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Physiological behavior of olive (*Olea europaea* L.) varieties under different foliage nutrition and irrigation regimes in the hyper-arid zone

Sherif El-Gioushy [a], Ibrahim Dobiea [a,b], Botir Khaitov [c,*], Aziz Karimov [c], Reda Zewail [d]

[a] Department of Horticulture, Faculty of Agriculture, Benha University, Egypt
[b] Department of Plant Production, Desert Research Center, Egypt
[c] International Center for Biosaline Agriculture (ICBA), Regional office for Central Asia and the South Caucasus, Tashkent, Uzbekistan
[d] Department of Botany, Faculty of Agriculture, Benha University, Egypt

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Author(s)

S. El-Gioushy
I. Dobiea
B. Khaitov *
A. Karimov
R. Zewail
* Corresponding author

Abstract

Olive (*Olea europaea*) is an emblematic tree in the Mediterranean regions that grows an integral part of the area. The Mediterranean vegetation often undergoes challenging periods of severe drought stress, which causes significant impairment to olive trees' growth and production performance. The practical study was designed to follow up the effect of three irrigation regimes (50%, 75% and 100% ETc) in combination with four doses (0, 2, 4 and 6 g/L) of Lithovit ($CaCO_3$+$MgCO_3$, micronized calcium carbonate) on growth performance, yield, and fruit quality of two olive (Picual and Manzanello) varieties during 2017 and 2018 growing seasons. Regardless Lithovit doses, irrigation regime 100% of ETc exhibited the highest values of leaf water content, leaf relative water content, total chlorophyll and N, P, K, Ca and Mg concentrations of both olive varieties compared to the other watering regimes. Interestingly, proline content in the fruit was enhanced with increasing water deficit (50% of ETc) and Lithovit dose (6 g/L). However, the highest yield and fruit oil content were obtained by the combination of 75% ETc irrigation level and Lithovit treatment at a rate of 4 g/L in both olive varieties. This study contributes to developing olive production technologies, thereby ensuring sustainable olive culture farming with high-quality yield in hyper-arid zones.

Keywords: Olive, Lithovit, drought, irrigation requirements, chemical aspects, water relations, fruit quality, fruit yield.

Introduction

Olive trees were widely grown throughout the Mediterranean basin for around 5000 years. Olives can thrive and produce in arid, semi-arid and new reclaimed areas, as it can resist abiotic stresses such as drought, fluctuation in temperature, salinity, drought (Xiloyannis et al., 1999; Shaheen et al., 2011).

Egypt is a one of the largest olive producer in the world, whereas, in the 2018-2019 growing season the country produced around 450,000 tons of olives, of which approximately 100,000 tons were exported (FAO, 2020). There is a prediction that increasing olive production in Egyptian desert lands will bring much needed added value to the sector through upgrading olive cultivation technology.

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However, drought stress is one of the main challenges that constrain growing olives in Egypt's newly reclaimed areas. Deficit irrigation can seriously impair the growth and production of olives. Although olive trees control water loss by transpiration effectively and can withstand intense internal water deficit, however, its growth and fruit quality gradually reduce with increasing water stress (Lavee et al., 1990). Previous studies also indicated that water stress has an irreconcilable role in olive growth and productivity, seriously deteriorating vegetative and generative performance (Xiloyannis et al., 1999; Tangu, 2014). On the contrary, sufficient water supply certainly increases vegetative growth, yield, and olives' fruit quality (Asik et al., 2014).

According to the climate change forecast scenarios of the Intergovernmental Panel on Climate Changes (IPCC), air temperature will rise and precipitation trends will alter, contributing to enhanced evaporative indicators and diminishing supply of irrigation. In addition, night-time temperature will rise to a larger degree than day-time temperature, whereas, the intensity of drought and heat waves are expected to increase (Stocker et al., 2019). These environmental factors have adverse pleiotropic effects on olive growth and production. Specifically, the water shortage has negative impacts on water connections, nutrient absorption, carbon assimilation, canopy dimension, oxidative pathways, phenology and reproduction processes of olive trees (Bacelar et al., 2006; Brito et al., 2019).

New agro-technologies help plants to alleviate abiotic stresses, which usually cause a big challenge for olive production. As a new material – Lithovit, a new technological fine powder created by tribiodynamic activation and micronization, was found to alleviate a negative impact of drought stress. In addition, some nutrients also contain in this product, including trace elements that influence physiological processes, growth, vitality and quality of the fruit crop as well as increase the resistance to abiotic stresses (Hamoda et al., 2016). Micronized calcium carbonate (Lithovit) fertilizer is a natural stone that was converted to a fine powder in special mills. This material as a foliar application leads to decompose its particles and release among other substances, especially calcium oxide (CaO) and carbon dioxide (CO_2) at high concentration in the intercellular compartment inside the leaves as well as on leaves surface which penetrates directly through the stomata (Kumar et al., 2013). The process of elevating CO_2 in intercellular compartment and leave surface leads to close stomata and reduce photosynthesis efficiently due to diffused carbon dioxide inside the leaves, so plant decreases transpiration rate and reduces water requirement due to high drought tolerance (Bunce, 2003; Ainsworth and Rogers, 2007; Carmen et al., 2014). Recent studies showed the metabolic changes and efficiency of Lithovit treatment on the productivity of various crops, including soybean (Abd El-Nabi and Eid, 2018), wheat (Morsy et al., 2018), onion (Abdelghafar et al., 2016), potato (Farouk, 2015) and many other crops.

