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ORIGINAL PAPER

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GENOTYPIC DIFFERENCES OF OLIVE IN REPRODUCTIVE CHARACTERISTICS AND FRUIT YIELD RESPONSE TO DEFICIT IRRIGATION

Rahmatollah Gholami[1✉], Seyed Morteza Zahedi[2]

[1] Crop and Horticultural Science Research Department, Kermanshah Agricultural and Natural Resources Research and Education Center, AREEO, Kermanshah, Iran

[2] Department of Horticultural Science, Faculty of Agriculture, University of Maragheh, Maragheh, Iran

ABSTRACT

Water is the most important environmental factor in growth and fruit yield of trees. To study the effect of deficit irrigation on reproductive characteristics and yield of seven superior olive genotypes of D_1, Dd_1, Gw, Ps_1, Bn_3, Bn_6, and Ds_{17}. The present research was accomplished in Dallaho Olive Research Station of Sarpol-e zahab, Kermanshah, Iran, in 2014 and 2015. Seven superior olive genotypes were studied in a randomized complete block design with three replicates and three irrigation regimes. The irrigation treatments included: 100% full irrigation (control), 75% deficit irrigation, and 50% deficit irrigation applied during the growth season. The results indicated that the genotypes had different reactions to the deficit irrigation regimes. Dd_1 had the highest fruit weight, while the lowest fruit weight was observed in Ps_1 and Gw. The highest fruit yield was found in Bn_3, Bn_6, and Dd_1, while the lowest was observed in Ps_1. As a result, Bn_6 and Dd_1 are introduced as the genotypes that are resistant to drought in the field.

Key words: Olive, genotype, deficit irrigation, fruit characteristics, field

INTRODUCTION

Olive (*Olea europaea* L.) is one of the woody plants which are of outstanding social and economic importance in horticulture [Farzi et al. 2017]. It is evergreen and drought tolerant [Bacelar et al. 2006] and is one of the most important fruits of the Mediterranean area since it is extensively planted for preparing conserve and oil in the regions which suffer from shortage of water resources [Tognetti et al. 2006]. During the recent years, cultivating olive has expanded in the Middle East, especially Iran, due to the economic importance attributed to olive fruit and oil [Arzani and Arji 2000]. Genotypes with high yield which receive sufficient amount of water will give rise to high productivity. In the situations where there is shortage in water supply, olive trees may adapt themselves to water stress and provide proper yield in spite of low amount of water [Tognetti et al. 2005].

Water is a very important determining factor in plant growth and fruit yield in olive [Tognetti et al. 2006]. Considering the dramatic threats of drought and water shortage, providing water requirement of trees is one of the serious limitations in developing olive cultivation. During the recent years, attention was attracted to finding proper methods for optimal utilization of water resources namely using tolerant cultivars [Arzani and Arji 2000], determining critical irrigation times [Motilva et al. 2000], and using growth regulators which reduce respiration [Elhami et al. 2015],

✉ gholami.rahmat@yahoo.com

all of which were applied to save water. Deficit irrigation is an appropriate solution in horticulture which can improve water use efficiency. It involves watering trees on the basis of preserving inner water state of the plants due to the utmost water potential in special stages of plant growth cycle, particularly when fruit growth has the least susceptibility to drought stress [Iniesta et al. 2009, Dell'Amico et al. 2012, Rapoport et al. 2012]. Drought is harmful for plants and using tolerant trees and genotypes would be a suitable method to resist drought [Chen et al. 2011]. Drought stress widely damages trees around the world; therefore it has been the center of attention and the theme of a lot of research during the recent years. Berenguer et al. [2006] showed that decreasing irrigation water will linearly decrease branch length, fruit size, and fruit weight. Deficit irrigation in intensive Arbequina olive gardens led to a decrease in growth, diameter of trunk, and shoot growth while it caused intensive growth of trees [Rosecrance et al. 2015]. To increase and preserve fruit yield, researchers should use cultivars and genotypes with high compatibility whose physiological evolution, especially flowering stage and fruit set, was adapted to optimal climatic periods and have high physiological and genetic resistance against decreased fruit yield due to stress [Rossiel and Hanbelen 1981].

