AGRICULTURAL WATER MANAGEMENT 89 (2007) 297–304

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journal homepage: www.elsevier.com/locate/agwat

# The effect of irrigation schedules on the water relations and growth of a young olive (*Olea europaea* L.) orchard

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ARTICLE INFO

*Article history:*
Accepted 31 January 2007
Published on line 12 March 2007

*Keywords:*
Leaf conductance
Olive
Shoot growth
Trunk growth
Water potential

ABSTRACT

In recent years there has been a notable worldwide increase in the amount of land devoted to olive orchards. Most of these new orchards are irrigated and represent large financial investments. The irrigation of young olive trees should reduce the period during which their production is small or non-existent. Although the water requirements of young olive orchards are thought to be low, little is in fact known in this regard. In the present work, three irrigation treatments (100, 75 and 50% coverage of water needs) were designed using the Orgaz method, and their effects on young olive trees tested in different plots over a period of 3 years. The 50% deficit treatment was designed to provide the trees with an amount of water in the region of that stipulated by the FAO method, the most commonly used irrigation scheduling system for olive orchards. No significant differences in shoot water potential nor abaxial leaf conductance were seen between the trees receiving the different treatments. However, canopy volume and shoot growth were affected. These results indicate that the traditional FAO model, which would have supplied about 35% of the water supplied by the Control treatment, may well reduce the economic benefits to be derived from young olive orchards.



## 1. Introduction

Olive (*Olea europaea* L.) is one of the most characteristic tree crops of the Mediterranean basin. Some 98% of the land devoted to it lies within this region, with Spain, Italy and Turkey the main producers. In Spain, the world's foremost olive-growing nation, the area devoted to this crop has increased by 27% over the last 20 years, while production has increased by 230% (MAPA, 2004). This increase in productivity is mostly due to the irrigation of orchards.

With their higher planting densities, better plant material, and irrigation systems, new olive orchards demand a large capital investment. Irrigation allows young trees to grow more quickly, thus reducing the period during which fruit production is limited or nil. The olive has a long-respected reputation of being drought tolerant (Connor and Fereres, 2005) but few field studies have been undertaken to determine its response to water deficit during the first years after planting.

Irrigation schedules for olive orchards are commonly designed according to the FAO method (Doorenbos and Pruitt, 1974). This approach requires the crop $K_c$ and the reduction coefficient $K_r$ be known. The former varies over the season and estimates of it differ depending on the orchard analysed (range 0.5 to >1) (Orgaz and Fereres, 1997). The influence of the canopy volume is introduced via $K_r$. To our knowledge, however, $K_r$ has never been estimated for olives; instead, that for almond is commonly used (Fereres et al., 1982). The uncertainty of these values, especially for low ground cover orchards, plus the lack of research into the water requirements of young trees, leave considerable doubt regarding the

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0378-3774/$ – see front matter 
doi:10.1016/j.agwat.2007.01.015

optimum irrigation schedules for new orchards. Recently, however, Orgaz et al. (2006) have reported a model for calculating the $K_c$ from a mechanistic point of view in which the canopy volume, rainfall, and evaporation and transpiration are taken into account. This latter estimates greater water needs than the FAO method.

The aim of the present work was to determine the response of a young olive orchard to different irrigation schedules. The initial hypothesis was that the FAO method under-irrigates young orchards in comparison with the Orgaz method, therefore negatively affecting tree growth. Tests were also undertaken to determine whether water potential is a useful indicator for designing irrigation regimes.

## 2. Materials and methods

### 2.1. Experimental design

The experiment was performed between 2001 and 2003 in a young olive (cv. Cornicabra) orchard near Ciudad Real, Spain (39°N, 3°56′W; altitude 640 m). Olive plantlets were planted in 1998; the trees were therefore 3-years old in 2001. The climate of the study area is Mediterranean with an average annual rainfall of 397 mm, mostly distributed outside a 4-month summer drought period. The soil is a shallow clay-loam (Alfisol Xeralf Petrocalcic Palexeralfs) with a depth of 0.75 m and a discontinuous petrocalcic horizon between 0.75 and 0.85 m. The volumetric water content for the first 0.3 m (m $m^{-3}$) was 22.8% at field capacity (soil matric potential −0.03 MPa) and 12.1% at wilting point (soil matric potential −1.5 MPa), and 43.0 and 21.1% respectively at 0.3 and 0.75 m. Tree spacing was 7 m × 4.76 m (300 trees $ha^{-1}$).