To date, only a few studies were dedicated to the combined effect of irrigation regime and Lithovit treatment to olive performance under the arid environment. Thus, this study was initiated to follow up the effect of spraying Lithovit ($CaCO_3$ & $MgCO_3$) on water relations, chemical compositions and yield quality of Picual and Manzanello varieties of olive under severe water stress conditions of the desert area.

Material and Methods

Experiment area and design

This study was carried out at Wadi El-Natron of a private orchard at Wadi El-Natron, El Behera governorate, Egypt (30° 31' 05" N and 30° 07' 34" E). Surface soil samples were taken and air dried for carrying out a chemical analysis which presented in the Tables 1. The experimental field soil is considered sandy soil, consisting coarse sand 15.4%, medium sand 38.1%, fine sand 32.2%, very fine sand 6.5% and silt+clay 0.36%. The experiment was started in December in both two successive growing seasons (2017 and 2018). Two popular olive varieties, Picual and Manzanello, with an age of 11 years old were studied which were grown by vegetative multiplication. The stand density was 333 tree per hectare. Seventy-two bearing trees were selected and divided into 12 different treatments. Each treatment was divided into three replicates and two trees for each of them. These selected trees were treated with three irrigation levels (50, 75 and 100% of ETc) and four concentrations of micronized calcium carbonate (Lithovit) (0, 2, 4 and 6 g/L) which were sprayed as the foliar application in the first week of February, May and August.

Table 1. Soil chemical analysis

Soil layer	Ca^{2+}, mg/kg	Mg^{2+}, mg/kg	Na^{+}, mg/kg	K^{+}, mg/kg	CO_3^{2-}, mg/kg	HCO_3^{-}, mg/kg	Cl^{-}, mg/kg	SO_4^{2-}, mg/kg	pH	EC, ds/m	TDS, mg/L
0-30 cm	25.988	2.518	5.218	0.383	Nil	0.42	30.389	4.828	7.6	3.34	2334.3
30-50 cm	25.850	2.603	5.152	0.382	Nil	0.35	31.423	3.482	7.48	3.22	2243.1

Irrigation water was pumped out of a well and kept for a two hours before using for watering through a drip irrigation system. The well-water exhibited the following chemical indicators: EC 1617 µS/cm, TDS 641.5 mg/l, pH7.7, cations: Ca^{2+} 1.638, Mg^{2+} 1.467, Na^{+} 8.696, K^{+} 0.077 mg/kg, anions: CO_3^{2-} 0.799, HCO_3^{-} 2.599, SO_4^{2-} 0.262, Cl^{-} 7.668 mg/kg.

Climatic Data

El Behera governorate, Egypt is situated in an arid zone where the long-term annual average rainfall does not exceed 7 mm and a growing season average rainfall is around 4-9.5 mm (Table 2). Despite some rainfall (2-4.3 mm) at the beginning of spring, no rain is expected in the summer period. Whereas crop evapotranspiration (ETc) reached the maximum level in June with values of 5.967 and 4.42 mm/day, respectively of the 2017-2018 experiment years (Table 3). In this hyper-arid condition, crop growth is only possible with applying an appropriate irrigation regime (Table 4).

Table 2. Weather data on air temperature, rainfall and relative humidity of the study area, El Behera governorate, Egypt

	Month of the year											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					Air temperature (⁰C)							
2017	15.1	17.5	22.0	29.1	34.5	38.7	39.8	39.8	36,6	31.3	23.3	16.9
2018	15.2	17.3	21.6	29.7	34.0	38.0	39.2	39.3	36.4	30.9	22.2	15.9
LTA	15.2	17.4	21.8	29.4	34.3	38.4	39.5	39.6	36.5	31.1	22.8	16.4
					Rainfall (mm)							
2017	1.0	1.0	1.0	1.0	0	0	0	0	0	0	0	0
2018	1.5	1.5	2.0	2.3	0	0	0	0	0	0	0	2
LTA	1.3	1.3	1.5	1.7	0	0	0	0	0	0	0	1
					Relative humidity (%)							
2017	52.0	44.0	39.0	31.0	29.0	31.0	36.0	38.0	43.0	46.0	51.0	55.0
2018	54.0	46.0	41.0	33.0	28.0	32.0	37.0	37.0	44.0	45.0	52.0	54.0
LTA	53.0	45.0	40.0	32.0	28.5	31.5	36.5	37.5	43.5	45.5	51.5	54.5
					Evapotranspiration mm/day							
2017	1.43	1.95	3.37	4.69	5.43	5.96	5.60	5.23	4.55	5.60	2.48	1.95
2018	1.43	1.94	3.37	4.17	4.42	4.42	3.60	3.36	2.92	3.34	2.30	1.81
LTA	1.43	1.94	3.37	4.17	4.42	4.42	3.60	3.36	2.92	3.34	2.30	1.81
					Crop Coefficient (KC)							
2017	0.50	0.50	0.65	0.68	0.68	0.68	0.70	0.70	0.70	0.70	0.70	0.70
2018	0.50	0.50	0.65	0.60	0.55	0.50	0.45	0.45	0.45	0.65	0.65	0.65
LTA	0.50	0.50	0,50	0.64	0.61	0.59	0.57	0.57	0.57	0.67	0.67	0.67

LTA: Long-term average

Source: Meteorological Station of Damanhur, Bahira Governorate, Egypt.

Table 3. Kc and ETc. in El-Behara, by using climwatt and cropwatt programs.

