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Complementary irrigation for sustainable production in olive groves in Palestine

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ABSTRACT

Prolonged drought stress in Palestine is one of the major limiting factors in the production and yield of the fruit of the olive tree, as this directly affects crop load, oil production per tree, oil quality and alternate bearing. The objective of the present study was to investigate the use of limited amounts of water as complementary irrigation to improve olive fruit growth and yield at harvest. Field-grown adult olive trees (*Olea europaea* L. cv. Nabali Baladi) were selected in three villages on the northern West Bank, and they were subjected to different complementary irrigation regimes from June to September, 2010. They were thus supplied with 1, 3, 6 m^3 water irrigation per tree over this entire period, corresponding to 2.4%, 7.1%, 14.2% of the whole seasonal water requirement per tree (42 m^3 water), respectively. Additional five rain-fed trees per site were used as controls. In one of the three villages, an additional treatment with 15 m^3 (35.6% of the total need) water irrigation per tree, was also applied. The results showed that the fruit size, pulp-to-pit ratio (on a fresh and dry weight basis) and 1-year-old mixed shoots were not affected by these water irrigation regimes. Total fruit yield per tree increased as the water irrigation increased, with the greatest effects for the highest water irrigation treatment, due to a higher number of fruits per tree (apparently due to lower fruit abscission). This study demonstrates that complementary water irrigation of olive trees to 35% of the whole seasonal water requirement can produce positive effects on olive fruit production in Palestine.

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1. Introduction

Olive oil value-chain represents a pivotal sector in Palestine's economy and the primary source of income for more than 100 thousand families: olive tree cultivated areas account for about 93,000 ha (PCBS, 2009) and the average olive oil production is around 17,000 t per year (IOC, 2012).

However, olive trees in Palestine suffer for prolonged drought and high temperatures during the growing season. Under such conditions, the canopy and root vegetative development are negatively affected (Tognetti et al., 2006; Lodolini et al., 2011b). This aspect strongly affects the olive fruit production, and accentuates the natural tendency of the olive trees to alternate bearing bringing yield fluctuations up to 90% between year to year. Therefore, irrigation was considered the most effective tool to enhance olive fruit production and to maintain balanced vegetative growth, with the objective being to reduce the alternate bearing of these olive trees.

For water-irrigated olive groves, it has been shown that the olive yield can be increased by more than 100% in comparison with rain-fed olive trees (Goldhamer et al., 1994; Pastor et al., 1998; Patumi et al., 1999), depending on climate conditions, olive cultivar, and olive tree density and cultivation technique. Several studies have reported that particularly the fruit size, pulp-to-pit ratio, mesocarp cell size, and oil content can be positively affected by increasing the water supply to olive trees (Lodolini et al., 2011a,b; Gucci et al., 2009, 2011; Costagli et al., 2003; Inglese et al., 1996; Lavee et al., 1990; Proietti and Antognozzi, 1996). Moreover, recent studies have suggested that it is not necessary to irrigate olive trees with the whole yearly water amount that would be required by their calculated evapotranspiration. Indeed, in different environments, it was possible to reduce the amount of water applied during the growing season without negative effects on the olive fruit and oil yields (Moriana et al., 2003; Alegre et al., 2002).

Gucci et al. (2007) reported that water irrigation of olive trees can increase the number of fruits per tree, the fruit yield (on both a fresh weight [FW] and a dry weight [DW] basis), the single fruit FW, and the oil content in the mesocarp (on a DW basis) at harvest.

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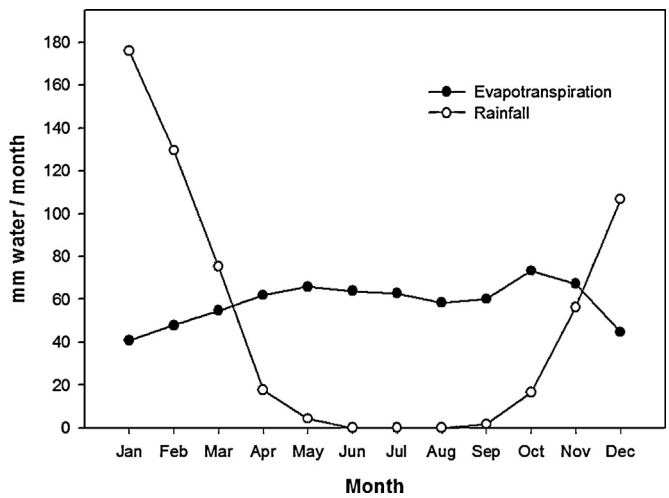

Fig. 1. Monthly olive evapotranspiration and rainfall trend during the year for northern Palestine, estimated as means from 11 years of data (1997–2008). The water deficit period runs from April to November (8 months).

Furthermore, no significant differences were shown between fully water-irrigated olive trees (i.e. 100% evapotranspiration requirement) and those receiving 46% of this total water requirement, using regulated deficit irrigation conditions (Servili et al., 2007). Indeed, this study showed a negative correlation between the total polyphenol content in the olive oil produced and the water status of the olive trees.