Water needs were estimated using the Orgaz model (Orgaz et al., 2006). This estimates the crop coefficient ($K_c$) as the sum of the ratios between the four components of evapotranspiration (ET) and the potential evapotranspiration ($ET_o$) (Orgaz et al., 2006). The components of ET are: soil evaporation ($K_{s1}$), tree canopy transpiration ($K_p$), evaporation from the emitter-wetted areas ($K_{s2}$), and the direct evaporation from the canopy after a rainfall event ($K_{pd}$). $K_{s1}$ and $K_{s2}$ apply to different parts of the soil surface: $K_{s2}$ must be weighted depending on the fraction of the soil that is wetted by the emitters, and $K_{s1}$ to the fraction not wetted by the emitters. The $K_c$ and its components are shown in Table 1. The importance of tree transpiration is very low in comparison with that of the soil evaporation components, although this increased six-fold from 2001 to 2003 season.

Experimental irrigation treatments were designed for May to September to supply a percentage of the water needs:

(1) Control: 100% of water needs as estimated by the Orgaz method.
(2) Mild deficit (MD) treatment: 75% of the amount of water supplied in the Control treatment.
(3) Severe deficit (SD) treatment: 50% of the amount of water supplied in the Control treatment.

Water was supplied under the different regimes 5 days per week, using the drip method and employing four (8 l $h^{-1}$) emitters per tree. The latter were equally spaced around each tree, 0.75 m from the main trunk. No pruning was performed during the experimental period. A randomised complete-block design was used with four replicates of 21 trees per block.

**Table 1 – Components of the crop coefficient ($K_c$) during 2001, 2002 and 2003, according to the Orgaz model: $K_p$ is the transpiration of the tree canopy, $K_{pd}$ the evaporation from the canopy after a rainfall event, $K_{s1}$ the soil evaporation (i.e. that not wetted by the emitters), and $K_{s2}$ the evaporation from the emitter-wetted soil**

| Month | $K_p$ | $K_{pd}$ | $K_{s1}$ | $K_{s2}$ | $K_c$ |
|---|---|---|---|---|---|
| 2001 | | | | | |
| May | 0.01 | 0.01 | 0.36 | 0.23 | 0.36 |
| June | 0.01 | 0 | 0.12 | 0.20 | 0.15 |
| July | 0.01 | 0 | 0.09 | 0.20 | 0.12 |
| August | 0.01 | 0 | 0.10 | 0.20 | 0.13 |
| September | 0.01 | 0 | 0.24 | 0.22 | 0.25 |
| 2002 | | | | | |
| May | 0.03 | 0.01 | 0.26 | 0.26 | 0.30 |
| June | 0.04 | 0 | 0.16 | 0.23 | 0.21 |
| July | 0.04 | 0 | 0.10 | 0.23 | 0.16 |
| August | 0.03 | 0 | 0.15 | 0.24 | 0.20 |
| September | 0.03 | 0.01 | 0.37 | 0.27 | 0.40 |
| 2003 | | | | | |
| May | 0.05 | 0.01 | 0.24 | 0.25 | 0.29 |
| June | 0.06 | 0 | 0.10 | 0.22 | 0.18 |
| July | 0.06 | 0 | 0.06 | 0.22 | 0.15 |
| August | 0.05 | 0 | 0.13 | 0.22 | 0.20 |
| September | 0.05 | 0 | 0.17 | 0.24 | 0.24 |

Table 2 shows the amount of water applied in 2001, 2002 and 2003 in each treatment and the theoretical irrigation needs as estimated by the FAO and Orgaz methods. Both the amount of water applied and the estimated needs were calculated taking into account the rainfall in the irrigation period. The amount of water applied varied from 61 to 83 mm in 2001, from 69 to 93 mm in 2002, and from 97 to 175 mm in 2003. In all years, the FAO water need estimates were lower than the amounts of water actually applied. During 2002, problems with the flow-meters reduced the amount of water supplied in the Control and MD treatments by 25% of that estimated.

Crop evapotranspiration ($ET_c$) was calculated for all irrigation seasons (from June to September). Rainfall was very low during these times, and deep percolation was assumed to be negligible. Although the irrigation season was actually from May to September, May was not taken into account in the estimation of $ET_c$ because of the heavy rains during the 2001 and 2002 seasons. $ET_c$ was calculated as:

$$ET_c = (\theta_1 - \theta_2) + I + R \quad (1)$$

where $\theta_1$ and $\theta_2$ are the volumetric water contents of the first and last day of the irrigation period respectively, $I$ is the amount of irrigation water provided, and $R$ is the rain during the period considered.

### 2.2. Plant water relations

The volumetric water content of the soil was measured with a neutron probe calibrated for the soil in question. Four access tubes, 0.8 m long, were placed at the corners of a square between two trees per replicate plot in all three irrigation