	First season		Second season	
	Kc	ETc mm/day	Kc	ETc mm/day
January	0.50	1.43000	0.50	1.43000
February	0.50	1.94500	0.50	1.94500
March	0.65	3.37350	0.65	3.37350
April	0.68	4.69125	0.60	4.17000
May	0.68	5.43375	0.55	4.42750
June	0.68	5.96700	0.50	4.42000
July	0.70	5.60700	0.45	3.60450
August	0.70	5.23600	0.45	3.36600
September	0.70	4.55000	0.45	2.92500
October	0.70	3.60500	0.65	3.34750
November	0.70	2.48500	0.65	2.30750
December	0.70	1.95300	0.65	1.81350

Table 4. Irrigation water levels, dates and intervals.

Months	First season						Second season					
	Irrigation requirement L/ day			Irrigation duration	Irrigation interval days	Number of irrigation time/month	Irrigation requirement L/ day			Irrigation duration	Irrigation interval days	Number of irrigation time/month
	100%	75%	50%	hours/ day			100%	75%	50%	hours/ day		
January	23.32	17.49	11.66	0.25	9	3	23.3	17.5	11.7	0.25	9	3
February	31.72	23.79	15.86	0.34	6	5	31.7	23.8	15.9	0.34	6	5
March	55.02	41.27	27.51	0.60	4	7	55.0	41.3	27.5	0.60	4	7
April	76.51	57.38	38.26	0.83	3	10	68.0	51.0	34.0	0.74	3	10
May	88.61	66.46	44.31	0.96	2	15	72.2	54.2	36.1	0.78	3	10
June	97.31	72.98	48.66	1.06	2	15	72.1	54.1	36.0	0.78	3	10
July	91.44	68.58	45.72	0.99	2	15	58.8	44.1	29.4	0.64	3	10
August	85.39	64.04	42.70	0.93	2	15	54.9	41.2	27.4	0.60	4	7
September	74.20	55.65	37.10	0.81	3	10	47.7	35.8	23.9	0.52	4	7
October	58.79	44.09	29.40	0.64	3	10	54.6	40.9	27.3	0.59	4	7
November	40.53	30.40	20.27	0.44	5	6	37.6	28.2	18.8	0.41	5	6
December	31.85	23.89	15.93	0.35	6	5	29.6	22.2	14.8	0.32	7	4

Meteorological data was determined by using climwatt and cropwatt programs to calculate reference evapotranspiration.

ETc calculated as follow:

$$ETc = ETo \times Kc$$

ETc : crop evapotranspiration
ETo : reference crop evapotranspiration
Kc : crop coefficient

Lithovit composition

Natural CO_2 as a Nano-foliar fertilizer in the form of Lithovit (a Nano $CaCO_3$) is a new top quality nanotechnological nanopowder created by tribodynamic activation and micronization. The main constituents of Lithovit® were illustrated as follow: Calcium carbonate 79.19, Sulphate 0.33, Nitrogen 0.06, Iron 1.31, Phosphate 0.01, Zinc 0.005, Potassium oxide 0.21, Manganese 0.014, Magnesium carbonate 4.62, Copper 0.002, Selinium dioxide 11.41, Clay 0.79. Lithovit 2, 4, and 6 g/L concentrations were prepared by mixing with sterile water two hours before the treatment. 10 L of suspension with appropriate concentration were sprayed per olive tree.

Determinations of water relation

Leaf water content (L.W.C.)

The leaves were excised before dawn and fresh weight of the leaf samples was determined. Then, the samples transferred to the oven at 72-75^{0}C., until constant weight. The samples were weighed again after the drying process. This procedure was repeated after 10, 15 and 20 days of the last spray in each experiment in both season and the average data were presented.

Leaf water content was calculated according to the following equation:

$$LWC = \frac{Fw - dw}{Fw} \times 100$$

Fw = fresh weight of leaves

Dw = dry weight of leaves

Leaf relative water content (L R.W.C)

10 leave samples were prepared to determine fresh weight immediately after removal from the trees. These samples were placed into a closed container filled with distilled water and kept until they reached constant weight (about 48 hours after) in a shade place. The leaves were surface dried with a blotting paper and weighted to determine their turgid weight. The dry weight of the discs was determined after 24 hours; this procedure was repeated after 10, 13 and 20 days of the last spray in each experimental season and the average data were presented.

Leaf water relative content was calculated according to the following equation:

$$L.W.R.C = \frac{Fw - Dw}{Tw - Dw} \times 100$$

Tw = Turgid weight

Chemical analysis

The leaf proline content was estimated according to the method described by Bates et al. (1973). Total carbohydrate was estimated according to the method described by Smith et al. (1964).

The percentage of moisture and oil content of fruits

The fresh fruit samples were dried in an oven at 60ºC until constant weight then moisture percentage was calculated. Oil content percentage was estimated from the fresh fruit samples by extracting the oil using hexan at 60-80ºC boiling points by Soxhlet fat extraction apparatus as described in the A.O.A.C. (1990).

Total chlorophyll contents (SPAD)

Total chlorophyll contents on the 5th or the 6th leaves of ten shoots per tree were determined at the end of November in the experimental field by using Minolta chlorophyll meter "SPAD 502" (Wood et al., 1993).

Leaf mineral content

Samples of 30 leaves for each replication were collected from the first full mature leaves (5th – 7th leaves from shoot tips) in mid of October. The leaves were washed with distilled water then dried using an electric oven at 60-70°C until constant weight, then were ground in a stainless-steel mill. Wet digestion was done by using concentrated sulphoric acid and hydrogen peroxide according to Parkinson and Allen (1975). Total nitrogen content was determined by modified the Micro-kjeldahl method as described by Plummer (1971). Phosphorus percentage was determined by the method of Truog and Meyer (1929).

