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Scheduling deficit irrigation of citrus trees with maximum daily trunk shrinkage

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ABSTRACT

The feasibility of scheduling deficit irrigation using maximum daily trunk shrinkage (MDS) was evaluated during two consecutive seasons in a citrus orchard planted with mature 'Clementina de Nules' trees, in Valencia, Spain. Results showed that MDS in well irrigated trees varied largely according to the environmental conditions (higher correlation was obtained with global radiation), and therefore, the absolute values of MDS cannot be employed as the only variable to schedule irrigation. To avoid the effects of the climatic conditions we scheduled deficit irrigation using the MDS ratio, which is the MDS of any treatment related to the MDS of a control, well irrigated, treatment located in the same plot. We explored the feasibility of scheduling irrigation based on the MDS ratio in a deficit irrigated treatment, where water was applied as necessary, from July until mid October, in order to maintain the MDS values at 125% of that of the control treatment. Despite the large variability observed in the MDS measurements in both years no significant reduction in yield and fruit weight was observed in the deficit irrigated treatment compared with the control, allowing seasonal water saving between 18 and 12%.

1. Introduction

Traditionally, irrigation scheduling in citrus orchards has been done according to the FAO method, using the crop coefficient there reported (Doorenbos and Pruit, 1977), or those obtained in Valencia (Castel, 1997). However, this strategy has some uncertainty particularly in citrus trees where water use might change depending on tree light interception (Consoli et al., 2006) or crop load (Syvertsen et al., 2003; Yonemoto et al., 2004).

Previous research investigated the effects of reducing water application in citrus trees during certain phenological periods (Ginestar and Castel, 1996a; González-Altozano and Castel, 1999). In general, the period after June fruit drop is less sensitive to water restrictions, providing that water applications returned at full dosage sufficiently before harvest in order to allow for compensation in fruit growth (Cohen and Goell, 1988). However, even if water restrictions are applied only during the lineal phase of fruit growth, severe plant water stress might reduce final fruit size at harvest (Hutton et al., 2007). Precise determination of plant water status could be then used to schedule deficit irrigation avoiding that the water stress becomes too severe and detrimental to yield and fruit quality.

The measurement of plant water status integrates the soil water available to the plant and the climatic conditions, and might provide for a prediction of tree responses to water supply (Intrigliolo and Castel, 2006a,b). In this sense, stem water potential is the more commonly used parameter to estimate plant water status (Shackel et al., 1997). However, since its measurement cannot be easily automated the use of

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trunk diameter variations as water stress indicators has also been evaluated in the last years (Naor, 2006). In this respect, the maximum daily trunk shrinkage (MDS) has been proposed as a reliable water stress indicators in citrus trees (Ginestar and Castel, 1996b; Ortuño et al., 2006a).

In a number of studies, it has been shown that in well irrigated trees MDS depended largely on the climatic conditions (Fereres and Goldhamer, 2003; Intrigliolo and Castel, 2006b; Ortuño et al., 2006b). This complicates the use of MDS in absolute terms to schedule irrigation as proposed by Bussi et al. (1999). To avoid the effects of the climatic conditions two different approaches appear suitable. Growers might previously define the effects of the evaporative demand on MDS and later use this relationship or "baseline" as a reference to correct the actual MDS values obtained. However, recent findings have shown that other factors can also affect MDS independently of environmental conditions, such as the phenological period (Marsal et al., 2002; Fereres and Goldhamer, 2003; Intrigliolo and Castel, 2004), the crop load (Intrigliolo and Castel, 2007) or the size of the trees (Intrigliolo and Castel, 2006b). These features imply that a reference equation obtained under certain conditions might not be applied in following years, if tree characteristics change. To avoid this problem, the other approach suitable is to relate the actual MDS values of a given treatment to the reference MDS values obtained in well irrigated trees in the same plot (García-Orellana et al., 2007). The ratio actual MDS/MDS well irrigated can then be the used as an indication of the water status of the trees to schedule irrigation.

Given these considerations the objectives of the work were: (1) to obtain reference equations for MDS as a function of environmental variables, (2) to explore the feasibility of using the MDS ratio as a parameter to schedule deficit irrigation, (3) to study the yield and fruit quality responses to deficit irrigation scheduled with MDS ratio compared with well watered plants.

