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SOIL WATER CONTENT MEASURED BY FDR PROBES AND THRESHOLDS FOR DRIP IRRIGATION MANAGEMENT IN PEACH TREES*

CONTENIDO DE AGUA EN EL SUELO MEDIDO CON SONDAS FDR Y UMBRALES PARA MANEJO DE RIEGO POR GOTEO EN DURAZNO

Oussama Hussein-Mounzer[1], José Rodolfo Mendoza-Hernández[2], Isabel Abrisqueta-Villena[1], Luis Mario Tapia-Vargas[3], José María Abrisqueta-García[1], Juan Vera-Muñoz[1§] y Mari Carmen Ruiz-Sánchez[1]

[1]Departamento de Riego, Centro de Edafología y Biología Aplicada del Segura-Consejo Superior de Investigaciones Científicas (CEBAS-CSIC) P. O. Box 164, 30100 Espinardo, Murcia, España. [2]Colegio de Postgraduados, *Campus* Tabasco, México. [3]Campo Experimental Uruapan, INIFAP, Uruapan, México. [§]Author for correspondence: jvera@cebas.csic.es

ABSTRACT

Soil water content was monitored continuously with multisensor capacitance probes, based on the frequency domain reflectometry (FDR) technique, in drip irrigated young peach trees (*Prunus persica* (L.) Batsch) cv. Flordastar in a semiarid region of Murcia, Spain during 2004. The aim of this work was to study the effect of two irrigation treatments on volumetric soil water content and to determine the irrigation management thresholds of the soil water store (SWS) as monitored by FDR probes. The treatments consisted in restoring the soil water content to 100% (T1) and 50% (T2) of the crop evapotranspiration (Etc) by applying different irrigation doses with similar frequency. The continuous measurements of soil water content by the capacitance sensors reflected properly the impact of different irrigation events on the soil water stored and provide useful information upon the advance of the wetted front, the depth of the root system activity and the fate of the applied water. Through the continuum soil-plant-atmosphere, the variations of the soil water content were used to determine the *in situ*: “fullpoint” (142 mm 0.5 m^{-1}), field capacity (132 mm 0.5 m^{-1}), and “refillpoint” (124 mm 0.5 m^{-1}) as practical thresholds for irrigation management to match the irrigation doses and frequency with the actual plant water requirements. Graphical determination of irrigation thresholds minimized the importance of small fluctuations in soil water content. For the early ripening “Flordastar” peach cultivar the reduction of water application down to 50% ETc has lead to a progressive depletion of the soil water storage without a significant effect on final fruit yield and increased water use efficiency from 2.7 kg m^{-3} in T1 to 5.0 kg m^{-3} in T2.

Key words: capacitance FDR probe, drip irrigation, fruit yield, irrigation scheduling thresholds, *Prunus persica* L. *Batsch*, water use efficiency.

RESUMEN

El contenido de agua en el suelo fue monitoreado en tiempo real con un multisensor de capacitancia, basado en la técnica de reflectometría en el dominio de la frecuencia (FDR), en una huerta joven de durazno (*Prunus persica* L. Batsch cv. Flordastar) con riego por goteo. El objetivo de este trabajo fue estudiar efecto de dos tratamientos de riego en el contenido volumétrico de agua del suelo y establecer los umbrales de manejo del agua de almacenamiento del suelo (SWS), bajo monitoreo con sensores FDR durante