The percentages of potassium, calcium and magnesium were measured by using Atomic Absorption spectrophotometer (Model 3300, MS-DOS, detection limit is 3 s, µg/L, PerkinElmer Inc., USA) according to the method described by Chapman and Pratt (1961).

Fruit weight and yield

Fruit weight was measured by using a balance for 20 fruits per tree. Fruit yield was recorded as kg/tree by using a digital balance.

Statistical analysis

The results in each parameter were exposed to proper statistical analysis of variance for a split plot design with two factors by using statistics computer program (Anonymous, 2008) with three replicates each of them includes average of two trees values. The irrigation regimes were considered as the main plot and the Lithovit treatments as sub plot. Duncan's multiple range tests was used for comparison between means. Different alphabet letters in the column significantly differed at (0.05) level of significance (Duncan, 1955). The same trees were used throughout both experimental seasons.

Results

Water relations in leaves and fruits

Averaged across irrigation treatments, the highest ETc irrigation regime (100%) exhibited the greatest values of leaf water content, relative water content, total chlorophyll and fruit moisture in both Manzanello and Picual olive varieties (Tables 5 and 6). As the subplot effect, the Lithovit treatments significantly enhanced the above-mentioned vegetative parameters of both olive varieties at all ETc irrigation levels, indicating positive effects of the foliage nutrition.

The above-mentioned physiological parameters declined gradually with decreasing ETc irrigation levels and Lithovit application rates. The main plot (ETc irrigation regime) effect was significant for all these parameters, while the subplot (Lithovit treatments) effect values did not reach to significant level at the closed doses.

The highest leaf water content was recorded at an irrigation level of 100% ETc was interacted with 6 g/L Lithovit treatment with values 55.68 and 57.13% in Manzanello and 55.20 and 58.96% in Picual, respectively in the first and second seasons. Conversely, the lowest leaf water content was found at an irrigation level of 50% ETc was used without Lithovit treatment, reducing the values by 54.2 and 41.4% in Manzanello and by 65.5 and 73.6% in Picual, respectively in the first and second seasons. These results were not significantly differed from the values attained at an irrigation regime of 50% ETc when was interacted with 2 g/L Lithovit treatment in both olive varieties, confirming slight changes among the closed Lithovit rates. Whereas, there were the substantial difference in the determined value of both olive varieties when was compared between irrigation levels of 50%, 75% and 100% ETc, proving water deficit is the decisive factor for olive growth performance under the arid zone.

Table 5. Effect of ETc and Lithovit applications on water relations of Manzanello.

Treatments		Leaf water content		Relative water content		Total chlorophyll		Fruit moisture (%)	
ETc	Lith	2017	2018	2017	2018	2017	2018	2017	2018
				Manzanello					
100%	0 g/L	51.77b	52.16b	57.51b	74.56b	70.33bc	78.83c	51.24bc	53.43a
	2 g/L	53.52ab	54.61ac	59.01ab	77.43ab	73.70b	79.27c	52.47ab	54.19a
	4 g/L	54.82ab	56.30ab	60.04ab	79.27ab	74.80ab	80.67b	52.06a	53.37a
	6 g/L	55.68a	57.13a	61.90a	80.61a	75.23a	82.17a	52.86a	54.90a
75%	0 g/L	46.30c	46.48c	52.90d	57.70c	68.57cd	78.57c	48.90cd	50.17bc
	2 g/L	46.83c	46.91c	53.63cd	62.47bc	70.17c	78.60c	50.23c	50.29bc
	4 g/L	46.91c	48.69bc	54.07c	64.14bc	71.30bc	78.60c	51.40bc	51.53bc
	6 g/L	47.04c	49.57bc	54.23c	65.53bc	73.53b	79.03c	51.82ab	51.14bc
50%	0 g/L	36.11d	40.39e	43.51f	43.14e	67.47d	70.27f	46.24e	48.95c
	2 g/L	37.69d	42.13de	47.45ef	46.17f	68.50cd	73.27e	47.24de	48.72c
	4 g/L	38.46d	43.62de	49.32e	51.30d	69.17cd	74.10de	49.15cd	49.93bc
	6 g/L	38.70d	44.32d	49.04e	52.27d-f	71.87c	74.90d	49.67cd	50.23bc

Means followed by the same letters (S) in each column are not significantly different at 5% level.

Table 6. Effect of ETc and Lithovit applications on water relations of Picual.

Treatments		Leaf water content		Relative water content		Total chlorophyll		Fruit moisture (%)	
ETc	Lith	2017	2018	2017	2018	2017	2018	2017	2018
				Picual					
100%	0 g/L	51.49bc	54.29bc	62.21c	70.99b	68.27cd	70.80c	59.05ab	60.14b
	2 g/L	53.01b	55.62b	64.08b	72.13ab	69.63c	71.93c	59.40ab	61.21ab
	4 g/L	54.07ab	57.29ab	65.41ab	72.69ab	72.40ab	74.00b	60.11ab	61.34ab
	6 g/L	55.20a	58.96a	66.46a	74.72a	74.47a	76.93a	61.12a	61.82a
75%	0 g/L	46.54 e	48.70d	50.44e	57.54d	67.53d	68.53d	56.27bc	56.95c
	2 g/L	47.14d	48.81d	52.23d	59.16cd	68.43cd	71.33c	52.76e	58.74bc
	4 g/L	48.95cd	49.70d	52.82d	59.73cd	70.30ab	73.93b	57.26bc	58.92bc
	6 g/L	49.38c	50.52c	53.57d	62.17c	72.80ab	75.80ab	58.35b	59.81bc
50%	0 g/L	33.35f	33.96f	39.42g	47.41fg	65.73g	64.37f	52.51e	54.92d
	2 g/L	34.62f	36.40ef	41.05e	49.02f	66.07de	66.10e	53.46de	55.72cd
	4 g/L	34.61f	36.71ef	42.39fe	51.38ef	67.83cd	67.33d	55.17d	58.13bc
	6 g/L	35.18f	38.29e	43.69f	53.61e	69.17cd	70.77c	57.12bc	57.62bc

Means followed by the same letters (S) in each column are not significantly different at 5% level.