2. Materials and methods

2.1. *Experimental plot and irrigation treatments*

The experiment was performed during 2003 and 2004 in an orchard planted with 'Clementina de Nules' citrus trees (*Citrus clementina*, Hort ex Tan) grafted on Carrizo Citrange (*Citrus sinensis*, Osb. 3 *Poncirus trifoliata*, Raf.). The trees were planted in 1985 at a spacing of 6 m $\times$ 3.85 m and were drip irrigated by six pressure compensated emitters per tree, each giving 4.l h^{-1}. The orchard is located at the Instituto Valenciano de Investigaciones Agrarias (IVIA) experimental farm, in Moncada (39° 30′ N, 0° 24′ E, elevation 68 m) where the climate is Mediterranean.

The soil is a calcareous, sandy loam to sandy clay loam, with an effective depth of 0.6 m, limited by a petrocalcic horizon. Available water capacity is of 125 mm m^{-1}, and bulk density ranges from 1.430 to 1.550 kg m^3. The soil is rich in available potassium (6.4 mmol kg^{-1}), and poor in both organic matter (0.7%) and phosphorus (1.0 mmol kg^{-1} Olsen). The irrigation water used had an average electrical conductivity (at 25 °C) of 1.2 dS m^{-1}, an average chloride content of 3.4 mol m^{-3} and a SAR value of 1.4.

Water meters (Contagua, S.A., Model 13.115) were used to measure irrigation applied to each experimental unit. All treatments received through the irrigation system a seasonal average of 132–44–94 kg ha^{-1} of N, P_2O_5, and K_2O, respectively, split almost evenly in weekly applications from April to September. Climatic data were recorded at an automated weather station near, the orchard, about 1 km away, and daily average air vapour pressure deficit (VPD) and daily reference evapotranspiration (ET_o) were calculated according to Allen et al. (1998).

The statistical design was a randomized complete-block with three replicates per treatment. The experimental unit had six rows with six trees per row for the control and four to five rows for the deficit irrigated treatment. In all cases, perimeter trees were used as guard.

The irrigation treatments were: (1) control, irrigated without restriction during all year at 115% in 2003 and 100% in 2004 of the evapotranspiration measured in a weighing lysimeter planted with a tree similar to others in the orchard (Castel, 1997); (2) $MDS_{1.25}$, that was deficit irrigated from July (after June fruit drop) to October, in order to maintain its MDS at a level of 125% of that of the control treatment. This was done by varying in a $\pm$10 to 20% the water applied with respect to the control according to the evolution of the MDS ratio ($MDS_{1.25}$:$MDS_{control}$). At the beginning of the experiment, before deficit irrigation was applied, the MDS ratio was of 0.74 and 0.79, in 2003 and 2004, respectively, and therefore the target values of the ratio were $0.74 \times 1.25 = 0.92$ and $0.79 \times 1.25 = 0.99$. The MDS signal intensity of 1.25 was adopted based on previous results obtained in this same orchard (González-Altozano, 1998) it would induce a mild plant water stress.

2.2. *Water relation determinations*

Due to equipment limitations, trunk diameter variations (TDV) were measured in three and four trees per treatment, in 2003 and 2004, respectively. On each experimental tree, a sensor was fixed to the main trunk by a metal frame of Invar (a metal alloy with a minimal thermal expansion) located about 20 cm from the ground. Average stem diameters at sensors installation height were 14.9 and 13.5 cm in 2003 and 15.3 and 13.9 cm in 2004 for the control and deficit treatments, respectively. Other details on sensors installation and calibration, and data recording were given in Ginestar and Castel (1996b). From TDV, we calculated the maximum daily trunk shrinkage (MDS) obtained as the difference between the maximum diameter reached early in the morning and the minimum reached normally during the afternoon.

Pre-dawn water potential (Ψ_{pd}) and mid-day stem water potential (Ψ_{stem}), were measured with a pressure chamber, following procedures described by Turner (1981), in three leaves per tree of each of the trees used for TDV measurements. Determinations of Ψ_{stem} were carried out (between 12:00 and 13:00 h solar time, approximately every 15 days) in mature leaves from the north quadrant close to the trunk, enclosed in plastic bags covered with silver foil at least 2 h prior to the measurements. Pre-dawn water potential was determined on a monthly basis.