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2004. Los tratamientos consistieron en restaurar el contenido de agua del suelo a 100% (T1) y 50% (T2) de la evapotranspiración del cultivo (ETc) aplicando diferentes dosis de riego a igual frecuencia. Las medidas continuas del SWS registradas por los sensores FDR reflejaron el impacto de los diferentes eventos de riego en el contenido de agua del suelo, proporcionaron información del avance del frente de humedad, de la profundidad activa del sistema radicular y del destino del agua de riego. A través del continuo suelo-planta-atmósfera, las variaciones del SWS, fueron usadas para determinar *in situ* el "nivel superior (fullpoint)" (142 mm 0.5 m^{-1}), la "capacidad de campo" (132 mm 0.5 m^{-1}) y el "nivel inferior (refillpoint)" (124 mm 0.5 m^{-1}) como umbrales prácticos para manejo de riego y ajuste de la dosis y frecuencia de riego con los requerimiento reales de agua de la planta. La determinación gráfica de los umbrales de riego minimizó la importancia de pequeñas fluctuaciones del contenido de agua del suelo. Para el cultivar de durazno "Flordastar" la reducción de aplicación de agua hasta 50% de ETc condujo a una reducción progresiva del contenido de agua del suelo sin producir efecto significativo en el rendimiento de fruto y un incremento de la eficiencia de uso de agua de 2.7 kg m^{-3} en T1 a 5.0 kg m^{-3} en T2

Palabras clave: *Prunus persica* L. *Batsch*, eficiencia del uso de agua, riego por goteo, rendimiento de fruto, sensor de capacitancia FDR, umbrales de riego.

INTRODUCTION

Drip irrigation systems have played a major role in improving irrigation water use efficiency and have contributed to reduce the volume of water applied to horticultural crops. Accordingly, in the region of Murcia-Spain, the extension of drip-irrigated land has increased from 60 ha in 1975 to more than 70 000 in 2006, of those more than 65% are cultivated with fruit trees. More than 40% of the irrigated stone fruit orchards are planted with peach trees; therefore, peach is one of the most widely cultivated and well-equipped deciduous fruit tree (CAAMA, 2006). However, the use of drip irrigation has not always resulted in water saving and has not been a cost effective solution to improve water use efficiency. Therefore and due to the shortage of available water resources, mainly in arid and semiarid regions, the feasibility and precision of irrigation scheduling methods has to be reviewed.

During the last years, several tools have been developed to support the appropriate decision making on irrigation management by means of the continuous monitoring of either the environment (Dane and Topp, 2002), the plant (Jones, 2004) or soil variables (Allen *et al*., 1998). However, most irrigators do not use these tools in a systematic way (Meyer and Nobel, 1993; Australian Academy of Technological Sciences and Engineering, 1999). In addition, these highly sophisticated tools are unreliably in the field, or farmers can not afford the time and expense for collecting, interpreting and implementing the information they provide. Therefore, there is a continuous search to develop a feasible and accurate irrigation scheduling method that maximizes water use efficiency and takes into account the needs of irrigators through the use of soil, plant or environmental sensors.

A well developed method to precisely calculate and estimate reference evapotranspiration (ETo) by measuring environmental variables (solar radiation, air temperature, relative humidity and wind speed) is in place (Allen *et al*., 1998). However, the generation of irrigation schedules requires the ETo values to be multiplied by experimentally developed crop coefficients (Kc) to take into account the actual plant water requirements. The determination of these coefficients, for each crop *in situ*, is usually avoided because it is difficult and time consuming. This situation makes the use of the available Kc values from the literature to be widely extended which consequently lead to a mismatch between the actual plant water requirements and the applied irrigation schedules. The Kc coefficients are annually variable and need to be continuously reviewed. In the case of deciduous trees, they are affected by additional factors such as canopy architecture, tree density, pruning practices, crop load, irrigation method, and soil surface management (Fereres and Goldhamer, 1990).

Plant-based sensing has several potential advantages to assess the actual water status in the continuum soil-plant-atmosphere CSPA (leaf and stem water potential, sap flow, trunk diameter fluctuations, stomatal leaf conductance, among others), including a greater relevance to plant functioning than soil based measures, nonetheless, these still have a number of practical difficulties for implementation that are limiting the development of commercially successful systems (Jones, 2004).