A similar trend was observed in leaf relative water content irrespective of different treatments in both seasons. The interaction between 100% ETc irrigation regime of and 6 g/L Lithovit treatment resulted in the highest leaf relative water content with values of 61.90% and 80.61% in Manzanello and 66.46% and 74.72% in Picual, respectively in the first and second seasons.

Reasonably significance was observed on fruit moisture content that Lithovit at a rate of 6 g/L and 100% ETc irrigation had the maximum fruit moisture content in Manzanello with values of 52.86 and 54.90% and in Picual with values of 61.12% and 61.82%, respectively in the first and second seasons.

Total chlorophyll values were also more influenced by the irrigation regime than the Lithovit treatments. The highest values were recorded in the well-watered treatment (100% ETc) coming together with 6 g/L Lithovit application. Whereas the lowest readings were noted under the severely water-stressed (50% ETc) treatment combined without (0 g/L) Lithovit spray in both olive varieties. The differences between the highest and lowest values were 11.5% and 16.9% in Manzanello and 13.3% and 19.5% in Picual as compared to the control, respectively in the first and second seasons. Although the impact of these treatments showed a similar tendency, a significant difference was revealed in chlorophyll content values between these two olive varieties in majority same treatments, showing variety-specific reactions.

Chemical composition of olive leaves

Lithovit significantly enhanced olive leaf N, P, K, Ca and Mg concentrations, however, the highest readings were detected at 100% ETc irrigation level in both olive varieties (Tables 7 and 8). The leaf nutrients contents increased with increasing irrigation level. The Lithovit effect was not significant at the closed doses in most cases. Averaged across the main plot values, the leaf chemical content was significantly increased at the irrigation regime of 100% ETc as compared to 50% ETc: N 50.4% and 87.1%, P 52.3% and 116.7%, K 99.3% and 56.3%, Ca 23.9% and 28.3%, Mg 104.5% and 75.0% in Manzanello, respectively in the two seasons. Likewise, similar increments under the same treatment were revealed in Picual, N 72.4% and 50.9%, P 27.3% and 77.8%, K 57.5% and 52.8%, Ca 27.3% and 49.2%, Mg 75.0% and 81.8%, regardless of the Lithovit treatments.

Table 7. Effect of ETc and Lithovit applications on chemical content of Manzanello.

Treatments		N, %		P, %		K, %		Ca, %		Mg, %	
ETc	Lith	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
						Manzanello					
100%	**0 g/L**	1.45c	1.69c	0.18b	0.31b	1.19b	1.47bc	1.87b	1.93c	0.19d	0.20d
	2 g/L	1.47bc	1.72b	0.19a	0.33a	1.54a	1.88a	1.90c	1.97bc	0.21c	0.21cd
	4 g/L	1.48b	1.74b	0.16cd	0.29c	1.45a	1.82a	1.92ab	2.01a	0.24b	0.23b
	6 g/L	1.51a	1.81a	0.14ef	0.24d	1.24b	1.38c	1.93a	2.02a	0.26a	0.27a
75%	**0 g/L**	1.28f	1.42f	0.15de	0.21f	0.87d	1.05de	1.69f	1.70f	0.15f	0.16g
	2 g/L	1.32e	1.44ef	0.16c	0.23e	1.25b	1.71ab	1.72e	1.73ef	0.17e	0.18f
	4 g/L	1.35d	1.45e	0.15cd	0.19g	1.02c	1.30cd	1.75d	1.75e	0.19d	0.19e
	6 g/L	1.35d	1.51d	0.13f	0.17h	0.64 e	0.70f	1.76d	1.81d	0.21c	0.22 c
50%	**0 g/L**	0.95i	0.12i	0.11g	0.14i	0.76d	0.88ef	1.51i	1.51h	0.09i	0.11i
	2 g/L	0.98h	1.17h	0.13f	0.16h	0.60ef	1.48bc	1.53hi	1.51h	0.11h	0.13h
	4 g/L	0.99h	1.19h	0.11g	0.14u	0.85d	1.23cd	1.55gh	1.57g	0.12g	0.14h
	6 g/L	1.01g	1.24g	0.09f	0.10j	0.51f	0.60f	1.56g	1.59g	0.12g	0.14h

Means followed by the same letters (S) in each column are not significantly different at 5% level.