During periods of water shortage, defining deficit irrigation intervals during selected physiological stages leads to a decrease in growth and developed fruit properties and income, compared to the highest production on the basis of yield per unit of water consumption [Tognetti et al. 2006]. Although decreased irrigation causes reduction in growth, reproductive growth, and plant yield, in some areas where there is limited water resources, deficit irrigation has advantages such as lower water consumption, a decrease in growth and reproductive growth, proper corona creation, and a decrease in the expenses related to preserving the garden [Costa et al. 2009, Moriana et al. 2012].

So far, several investigations have been done on the effect of drought and deficit irrigation treatments on the growth of one to several year-old olive plants in pots. Thus, considering cultivation of olive in different climatic areas of the world and threats like drought and water shortage, it is necessary to study this issue in mature native superior genotypes of olive trees.

Since it seems that no research has been done on the effect of deficit irrigation on mature trees and the yield of Iranian superior olive genotypes, the present research aimed at studying and comparing the effect of deficit irrigation treatments on growth and reproductive characteristics of seven Iranian superior genotypes in semi-arid climatic conditions.

MATERIALS AND METHODS

Plant materials and treatments

The present research was carried out in Dallaho Olive Research Station (34°27'N, 45°51'E; elevation above sea level: 547 m) in Sarpol-e zahab, Kermanshah province, Iran, in 2014 and 2015. The results obtained from water and soil analysis of the research site indicated that soil texture is sandy loam with pH of 7.20 and its water pH is 7.25 with EC of 545 mmhos/cm. The experimental materials consisted of 10 year old trees of seven superior olive genotypes named D_1, Dd_1, Gw, Ps_1, Bn_3, Bn_6, and Ds_{17} (Tab. 1). The superior genotypes of

Table 1. Abbreviation of genotypes, collecting location, and usage of local superior genotypes

Abbreviation genotype	Collecting location	Usage
D_1	Dallaho	table olive
Dd_1	Dast Direh	table olive
Gw	Gilan Gharb	oil olive
Ps_1	Srpl Zahab	oil olive
Bn_3	Ban Avareh	table and oil olive
Bn_6	Ban Avareh	table and oil olive
Ds_{17}	Deh Sefid	table olive

Table 2. Mean monthly temperature, relative humidity, evaporation, and rainfall, Sarpol-e Zahab

Year	Month	Temperature (°C)	Relative humidity (%)	Monthly evaporation (mm)	Monthly rainfall (mm)
2014	May	23.90	42	189.30	2.00
2015		23.40	33	244.40	3.70
2014	June	29.50	25	297.30	1.80
2015		30.30	22	353.10	0
2014	July	33.00	22	364.40	0
2015		33.20	21	391.30	0
2014	August	33.20	25	388.00	0
2015		35.10	21	435.20	0
2014	September	29.40	28	302.90	0
2015		31.30	26	356.70	0.10
2014	October	23.10	46	161.50	0.30
2015		25	36	200.70	1.90

this experiment were selected based on the results of our previous experiments. They were treated by three irrigation regimes: 100% full irrigation (control), 75% deficit irrigation, and 50% deficit irrigation. Drip system was applied for irrigating these trees.

This study was conducted in Randomized Complete Block Design with three replications and two factors (olive genotypes and irrigation regimes). The trees were planted in a frame of 5×5 m and each experimental unit consisted of two trees. The data obtained daily from the Synoptic Weather Station of Sarpol-e zahab (Tab. 2) and the Penman-Monteith equation (ETo calculator software) were utilized to measure the potential evapotranspiration and water requirement of the trees from late April (end of rain season) until late October (start of rain season); based on this measurement, the required irrigation water of each tree was estimated based on its evapotranspiration. Drip irrigation was performed every three days by measuring daily evapotranspiration and water requirement of the trees, considering the crop coefficients of olive plants. A water volume meter was applied on each row to estimate the amount of water utilized by the trees. The trees were equally protected in each treatment.