Therefore, the soil as a water reservoir is still relevant and since 1980 several methods that rely on the measurement of soil electric properties as a substitute for volumetric soil water content have been studied (Topp *et al*., 1980; Dean *et al*., 1987; Paltineanu and Starr, 1997). The use of electromagnetic techniques are spreading increasingly because they facilitate a rapid, safe, nondestructive, and easily automated estimation of soil water content. Capacitance probes are relatively inexpensive and easy to operate. Furthermore, the sensor design is very adaptable, facilitating the development of a variety of configurations (Robinson *et al*., 1998) and the continuous records by capacitance probes; provide information about the dynamic variation of the soil water content due to water application, the soil hydraulic properties, plant water uptake and climatic demand (Starr and Paltineanu, 1998; Goldhamer *et al*., 1999).

The aim of this paper was to study the effect of two irrigation treatments on the volumetric soil water content and to set the irrigation management thresholds of the soil water store (SWS) in young early-ripening peach trees. This was assessed by analyzing the dynamic in the variations of soil water content, measured in continuous by multisensor capacitance probes, based on frequency domain reflectometry (FDR) technique placed within the plant root zone.

MATERIAL AND METHODS

Experimental site

The present work was conducted during 2004, from full bloom to leaf senescence, in an experimental 0.8 ha plot located in Santomera-Murcia (Spain): 38º 06' N, 1º 02' W. The soil is stony and shallow, highly calcareous (56% Calcium carbonate), with a clay-loam texture and low organic matter content (0.34%) and cationic exchange capacity of 12.6 meq 100 g^{-1}, classified as Lithic xeric haploxeroll (Soil Survey Staff, 1998). The bulk density of the soil was 1.45 Mg m^{-3} down to 50 cm, but more compacted (1.67 Mg m^{-3}) at deeper layers. The volumetric soil water content was 0.24 cm^3 cm^{-3} at field capacity (θ_{FC}) and 0.15 cm^3 cm^{-3} at wilting point (θ_{WP}), as determined in undisturbed soil samples with a matric potential of -0.33 and -15 bar respectively using the Richards pressure plate technique, which implied an available soil water content of 90 mm m^{-1}.

The plant material consisted of three-year-old peach trees (*Prunus persica* L. Batsch) cv. "Flordastar", on GF-677 peach rootstock, planted at 5 x 5 m. The trees were irrigated by a single lateral line per plant row with four self-compensating emitters per tree, spaced at 0.5 m and placed 1 m from each side of the trunk, providing 2 L h^{-1}. Irrigation was scheduled on the basis of weekly estimated ETc and automatically controlled by an irrigation programmer and electro-hydraulic valves. The irrigation water volumes were measured with in-line water meters.

Agro-meteorological data were recorded by an automated station located within the peach orchard. During the experimental period the average maximum and minimum air temperatures were 30.1 and 7.7 ºC, respectively. The annual reference evapotranspiration (ETo) determined by the Penman-Monteith equation (Allen *et al*., 1998) was 1 100 mm, with a maximum of 10 mm day^{-1} in August. Total rainfall was 440 mm, from which 245 mm occurred during the spring season.

Treatments

To achieve the objective of this work, two irrigation treatments were considered. In the T1 treatment, the trees were irrigated to 100% of ETc estimated as reference evapotranspiration (ETo), calculated with the Penman-Monteith methodology (Allen *et al*., 1998), crop coefficients (Table 1) (Doorenbos and Pruitt, 1986; Fereres and Goldhamer, 1990), and the percentage of ground area shaded by the tree (Fereres and Goldhamer, 1990). The T2 treatment was irrigated at 50% of the T1 with the same irrigation frequency.

Treatments were distributed in a completely randomized design with four replications, each consisting of one row of 13 trees. The central nine trees were used for experimental measurements and the others served as guard trees.