Table 8. Effect of ETc and Lithovit applications on chemical content of Picual olives

Treatments		N, %		P, %		K, %		Ca, %		Mg, %	
ETc	Lith	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
						Picual					
100%	**0 g/L**	1.40c	1.71c	0.18b	0.31b	1.47c	1.74b	1.87c	1.92c	0.24c	0.25d
	2 g/L	1.65b	1.74b	0.19a	0.33a	1.79a	2.00a	1.90bc	1.97c	0.26b	0.27bc
	4 g/L	1.68a	1.76b	0.16cd	0.29c	1.62b	1.81ab	1.92b	2.11b	0.26b	0.28b
	6 g/L	1.69a	1.80a	0.14ef	0.24d	1.41 c	1.57bd	1.96a	2.32a	0.28a	0.30a
75%	**0 g/L**	1.27g	1.42f	0.15de	0.21f	1.13d	1.38d	1.69f	1.70de	0.18gh	0.21g
	2 g/L	1.33f	1.47e	0.16c	0.23e	1.21d	1.17e	1.72e	1.73d	0.19ef	0.22f
	4 g/L	1.37e	1.48e	0.15cd	0.19g	1.13d	1.44bd	1.75d	1.75d	0.20e	0.24e
	6 g/L	1.40d	1.52d	0.13f	0.17h	0.86 f	1.07fg	1.77d	1.78d	0.22d	0.26cd
50%	**0 g/L**	0.95j	1.15j	0.11g	0.14i	0.89f	0.99fg	1.50i	1.51ef	0.14j	0.14j
	2 g/L	0.97i	1.18i	0.13f	0.16h	1.00e	1.18dg	1.53h	1.54f	0.15i	0.16i
	4 g/L	0.99i	1.21h	0.11g	0.14u	0.93ef	1.03fg	1.55gh	1.57f	0.17h	0.18h
	6 g/L	1.01h	1.23g	0.09f	0.10j	0.76g	0.91g	1.58g	1.60f	0.18fg	0.18h

Means followed by the same letters (S) in each column are not significantly different at 5% level.

However, the Lithovit treatment at various doses promoted irrigation regimes' effect on leaf chemical content with more obvious indicators than without Lithovit treatment.

The highest N content was detected under the combined application of 100% ETc with 6 g/L Lithovit treatment with values 1.51 and 1.81% in Manzanello and 1.69 and 1.80% in Picual, respectively the first and second seasons. The leaf N contents of these two olive varieties at this combined treatment were significantly higher by 49.5% and 46.0% in Manzanello, by 66.3% and 43.1% in Picual, respectively in the two seasons than those at irrigation level of 50% ETc was used without the Lithovit treatment.

Similarly, leaf Ca and Mg contents were higher under combined application of 100% ETc with 6 g/L Lithovit treatment with values of Ca 1.93% and 2.02%, Mg 0.26 and 0.27% in Manzanello, Ca 1.96 and 2.32, Mg 0.28 and 0.30 in Picual, respectively in the first and second seasons.

The highest P and K contents were found at the irrigation level of 100% ETc was coming together with 2 g/L Lithovit treatment, exhibiting P 0.19% and 0.33%, K 1.54% and 1.88% in Manzanello, P 0.19% and 0.33%, K 1.79% and 2.0% in Picual, respectively in the two seasons.

Whereas, the lowest N, P, K, Ca and Mg concentrations in olive leaf were detected following the application of 50% ETc coupled with 0 g/L Lithovit treatment.

Regardless of Lithovit addition, the plant nutrients (N, P, K, Ca and Mg) contents were higher under 100% ETc irrigation level which was significantly higher than those of other irrigation regimes, confirming the effectiveness of the sufficient irrigation for olive nutritional balance.

Fruit chemical content and yield

The increase of fruit quality and yield was substantially influenced by the interaction of irrigation level and Lithovit application doses in both olive varieties (Tables 9 and 10).

Table 9. Effect of ETc and Lithovit applications on fruit quality and yield of Manzanello.

Treatments		Fruit oil content (%)		Total carbohydrates (%)		Proline content (ppm)		Fruit weight (g)		Fruit yield (kg/ tree)	
ETc	Lith	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
		Manzanello									
100%	0 g/L	38.14f	39.12ef	3.17f	11.29de	14.60g	8.43h	5.04c	5.07f	54.75f	27.83e
	2 g/L	38.47ef	40.23bc	5.03c	13.98ab	14.80g	10.70g	5.62b	5.87d	61.67d	33.67d
	4 g/L	39.02ef	39.65cd	4.05de	12.91bc	16.30f	13.57f	5.71b	6.86b	76.33c	37.83c
	6 g/L	38.01f	38.17f	3.73e	12.55cd	17.37f	15.15e	6.90a	7.93a	56.17e	33.67d
75%	0 g/L	42.15ab	42.76ab	6.90b	12.79bc	19.90e	14.61ef	4.35d	4.57g	62.83d	33.87d
	2 g/L	42.45ab	42.91ab	8.42a	15.23a	21.10de	19.20d	4.87c	4.97fg	75.17ab	41.60b
	4 g/L	43.37a	44.17a	7.31b	14.83ab	22.40d	20.32d	5.72b	5.77de	75.33a	45.43a
	6 g/L	42.78ab	42.65ab	6.77b	13.19bc	25.67c	21.90c	6.02b	6.40c	66.83b	38.33c
50%	0 g/L	39.53d	40.12c	2.41g	8.33g	27.07bc	22.70bc	2.38f	4.00h	19.67i	14.77f
	2 g/L	40.50bc	41.69bc	4.66cd	11.29de	28.17b	23.50b	3.71e	4.17h	25.83g	17.60f
	4 g/L	41.20b	40.78bc	3.50ef	10.03ef	30.63ab	25.37ab	4.07de	4.47g	25.67g	17.10f
	6 g/L	40.01c	39.20d	3.71ef	9.17fg	32.10a	26.23a	4.37d	5.27e	24.17h	15.27f

Means followed by the same letters (S) in each column are not significantly different at 5% level.

Table 10. Effect of ETc and Lithovit applications on fruit quality and yield of Picual.