Measurements

Growth and reproductive characteristics of olive genotypes were determined by I.O.O.C [2002]. 40 fruits were randomly selected from each experimental unit and their length and diameter were measured by a digital caliper. To determine the amount of pulp and pit, first, they were separated with a knife; then, they were kept in an oven in 70°C for their dry weight to be stabilized. Afterwards, they were weighed for calculating pulp dry weight and dry matter percentage.

Statistical analysis

The collected data were subjected to analysis of variance (ANOVA) using the GLM procedure from the Statistical Analysis Software (SAS, version 9.1). The Duncan Multiple Range Test was applied to determine significant difference among treatments at the significance level of $P < 0.05$.

RESULTS

Fruit size and yield. There was a significant difference in fruit yield between irrigation regimes and also genotypes both in 2014 and 2015. 100 percent full irrigation caused an increase in fruit yield of the trees (Table 3). The highest fruit yield was observed in Bn_3 (36.40 and 31.7 kg/tree; 2014 and 2015), Bn_6 (38.29 and 37.65 kg/tree; 2014 and 2015), and Dd_1 (37.96 and 40.33 kg/tree; 2014 and 2015) genotypes while Ps_1 (7.15 and 9.27 kg/tree; 2014 and 2015) had the lowest fruit yield (Tab. 3). Fruit size also was significantly

Table 3. The effect of deficit irrigation and olive genotypes on fruit yield and fruit size

Treatments	Fruit yield/tree (kg/tree)		Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)	
	2014	2015	2014	2015	2014	2015	2014	2015
Deficit irrigation								
100% irrigation	28.89a	39.58a	4.91a	4.75a	2.59a	2.61a	1.82a	1.83a
75% irrigation	24.72b	25.23b	4.51b	4.49b	2.44b	2.42b	1.75b	1.76ab
50% irrigation	19.36c	18.78c	3.73c	3.82c	2.22c	2.23c	1.67c	1.72b
Superior olive genotypes								
D_1	22.26b	21.83c	4.32c	4.32c	2.59b	2.61b	1.58c	1.60c
Dd_1	37.96a	40.33a	6.86a	6.83a	2.84a	2.83a	2.19a	2.17a
Gw	13.03c	14.63d	2.93e	2.87d	2.28d	2.34c	1.50d	1.48c
Ps_1	7.15d	9.27e	2.78e	2.72d	2.14e	2.11d	1.52cd	1.51c
Bn_3	36.40a	31.78b	3.95d	4.98c	2.25d	2.23cd	1.81b	1.90b
Bn_6	38.29a	37.65a	5.04b	5.91b	2.41c	2.40c	1.81b	1.91b
Ds_{17}	15.18c	16.19d	4.83b	4.81b	2.41c	2.40c	1.83b	1.89b

Means with the same letter in traits are not significantly different by Duncan's multiple range test at 5%

Table 4. The effect of deficit irrigation and olive genotypes on fruit characteristics of seven superior olive genotypes