Soil and plant measurements

The volumetric soil water content was continuously monitored through the soil profile using multisensor capacitance probes (Cprobe^{TM}), based on frequency domain reflectometry (FDR) technique. Two probes per treatment were used. Each probe, with four sensors at 0.10, 0.20, 0.30 and 0.50 m depth, was installed perpendicular to the emitters's line and at 10 cm from it, within the wetted area of the first emitter of a randomly selected peach tree. An emitter gauge was installed to monitor the soil water inputs. Both, the capacitance probe and the rain gauge were connected to a radio transmission unit which registered the average of three measurements every 15 min. The multisensor capacitance probes were properly installed within the active root system zone and the soil water distribution by the emitters was highly uniform.

Table 1. Kc values utilized to calculate Etc for peach trees cv. Flordastar during the experimental period. Murcia, Spain, 2004.

January		February		March		April		May		Jun	
-	-	0.38	0.43	0.58	0.65	0.70	0.75	0.85	0.90	0.98	0.98
July		**August**		**September**		**October**		**November**		**December**	
0.55	0.50	0.38	0.40	0.40	0.38	0.40	0.38	0.38	0.30	-	-

Capacitance probe readings were converted to volumetric soil water content using a local calibration equation. The later was established after saturating the soil within 1 m around the access tube. Afterwards, with one-week interval, the readings of the capacitance sensors and the volumetric soil water content measurements were performed at intervals of 0.10 m from 0 to 0.80 m depth, within 0.40 m from the access tube.

Throughout the irrigation season, different frequencies and doses of irrigation water were applied either during the night or during the day in order to record a large number of different dynamic variations of soil water content within the active root zone. Afterward, these records were analyzed to establish soil water thresholds for irrigation scheduling considering the stem water potential.

Midday (13:00-14:00 h) stem water potential (Ψ_x) was measured every other week with a pressure chamber (Soil Moisture Equip., model 3000). Four trees per treatment were randomly selected and two leaves per tree were measured. The leaves were selected from within the canopy and close to the trunk and introduced into a small bag of polyethylene covered with aluminum foil at least 2 h prior to measurement. Leaves were placed in the chamber within seconds of excision and precautions recommended by Hsiao (1990) were taken.

The yield was evaluated by measuring weight and number of fruits per tree, in five trees of each replication, and water use efficiency (kg m^3) was calculated.

RESULTS

Advance of the wetted front

The observed changes in the soil water content measured with the multisensor capacitance probes during and after abundant drip irrigation (36 h), are shown on Figure 1. After 1 h of the start of irrigation, the wetted front was first detected by the sensor located at 0.10 m depth, and then it was detected at 0.20 m and 0.30 m, respectively and reached the sensor at 0.50 m depth about 4 h later. The advance of the wetted front within the wetted bulb is difficult of estimating because it depends on the soil characteristics, the initial soil water content, the emitter discharge rate, the root distribution and the crop evapotranspiration rate (Or and Coelho, 1996; Elmaloglou and Malamos, 2006). The FDR's continuous measurements facilitate the detection of the wetted front, allowing for determining the amount of water needed to wet the desired soil depth.

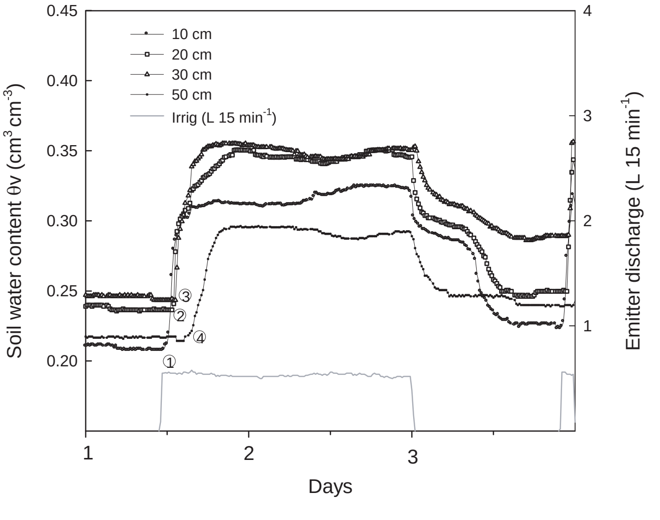

Figure 1. Changes in soil water content at different depths within the active root zone determined with multisensor capacitance probes during and after an abundant irrigation (0.10, 0.20, 0.30 and 0.50 m). The grey line indicates the emitter discharge rate and the duration of the irrigation event. The numbers within circles indicate the order of detection of the wetted front.