Treatments		Fruit oil content (%)		Total carbohydrates (%)		Proline content (ppm)		Fruit weight (g)		Fruit yield (kg/ tree)	
ETc	Lith	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
		Picual									
100%	0 g/L	41.13bc	39.21f	3.77d	14.82de	12.92i	10.27h	5.03f	5.47g	38.83h	26.93f
	2 g/L	42.14ab	40.21ef	4.70bc	19.18b	14.70h	13.51g	5.83c	5.47d	48.33f	33.83c
	4 g/L	41.78b	40.07ef	3.78de	16.90cd	18.49g	14.86fg	6.54b	6.90b	52.17e	31.27d
	6 g/L	40.84d	40.76de	3.71d	15.16de	19.76fg	17.30de	7.84a	8.13a	45.67g	29.33e
75%	0 g/L	42.24ab	43.08b	3.74d	15.54ce	18.81g	10.27h	5.25e	5.67h	54.50d	31.10de
	2 g/L	43.39a	44.78a	5.45a	23.29a	21.40ef	15.68ef	5.51d	5.80g	62.67b	38.10b
	4 g/L	42.98ab	42.84bc	5.34ab	16.58cd	22.51e	17.84d	6.03c	6.53g	65.17a	40.60a
	6 g/L	41.83b	42.83bc	4.64bc	16.18cd	24.73d	19.73 c	6.62b	6.67f	58.17c	34.77c
50%	0 g/L	41.13cd	42.09b-d	4.28c	9.69g	26.22c	20.54bc	3.67i	4.77ef	18.00k	11.10i
	2 g/L	42.14ab	42.77bc	4.49bc	14.31e	26.97bc	21.08bc	4.18h	5.33e	22.33i	17.20g
	4 g/L	41.78b	42.03b-d	3.46de	12.14f	28.62ab	21.62ab	4.63g	5.37cd	20.67j	16.27g
	6 g/L	40.84d	41.22c-e	3.15e	11.22fg	29.92a	22.43 a	5.05f	5.63c	19.83j	14.17h

Means followed by the same letters (S) in each column are not significantly different at 5% level.

There was no significant difference in fruit oil content in the closed doses of Lithovit treatment as a sub-plot effect, however, the main plot effect was permanently significant at all irrigation levels.

The highest oil content was detected at 75% of ETc irrigation level was interacted with 4 g/L Lithovit treatment with values of 43.37 and 44.17% in Manzanello, whereas, this parameter in Picual was obtained at

75% of ETc irrigation level combined with 2 g/L Lithovit with values of 43.39 and 44.78%, respectively in the first and second seasons.

Total carbohydrates percentage was significantly varied regarding the interaction between irrigation levels and spraying Lithovit. The highest readings of total carbohydrates percentage were noted under the combined treatment of 75% of ETc irrigation and 2 g/L Lithovit spray with values of 8.42 and 15.23% in Manzanello as well as 5.45 and 23.29% in Picual, respectively in the first and second seasons.

Proline content substantially increased with decreasing irrigation level, however, an opposite increasing trend was observed regarding Lithovit doses in both olive varieties, as well as, Lithovit application doses were significant in most cases. The highest proline content was obtained at 50% of ETc irrigation level combined with 6 g/L Lithovit application in Manzanello with values of 32.10 and 26.23 ppm and in Picual with values of 29.92 and 22.43 ppm, respectively in the first and second seasons. Whereas, the lowest proline content in both olive varieties was revealed at 100% of ETc irrigation level when interacted with 0 g/L Lithovit application, decreasing the above-mentioned parameter by 119.9% and 211.2% in Manzarello and 131.6% and 118.4% in Picual, respectively in the first and second seasons.

A significant difference was observed in olive varieties' fruit weight value regarding the irrigation levels and Lithovit treatments. The highest fruit weight parameter was recorded at 100% of ETc irrigation when interacted with 6 g/L Lithovit in Manzanello (6.90 and 7.93 g) and Picual (7.84 and 8.13 g) in both seasons, respectively. Whereas, the lowest fruit yield was detected at 50% of ETc irrigation combined with 0 g/L Lithovit treatment in Manzanello (2.38 and 4.00 g) and Picual (3.67 and 4.77 g), showing a 2-fold decrease due to the water deficit and Lithovit absence.

Regarding olive fruit yield as a main component of the study, significant interactions were observed between irrigation levels and Lithovit doses. The highest fruit yield of Manzanello (75.33 and 45.43 kg/tree) and Picual (65.17 and 36.14 kg/tree) was achieved at 75% of ETc irrigation combined with 4 g/L Lithovit compared to other treatments, respectively in the two seasons. Whereas, the lowest yield was recorded at 50% of ETc irrigation level was integrated with 0 g/L Lithovit application in Manzanello (19.67 and 14.77 kg/tree) and Picual (18.00 and 11.10 kg/tree), decreasing by 137.6% and 163.2% in Manzanello and 167.8% and 150.8% in Picual compared to the highest values, respectively in the two seasons.

Discussion

Results show substantial differences in the vegetative and generative parameters of the two olive varieties due to the alternative bearing during the two growing seasons. The values of these measured parameters in the first season were higher than those in the second season. A Lithovit treatment at a rate of 6 g/L recorded the highest values of leaf water content and leaf relative water content in Picual and Manzanello, which is highly likely due to the enhanced assimilation and dissimilation process CO_2 in the intercellular compartment and on the leaf surface. Subsequently, it led to close stomata according to Kumar et al. (2013) and decreased the transpiration rate and enhanced photosynthesis. With regard to the irrigation levels, the fruit moisture content of Picual and Manzanello significantly increased with an increasing water supply and 100% of Etc irrigation regime surpassed the other levels in both seasons. Same results were obtained by Ben Rouina et al. (2007) and Boughalleb and Hajlaoui (2011). Thus, these might be the reason for improving fruits' physical characteristics.