To investigate olive tree responses to complementary irrigation as a sustainable water management in a country where water availability is greatly limited, the present study aimed to identify the minimum water irrigation levels for induction of significant increases in the fruit yield in adult olive groves in Palestine (West Bank), as compared to rain-fed conditions.

2. Materials and methods

2.1. Evapotranspiration in Palestine

The total water requirement for olive trees under these Palestinian environmental conditions was estimated by standard methods based on 11 years (1997–2008) weather data for the Nablus and Tulkarem districts (northern West Bank). The calculation of the monthly reference evapotranspiration was carried out according to the Hargreaves equation. Crop evapotranspiration was calculated according to the method of the Food and Agriculture Organization of the United Nations (Doorenbos and Pruitt, 1974). This used the monthly crop coefficients, as reported by Orgaz and Pastor (2005) for similar environmental conditions (Jan: 0.82, Feb: 0.83, Mar: 0.59, Apr: 0.50, May: 0.42, Jun: 0.40, Jul: 0.37, Aug: 0.38, Sep: 0.48, Oct: 0.72, Nov: 0.97, Dec: 0.89), and a coefficient of ground cover of 1.0, determined from the mean diameter of the canopy-projected area of each tree at solar noon (Orgaz and Fereres, 1997). The estimations show that the total water requirement for the olive groves in Palestine is supplied by water irrigation of ca. 42 m^3 per tree through the water-deficit season.

Fig. 1 shows the monthly olive tree evapotranspiration and rainfall trends during the year in the study area, indicating that the water-deficit period can be from April to November (8 months) and rainfall are absent or negligible from May to September.

Table 1
Complementary water irrigation schedule.

Irrigation timing	Irrigation treatment (m^3/tree)			
Mid-June	–	1.0	1.0	2.0
End of June	–	–	1.5	2.2
Mid-July	0.5	1.0	1.5	2.2
End of July	–	–	–	2.2
Mid-August	0.5	1.0	1.0	2.2
End of August	–	–	–	2.2
Mid-September	–	–	1.0	2.0
Total (m^3/tree)	1	3	6	15
%Total evapotranspiration (100% = 42 m^3)	2.4	7.1	14.2	35.6

2.2. Experimental layout

The experimental work was carried out in three different olive groves with adult olive trees. These were selected in three villages in Palestine: Burin (latitude 32°10′41″N; longitude 35°14′54″E; altitude 545 m a.s.l.; Nablus district), Far'un (latitude 32°17′07″N; longitude 35°01′16″E; altitude 139 m a.s.l.; Tulkarem district) and Haja (latitude 32°11′49″N; longitude 35°07′25″E; altitude 324 m a.s.l.; Qalqilya district).

In the spring of 2010, 20 olive trees (cv Nabali Baladi) at similar growth stages were selected in both Burin and Far'un, and 25 olive trees in Haja, for a total of 65 trees. The mean (±standard error) trunk diameter, trunk cross-sectional area and canopy volume (assuming a cylindrical shape) were measured as 0.51 ± 0.02 m, 0.2805 ± 0.029 m^2 and 165.66 ± 11.2 m^3, respectively. The olive trees were spaced in 10 m × 10 m arrays (tree density, ca. 100 tree ha^{-1}).

In each olive grove, completely randomized blocks of 5 replications were subjected to different complementary water irrigation regimes, using several 220 l barrels (according to the water needed) that had holes drilled in the lower side and were located under the perimeter of the canopy projection on the ground. These barrels were refilled with water according to the scheme reported in Table 1 and water release on the ground was controlled during each irrigation date. The different water irrigation treatments were kept well separated to prevent water infiltration across the randomized blocks that could confound the applied water treatments.

2.3. Water irrigation

The complementary water irrigation was managed to supply 1, 3, 6 (and 15 only for Haja) m^3 of water per tree over the period from mid-June (8 weeks after full bloom) to mid-September (20 weeks after full bloom). These water amounts corresponded to 2.4%, 7.1%, 14.2% (and 35.6%), respectively, of the total water requirement for olive tree evapotranspiration in Palestine (i.e. 100% = 42 m^3). In each olive grove, a group of five rain-fed trees was used as the control. The irrigation schedule and supplied water are reported in Table 1.

Data loggers (Testo 175–H1, Testo SpA, Milano, Italy) were placed in each olive grove inside the canopy of a tree, to record air temperature and relative humidity at 60 min intervals throughout the experimental period. The sensors were shielded from direct sunlight. The precipitation records were obtained from the nearest weather station to each olive grove.

In the period from June 1 to October 20, 2010, no precipitation was recorded, and the mean air temperature was 27.1 °C.

2.4. Cultivation practices

Standard cultivation practices for olive groves in Palestine were used, with no fertilizers applied during the irrigation period. Olive fly was periodically monitored, but no spray applications were

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