In situ determination of apparent soil water saturation (aSWsat)

While irrigation continued, the water content at each soil layer increased progressively up to a constant value which was maintained during a long time (more than 24 h) until irrigation was switch off (Figure 1). At this constant soil water content, the soil pores within the volume of influence of the sensors were *quasi* saturated and the water flow had reached a steady state (Jury *et al.*, 1991). The repeating pattern of nearly constant maximal soil water content following several abundant irrigation events indicated an *in situ* apparent soil water saturation (aSWsat). Under our experimental conditions the aSWsat for each sensor was about 0.32, 0.35, 0.35 and 0.29 $cm^3\ cm^{-3}$ at 0.10, 0.20, 0.30 and 0.50 m depths, respectively. Accordingly, the cumulative soil water content in the 0-0.50 m soil depth, called soil water store (SWS), was 162 mm 0.5 m^{-1}. The determination of aSWsat helps for the establishment of irrigation strategies that minimize drainage to deeper soil layers (Starr and Paltineanu, 1998).

In situ determination of field capacity within the wetted bulb (FC_b)

After the cessation of irrigation (Figure 1), at midnight of the second day, the soil water content decreased markedly during 2-3 hours due mainly to the redistribution of the gravitational water, then soil water content at each sensor depth showed a tendency to stabilize at a constant value because the water redistribution was decreasing significantly. The soil water content under these conditions fit well with the concept of "field capacity" defined as "the amount of water held in soil after excess water has drained away and the rate of downward movement has materially decreased" (Veihmeyer and Hendrickson, 1949). Thus, the field capacity values determined for each sensor were 0.26, 0.27, 0.30 and 0.25 $cm^3\ cm^{-3}$ at 0.10, 0.20, 0.30 and 0.50 m depth, respectively. The SWS at the 0-0.5 m soil depth at field capacity was 136 mm 0.5 m^{-1}.

Plant water uptake

On the third day, from sunrise until mid afternoon, a rapid decrease in the soil water content was detected by the different capacitance sensors (Figure 1). However, the magnitude of the diurnal soil water loss was more evident in the first layer (0.10 m depth), less important in the subsequent soil layers and negligible at the deepest one (0.50 m depth), which indicates the depth of the active root zone as well as the intensity of root water uptake at each soil layer. In general, root development under drip irrigation is constrained to the soil volume wetted by the emitter, near the soil surface with root length density decreasing with depth (Michelakis *et al.*, 1993; Stevens and Douglas, 1994).

Thresholds for irrigation scheduling

Thresholds for irrigation scheduling are practical guide lines to determine the quantity of water and irrigation frequency that supply the plant needs without producing undesired water losses. In agreement with the observations above described the continuous real time measurements of the soil water dynamics provided useful information for irrigation management such as: the advance of the wetted front, the apparent soil water saturation and the depth of the plant active root zone. Accordingly, two limits could be established to precisely determine the dose and frequency of irrigation:

- Lower limit or "Refillpoint"; it corresponds to the SWS at which irrigation should be resumed before the plants undergo water stress. The amount of water allowed to be depleted from the soil profile before resuming irrigation depends, among others aspects, on the crop, the cultivar, the phenological stage and on the intensity of the evaporative demand. For these reasons, exhaustive local studies should be carried out to determine the manageable allowable deficit for each crop. A refillpoint" equal to 90% of the field capacity might be practical for nearly all crops as it is equivalent to a manageable allowable deficit lower than most of the values recommended by FAO (Allen *et al.*, 1998).