An application of Lithovit at a 6 g/L led to maximising the value of total chlorophyll in the first and second seasons. These results in agreement with those obtained by Sabina (2013); Shallan et al. (2016); Hamoda et al. (2016); Abd El-Nabi et al. (2017); Abd El-Nabi and Eid (2018); Ghatas and Mohamed (2018); Fathelrahman et al. (2020). Irrigation level at 100% of ETc stimulated the fruit moisture and total chlorophyll of both varieties, while irrigation at 50% of ETc recorded an opposite trend. Several researchers reported that spraying dolomite nano-particles might play an influential role in enhancing chlorophyll content because of its components (Abd El-Nabi et al., 2017; Ghatas and Mohamed, 2018). Furthermore, the reduction of these parameters was related to the degree of water content, as these parameters decreased gradually with increasing water stress. The negative effect of prolonged water stress reduces the plant cell's water content and relative water content, which affects the rate of cell expansion and ultimate cell size. Drought affects not only physiological processes but also deteriorates biochemical processes. Thus, drought stress caused a reduction in vegetative growth parameters and it depends on the severity of the drought. The reduction of chlorophyll pigment due to water stress might be reflected on degradation and reduction of olives growth and production. These results are in harmony with Sharma (2006); Arzani et al. (2009);

Guerfel et al. (2009); Boughalleb and Hajlaoui (2011); Shaheen et al. (2011); Tangu (2014) and Rosecrance et al. (2015).

An application of Lithovit at a rate of 6 g/L recorded the highest values of leaves N, Ca and Mg contents of both varieties compared to other treatments, while spraying at 2 g/L increased the values of P and K of both varieties in the two seasons. These results were in harmony with Maswada and Abd El-Rahman (2014); Gatas and Mohamed (2018). Water stress at 50% of ETc led to a decrease in the values of leaf mineral contents such as N, P, K, Ca and Mg of both varieties in both seasons. These elements increased gradually with increasing irrigation levels up to 100% of ETc. These results agree with those reported by Benlloch-González et al. (2008) and Shaheen et al. (2011).

Exposure water deficit led to a decrease in total carbohydrates of both olive varieties. These results may be explained by the reason for the degradation and reduction of olives metabolic processes. Also, water deficit in plants is associated with deteriorating physiological, biological, assimilation, and dissimilation processes under water stress conditions. Similar results were proved by Tombesi et al. (1986); Arji and Arzani (2008); Lelago and Tadele (2019).

Regarding the fruit oil content of both varieties, 75% of ETc recorded the highest values of this parameter. These results were in line with previous reports of Berenguer et al. (2004). Results proved that the drought level had a significant effect on the proline content of both varieties. Exposure olives to drought conditions increased proline content. Accumulation of organic compounds like amino acids in cells cytoplasm plays a major role in osmotic adjustment in plants. It is not the only important role of proline accumulation but also proline stores carbon and nitrogen without damaging. Proline is accumulated to higher levels than other amino acids in many plants under drought conditions. This might conclude that olive performance was excellent and the proline accumulation saved olives alive under prolonged drought and environmental stress conditions. It does not mean that olives did not get affected under water stress conditions, but olives adapt excellence under water stress. These findings are in partial agreement with Ennajeh et al. (2006); Arji and Arzani (2008); Bacelar et al. (2009) and Shaheen et al. (2011).

Lithovit treatment at a rate of 4 g/L led to increasing fruit oil and fruit yield of both varieties under 75% of ETc irrigation regime, while 6 g/L dose recorded the highest values of fruit proline content under 50% of ETc irrigation regime. These results are very close with the facts declared by Wang et al. (2013); Carmen et al. (2014); Maswada and Abd El-Rahman (2014); Abo-Sedera et al. (2016); Shallan et al. (2016); Ghatas and Mohamed (2018) and Abdel Nabi and Eid (2018).

While the water deficit increased the amount of proline but decreased the levels of carbohydrates, fruit oil content, fruit weight and fruit yield. These results indicated that water is a key factor for olive survival and productivity in the arid zone. In general, the highest yield was obtained at an irrigation level of 75% ETc which were significantly higher than those of 50% and 100% ETc irrigation regimes, confirming the effectiveness of the sufficient water supply for olive culture in the hyper-arid condition. Furthermore, the additional Lithovit treatments significantly contributed to improving the physiological and morphological attributes of both olive varieties.

Conclusion

A Lithovit treatment as foliage nutrition at a 6 g/L rate combined with an irrigation level of 100% ETc recorded the highest values of leaf water content, leaf relative water content, total chlorophyll and N, P, K, Ca and Mg contents of the two studied olive varieties compared to other treatment combinations.

However, the highest olive yield was obtained at 75% of ETc irrigation regime together with Lithovit treatment at a 4 g/L rate on the Picual and Manzanello varieties. This is the best treatment to balance between vegetative growth and fruiting. Moreover, this positive variance among the irrigation levels and Lithovit concentrations may reduce the hardness of alternative bearing.

Finally, this research indicates that water stress is a vital factor limiting olive production in the Mediterranean basin; sufficient water supply enhances plant growth, while foliage nutrition reinforces the physiological performance of olive plants grown in the hyper-arid zone.

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