Treatments	Pulp fresh weight (g)		Pulp dry weight (g)		Dry matter (%)		Moisture (%)		Pulp (%)		Pulp/Pit	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Deficit irrigation												
100% irrigation	3.94a	3.76a	0.92a	0.89a	37.05c	37.55c	62.94a	62.45a	80.68a	79.52a	1.48a	1.43b
75% irrigation	3.67b	3.63a	0.85b	0.85b	40.18b	40.44b	59.81b	59.55b	80.33a	79.95a	1.56a	1.60a
50% irrigation	2.97c	3.03b	0.73c	0.72c	43.43a	44.21a	56.56c	55.79c	78.97ab	78.64ab	1.54a	1.49ab
Superior olive genotypes												
D_1	3.54c	3.48c	0.44c	0.43c	33.38d	33.59c	66.61b	66.40b	81.76b	80.63b	0.93b	0.90b
Dd_1	5.67a	5.66a	1.03a	1.01a	30.48e	30.67d	69.51a	69.33a	82.60b	82.40ab	1.27a	1.27a
Gw	2.23e	2.18e	0.87b	0.86b	51.15b	52.33a	48.84d	47.66d	75.87d	75.73d	1.74a	1.79a
Ps_1	2.09e	2.03e	0.84b	0.81b	53.73a	54.63a	46.27e	45.36d	75.19d	74.42d	1.73a	1.64a
Bn_3	3.10d	3.10d	0.86b	0.83b	39.71c	40.45b	60.28c	59.55c	78.42c	77.89c	1.68a	1.59a
Bn_6	3.99b	3.85b	0.97a	0.99a	40.45c	41.00b	59.54c	59.00c	79.21c	78.25c	1.58a	1.59a
Ds_{17}	4.08b	4.04b	0.82b	0.82b	32.62d	32.45cd	67.37b	67.54ab	84.56a	83.97a	1.76a	1.79a

Means with the same letter in traits are not significantly different by Duncan's multiple range test at 5%

Table 5. The effect of deficit irrigation and olive genotypes on pit characteristics of seven superior olive genotypes

Treatments	Pit length (cm)		Pit diameter (cm)		Pit fresh weight (g)		Pit dry weight (g)	
	2014	2015	2014	2015	2014	2015	2014	2015
Deficit irrigation								
100% irrigation	1.82a	1.80a	0.86a	0.85a	0.96a	0.99a	0.63a	0.62a
75% irrigation	1.64b	1.67b	0.81b	0.81b	0.83b	0.85b	0.54b	0.54b
50% irrigation	1.57b	1.57b	0.72c	0.78b	0.76c	0.78c	0.48c	0.49c
Superior olive genotypes								
D_1	2.06a	2.04a	0.78c	0.79c	0.78cd	0.84cd	0.46d	0.47cd
Dd_1	1.88b	1.89b	0.95a	0.93a	1.16a	1.19a	0.80a	0.79a
Gw	1.55de	1.51d	0.79c	0.78c	0.70de	0.69e	0.50c	0.49c
Ps_1	1.64cd	1.61d	0.78c	0.78c	0.69e	0.69e	0.49c	0.49c
Bn_3	1.39e	1.39e	0.81c	0.80c	0.84c	0.88c	0.52c	0.53c
Bn_6	1.48de	1.59d	0.86b	0.85b	1.04b	1.07b	0.62b	0.63b
Ds_{17}	1.76bc	1.75c	0.77c	0.78c	0.74de	0.77de	0.47cd	0.46d

Means with the same letter in traits are not significantly different by Duncan's multiple range test at 5%

different between irrigation regimes and olive genotypes. 100% full irrigation led to an increase in fruit weight, length, and diameter, while the highest fruit weight was observed in Dd_1 genotype. Gw (2.93 and 2.87 g; 2014 and 2015) and Ps_1 (2.7 and 2.72 g; 2014 and 2015) genotypes showed the lowest fruit weight and were placed in the same class. From among the olive genotypes studied in this research, Dd_1 (2.84 and 2.83 cm; 2014 and 2015) had the highest fruit length while Ps_1 (2.14 and 2.11 cm; 2014 and 2015) showed the lowest. The highest and lowest fruit diameters were observed in Dd_1 (2.19 and 2.17 cm; 2014 and 2015) and Gw (1.50 and 1.48 cm; 2014 and 2015) genotypes, respectively (Tab. 3).