- Upper limit or "fullpoint", which corresponds to the SWS value recorded when the wetted front reaches the bottom of the active root zone during a nightly irrigation event. That corresponds roughly to water content between aSWsat and FC_b. This may lead to decreasing percolation of water beneath the active root zone in excess of any required leaching for salinity management.

Therefore, the irrigation dose is related to the time needed to raise the SWS from the refillpoint up to the fullpoint, whereas the irrigation frequency is determined by the effect of the evaporative demand (ETc) to deplete the SWS from the fullpoint down to the refillpoint.

The dynamic of the SWS considering several irrigation events is shown on Figure 2. The SWS represents the cumulative water content within the active root zone (0-0.50 m depth) which is the sum of the sensors's values at 0.10, 0.20, 0.30 and 0.50 m depths plus interpolated values at 0.40 m depth. The predetermined irrigation scheduling limits and the dynamic of the soil water content at the bottom of the active root zone are also shown. Each rapid rise in the soil water stored corresponded to an irrigation event. The first abundant irrigation induced saturated conditions down to the deepest sensor and produced percolation beneath the root zone.

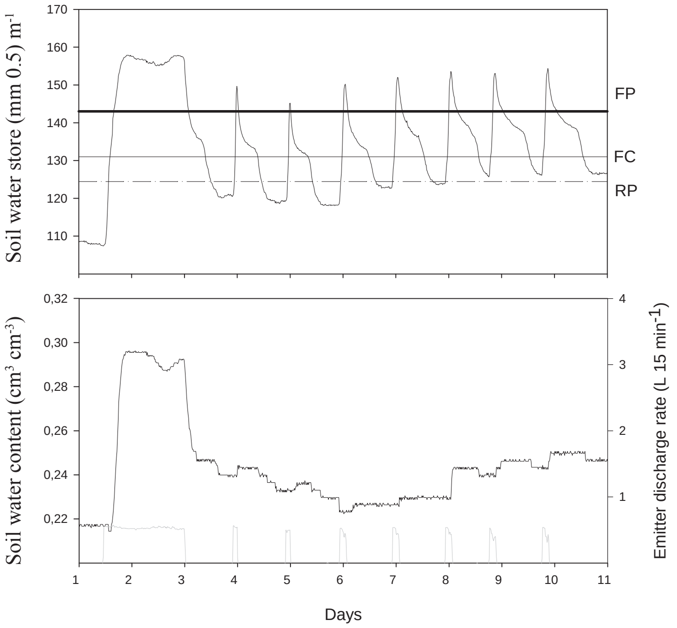

Figure 2. Changes in: A) the soil water store (SWS) within 0-50 cm depth, and B) in the soil water content at the bottom of the active root zone at 50 cm depth). The horizontal lines correspond to the upper limit or "fullpoint" (thick line FP), field capacity (thin line FC) and lower limit or "refillpoint" (dash-dot line RP). The dashed arrows represent the tendency of the soil water store toward field capacity.

The subsequent irrigation events were guided by the irrigation scheduling limits. On days 4, 5, 6 and 7 the quantity of water applied refilled the store up to its upper limit without increasing the water content at the lowest layer. On days 8, 9 and 10 the soil water content at 50 cm depth started to increase gradually as irrigation doses raised the store over its upper limit. After every irrigation event and the following water distribution within the soil layers the soil water content showed a tendency toward the FC (Figure 2, dashed arrows).

Accordingly, any irrigation event that did not increase the soil water store up to its upper limit can be considered deficient since it did not wet the profile of the active root zone, whereas the soil water store above the "fullpoint" can be interpreted according to the moment of the irrigation event:

- During a nightly irrigation event, it indicated an excess of applied water.

