پاسخ های فیزیولوژیکی و بیوشیمیایی ارقام زیتون به کاربرد برگی پتاسیم

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چکیده

این پژوهش در سال‌های ۱۳۹۱ و ۱۳۹۲، در شرایط آب و هوایی اهواز به منظور بررسی اثرات محلولپاشی پتاسیم بر برخی صفات فیزیولوژیکی و بیوشیمیایی سه رقم زیتون (میشن، کرونایکی و دزفولی) انجام شد. سولفات پتاسیم در غلظت های متفاوت (صفر، ۱ و ۲ گرم در لیتر) طی دو مرحله ۵۰ و ۶۵ روز پس از تمام گل، بر روی درختان ۱۰ ساله و بارور زیتون به کاربرده شد. محلولپاشی پتاسیم در هر دو سال سبب افزایش کلروفیل برگ در همه ارقام، میزان پتاسیم برگ در ارقام میشن و کرونایکی و آنتوسیانین میوه در رقم دزفولی شد. تیمارهای پتاسیم اثر معناداری بر نیتروژن و فسفر برگ، پتاسیم و فسفر میوه نداشتند. کاربرد برگی پتاسیم سبب افزایش کربوهیدرات محلول میوه در ارقام کرونایکی و دزفولی در سال دوم آزمایش شد. پتانسیل آب شاخه و هدایت روزنه‌ای برگ به طور معناداری در هر دو سال تحت تأثیر رقم و تیمارهای پتاسیم قرار گرفتند. نتایج نشان داد که کاربرد برگی پتاسیم سبب کاهش هدایت روزنه‌ای برگ در ارقام کرونایکی و دزفولی در هر دو سال گردید. بر اساس نتایج می‌توان بیان کرد که ارقام زیتون به طور متفاوت به تیمارهای پتاسیم طی دو فصل رشد پاسخ دادند و کاربرد برگی پتاسیم می‌تواند اثر مثبت بر کلروفیل برگ، پتاسیم برگ، کربوهیدرات محلول میوه و آنتوسیانین میوه در برخی ارقام زیتون داشته باشد.

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