Fruit characteristics. The results showed that pulp fresh weight, pulp dry weight, and moisture percentage were significantly different at 5% in both experimental years (2014 and 2015). Decreasing irrigation water caused a decline in pulp fresh weight, pulp dry weight, and moisture percentage, while dry matter percentage increased (Tab. 4). From among the olive genotypes studied in this research, Dd_1 (5.67 and 5.66 g; 2014 and 2015) had the highest pulp fresh weight, but Gw (2.23 and 2.18 g; 2014 and 2015) and Ps_1 (2.09 and 2.03 g; 2014 and 2015) showed the lowest pulp fresh weight and were assigned to the same class. The highest pulp dry weight was observed in Dd_1 (1.03 and 1.01 g; 2014 and 2015) and Bn_6 (0.97 and 0.99 g; 2014 and 2015) but the lowest was found in D_1 (0.44 and 0.43 g; 2014 and 2015) (Tab. 4). Considering dry matter percentage, the highest value was found in Gw (51.15 and 52.33%; 2014 and 2015) and Ps_1 (53.73 and 54.63%; 2014 and 2015) and the lowest in Dd_1 (30.48 and 30.67%; 2014 and 2015). The highest moisture percentage was observed in Dd_1 (69.51 and 69.33%; 2014 and 2015) while the lowest was found in Gw (48.84 and 47.66%; 2014 and 2015) and Ps_1 (46.27 and 45.36%; 2014 and 2015). Pulp percentage was the highest in Ds_{17} (84.56 and 83.97%; 2014 and 2015) and the lowest in Gw (75.87 and 75.73%; 2014 and 2015) and Ps_1 (75.19 and 74.42%; 2014 and 2015). In both of the years, D_1 (0.93 and 0.90%; 2014 and 2015) showed the lowest pulp/pit percentage (Tab. 4).

Pit characteristics. According to the results obtained during the two experimental years (2014 and 2015), there is a significant difference in the length, diameter, fresh weight, and dry weight of the pits in olives treated by irrigation regimes. From among the irrigation treatments, the highest length, diameter, fresh weight, and dry weight of the pit was observed in 100% full irrigation treatment (Tab. 5). Also in both of the years, D_1 (2.06 and 2.04 cm; 2014 and 2015) and Dd_1 (1.88 and 1.89 cm; 2014 and 2015) showed the highest pit length, respectively. The highest pit diameter was observed in Dd_1 (0.95 and 0.93 cm; 2014 and 2015) and Bn_6 (0.86 and 0.85 cm; 2014 and 2015), respectively, but the other genotypes were put in the same class. The highest dry (0.80 and 0.79 g; 2014 and 2015) and fresh weight (1.1 and 1.19 g; 2014 and 2015) was observed in Dd_1 (Tab. 5).

DISCUSSION

Considering the results obtained in both of the years (2014 and 2015), there is a relationship between the measured reproductive characteristics of 7 olive genotypes and the amount of irrigation water. Increased development of different organs of the plants is due to the sufficient amount of water they receive for cell division and growth. In other words, growth and development of different organs decrease in the plants under water stress since there is a decrease in cell turgor and also they don't receive enough water required for cell division and growth [Inglese et al. 1996].

The present research investigated the effect of genotype as well as drought stress on fruit size. This effect was also proved in some other studies. Research on Gemlik olive trees showed that 100% full irrigation and 50% deficit irrigation had significant effects on fruit weight, fruit diameter, and pulp/pit percentage, compared to rain fed conditions. The mentioned traits increased in 100% full irrigation and 50% deficit irrigation. Also there was a significant difference between 100% full irrigation and 50% deficit irrigation [Toplu et al. 2009]. The present research reached the same results as the investigations of Nikbakht [2011], Toplu et al. [2009], and Berenguer et al. [2006] did about the effect of deficit irrigation on olive fruit characteristics. Furthermore, compared to 100% full irrigation, increase in dry matter percentage in deficit irrigation treatments can be related to water content of the cells [Sofo et al. 2008]. To resist drought, various plants have different mechanisms such as altering physiochemical compounds inside the cells [Boughalleb and Mhamadi 2011]. There is a significant difference in fruit and pit characteristics and yield of seven olive genotypes, which led to various reactions of these cultivars to irrigation treatments.