- During a daily irrigation event, under high evaporative demand ETc, it indicated that the soil pores within the sensors' volume of influence were nearly saturated even before the wetted front reached the deepest sensor. A low unsaturated hydraulic conductivity on the limits of the wetted bulb, with a high rate of water absorption by the root system slows down the advance of the wetted front.

On the other hand, it is important to note that graphical determination of irrigation thresholds minimizes the importance of small fluctuations in soil water content. Independently of the value of soil water content, the soil saturation and deep percolation events can be easily detected and corrections made on time to maintain the crop at the optimum irrigation condition and water use efficiency at its maximum.

Soil and plant water status

The meteorological conditions (ETo and rain), the plant water status (stem water potential, Ψ_x) and the irrigation events together with the variation of the daily average of soil water store (SWS), measured with the multisensor capacitance probes, across the growing season, are shown in Figure 3. Each sudden increase in the SWS corresponds to an irrigation or rain event and the subsequent daily decreases are mainly due to crop evapotranspiration.

Under low climatic demand and frequent rain events, the Ψ_x was similar (-0.5 MPa) for both treatments from April to late May even the SWS was close or below the refillpoint. From June to late August the high evapotranspiration values (ETo > 6 mm d^{-1}) induced a gradual decrease of the Ψ_x while the leaf area index was increasing (Mounzer, 2005). In July, the Ψ_x decreased down to -1.0 and -1.2 MPa for T1 and T2, respectively, pointing out how high evapotranspiration can induce stress effects on the plant even to well watered trees (Figure 3). These observations are in accordance with the studies of Lampinen *et al.* (1995), Intrigliolo and Castel (2004) and with the results of McCutchan and Shackel (1992), which underlined that under non limiting SWS, the values of stem water potential higher than -1.0 MPa are due to high