The results of the present research show different reactions of superior olive genotypes of Iran to irrigation treatments. Bn_6 and Dd_1 showed better reactions to 75% deficit irrigation while this treatment remarkably decreased the yield of Gw and Ps_1. Several different studies have found that supplemental irrigation improves yield and fruit quality in olive trees [Grattan et al. 2006, Perez-Lopez et al. 2007]. Various olive genotypes show different reactions to irrigation treatments and other management factors; therefore, the observed significant differences in their reaction to deficit irrigation in the present study can be attributed to their resistance.

CONCLUSIONS

It is concluded that the olive genotypes under investigation showed various reactions to the irrigation treatments. The present research aimed at studying the effect of deficit irrigation on seven olive genotypes of Iran, identifying the most resistant genotype, and introducing the cultivars which have the highest potential for reproductive growth and yield. The results showed that Bn_6 and Dd_1 had satisfactory fruit size and yield and can properly adapt themselves o environmental stresses. So they can be introduced as suitable genotypes to be cultivated in different areas of the world.

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REFERENCES

Arzani, K., Arji, I. (2000). The effect of water stress and deficit irrigation on young potted Olive cv 'Local-Roghani Roodbar'. Acta Hortic., 537, 879–885. DOI: DOI10.17660/ActaHortic.2000.537.106

Bacelar, E.A., Santos, D.L., Moutinho-Pereira, J.M., Goncalves, B.C., Ferreira, H.F., Correia, C.M. (2006). Immediate responses and adaptative strategies of three olive cultivars under contrasting water availability regimes: Changes on structure and chemical composition of foliage and oxidative damage. Plant Sci., 170, 596–605. DOI: https://doi.org/10.1016/j.plantsci.2005.10.014

Berenguer, M.J., Vossen, P.M., Grattan, S.R., Connell, J.H., Polito, V.S. (2006). Tree irrigation levels for optimum chemical and sensory properties of olive oil. HortScience, 41, 427–432.

Boughalleb, F., Mhamdi, M. (2011). Possible involvement of proline and the antioxidant defense systems in drought tolerance of three olive cultivars grown under increasing water deficit regimes. Agric. J., 6(6), 371–391. DOI: 10.3923/aj.2011.378.391

Chen, W., Yao, X., Cai, K., Chen, J. (2011). Silicon alleviates drought stress of rice plants by improving plant water status, photosynthesis and mineral nutrient absorption. Biol. Trace Elem. Res., 142, 67–76. DOI: 10.1007/s12011-010-8742-x

Costa, J.M., Ortuno, M.F., Chaves, M.M. (2009). Deficit irrigation as a strategy to save water: Physiologyand potential application to horticulture. J. Integr. Plant Biol., 49 (10), 1421–1434. DOI: 10.1111/j.1672-9072.2007.00556.x

Dell'Amico, J., Moriana, A., Corell, M., Girón, I.F., Morales, D., Torrecillas, A., Moreno, F. (2012). Low water stress conditions in table olive trees (*Oleaeuropaea*L.) during pit hardening produced a different response of fruit and leaf water relations. Agric. Water Manag., 114, 11–17. DOI: https://doi.org/10.1016/j.agwat.2012.06.004

Elhami, B., Zaare-Nahandi, F., Jahanbakhsh-Godehkahriz, S. (2015). Effect of sodium nitroprusside (SNP) on physiological and biological responses of olive (*Olea europaea* cv. Conservolia) under water stress. Int. J. Biosci., 6(4), 148–156.

Farzi, R., Gholami, M., Baninasab, B. (2017). Water-retention additives' effects on plant water status and some physiological parameters of two olive cultivars under reduced irrigation regimes. Acta Physiol. Plant., 39, 126. DOI: https://doi.org/10.1007/s11738-017-2417-6

Grattan, S.R., Berenguer, M.J., Connell, G.H., Polito, V.S., Vossen, P.M. (2006). Olive oil production as influenced by different quantities applied water. Agric. Water Manag., 85(1–2), 133–140. DOI: 10.1016/j.agwat.2006.04.001

IOOC (2002). Methodology for the secondary characterization (agronomic, phonological, pomological and oil quality) of olive varieties held in collection. Project on conservation, characterization, collection of Genetic Resources in olive. International Olive Oil Council.

Inglese, P., Barone, E., Gullo, G. (1996). The effect of complementary irrigation on fruit growth, ripening pattern and oil characteristics of olive (*Olea europaea* L.) cv. Carolea. J. Hortic. Sci., 71, 257–263. DOI: https://doi.org/10.1080/14620316.1996.11515404

Iniesta, F., Testi, L., Orgaz, F., Villalobos, F.J. (2009). The effects of regulated and continuous deficit irrigation on the water use, growth and yield of olive trees. Eur. J. Agron., 30, 258–265. DOI: https://doi.org/10.1016/j.eja.2008.12.004

Moriana, A., Perez-Lopez, D., Prietoc, M.H., Ramírez--Santa-Pau, M., Perez-Rodriguez, J.M. (2012). Midday stem water potential as a useful tool for estimating irrigation requirements in olive trees. Agric. Water Manag., 112, 43–54. DOI: https://doi.org/10.1016/j.agwat.2012.06.003

Motilva, M.J., Tovar, M.J., Romero, M.P., Alegre, S., Girona, J. (2000). Influence of regulated deficit irrigation strategies applied to olive trees (*Arbequina cultivar*) on oil yield and oil composition during the fruit ripening period. J. Sci. Food Agric., 80, 2037–2043.

Nikbakht, J., Taheri, M. Sakkaki, M. (2011). Effect of continues deficit irrigation on yield and quality of fruit and oil of Koroneiki olive (*Olea europaea* L.) cultivar. J. Water Res. Agric., 26(1), 71–81.

Pérez-López, D., Ribas, F., Moriana, A., Olmedilla, N., de Juan, A. (2007). The effect of irrigation schedules on the water relations and growth of a young olive (*Oleae uropaea* L.) orchard. Agric. Water Manag., 89, 297–304. DOI: https://doi.org/10.1016/j.agwat.2007.01.015

Rapoport, H.F., Hammami, S.B.M., Martins, P., Perez-Priego, O., Orgaz, F. (2012). Influence of water deficits at different times during olive tree inflorescence and flower development. Environ. Exp. Bot., 77, 227–233. DOI: https://doi.org/10.1016/j.envexpbot.2011.11.021

Rosecrance, R.C., Krueger, W.H., Milliron, L., Bloese, J., Garcia, C., Mori, B. (2015). Moderate regulated deficit irrigation can increase olive oil yields and decrease tree growth in super high density 'Arbequina' olive orchards. Sci. Hortic., 190, 75–82. DOI: https://doi.org/10.1016/j.scienta.2015.03.045

Rossiel, A.T., Hambelen, Y. (1981). Theoretical of selection for yield in stress and non-stress environment. Crop Sci., 21, 1793–1795. DOI: 10.2135/cropsci1981.0011183X002100060033x

Sofo, A., Manfreda, S., Fiorentino, M., Dichio, B., Xiloyannis, C. (2008). The olive tree: a paradigm for drought tolerance in Mediterranean climates. Hydrol. Earth Syst. Sci., 12, 293–301. DOI: https://doi.org/10.5194/hess-12-293-2008

Tognetti, R., d'Andria, R., Morelli, G., Alvino, A. (2005). The effect of deficit irrigation on seasonal variations of plant water use in *Olea europaea* L. Plant Soil, 273, 139–155. DOI: https://doi.org/10.1007/s11104-004-7244-z

Tognetti, R., d'Andria, R., Lavivi, A., Morelli, G. (2006). The effect of deficit irrigation on crop yield and devel-