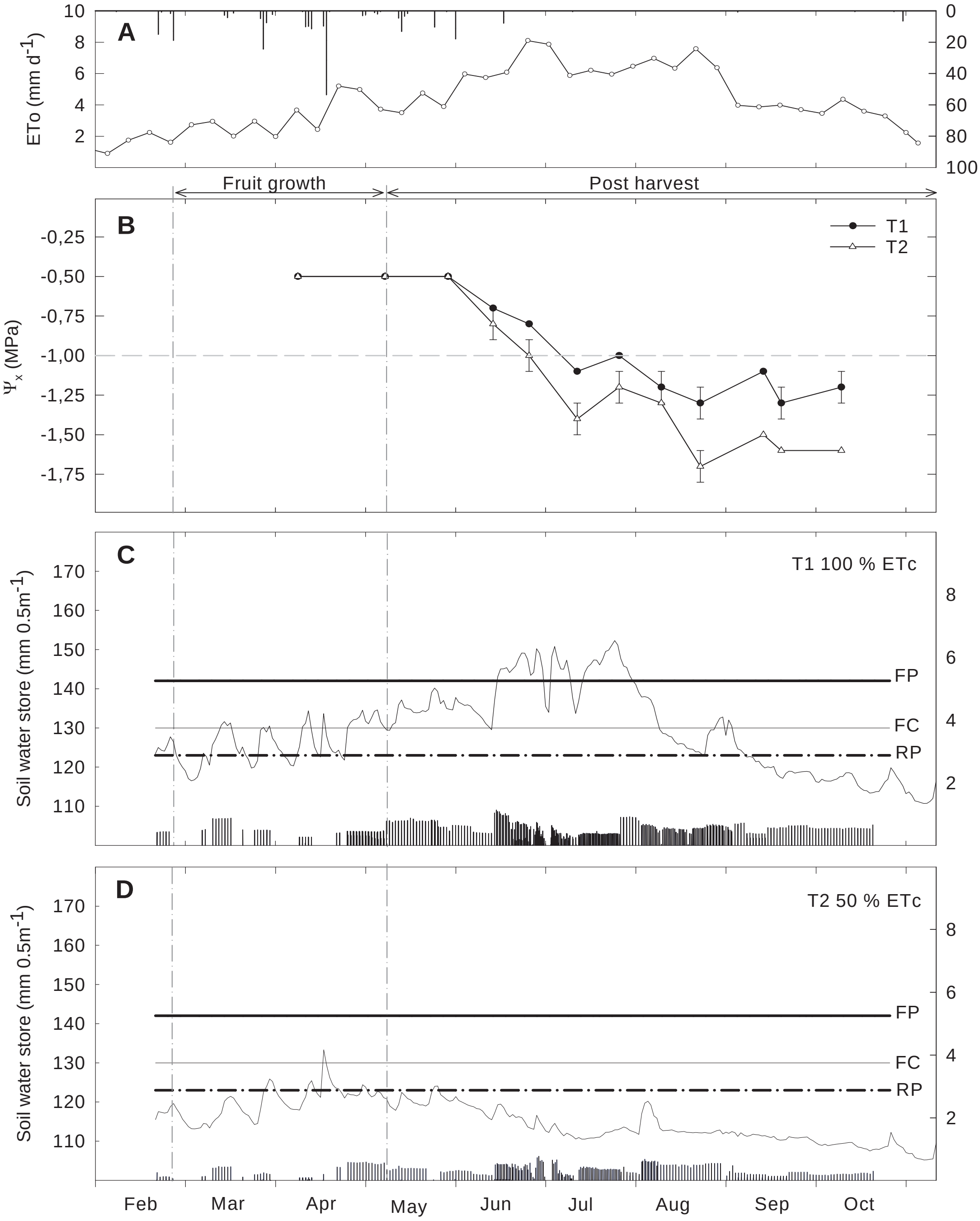

Figure 3. **A) Daily reference evapotranspiration and rainfall events, B) Seasonal trend of stem water potential (Ψ_x) in T1 (closed symbols) and T2 (open symbols) treatments, and C, D) seasonal pattern of soil water store in 0-50 cm soil layer and irrigation events for treatments T1 (100% ETc) and T2 (50% ETc), respectively. The horizontal lines correspond to the upper limit or "fullpoint" (thick line, FP), field capacity (thin line, FC) and lower limit or "refillpoint" (dash-dot line, RP).**

evaporative demand, whereas the values lower than -1.0 MPa are due to soil water deficit.

From late July, the Ψ_x of both treatments decreased progressively down to values of -1.25 and -1.75 MPa in T1 and T2, respectively, mainly due to the changes in the corresponding crop coefficients.

The SWS of the T1 treatment increased gradually from January to July, and then decreased to its minimum at the end of November. The seasonal pattern of the SWS took the shape of a bell due to a mismatch between irrigation schedules and actual plant water requirements since the soil water holding capacities do not change during the year. Irrigation scheduling based on weekly crop evapotranspiration induced excessive and deficit irrigation conditions before and after July, respectively.

The deficit treatment (T2) received 50% of the full water requirements all over the year. Therefore, its SWS remained below the refillpoint and its seasonal pattern has shown a lightly negative slope with little variation with respect to T1 treatment. This pattern could be due to the fact that the evapotranspiration demand was consistently higher than the water supplies, plant water requirements increased, while the soil water store was depleted. Nevertheless SWS was far from wilting point, (80 mm 0.5 m^{-1}) supplied water at 50% of the ETc was enough to afford the water requirements of this crop in a semiarid environment and to maintain a soil water status in an acceptable condition.

Irrigation water use efficiency

Reducing the quantity of water applied for peach trees down to 50% of the crop evapotranspiration produced an evident reduction in the soil water store values between T1 and T2 treatments (Figure 3) without affecting the fruit yield (Table 1). Total fruit yield was statistically similar in both treatments with 15.1 kg $tree^{-1}$ in T1 and 14.59 kg $tree^{-1}$ in T2, as well as the number fruits with 122.2 and 127.7 fruits $tree^{-1}$, for T1 and T2, respectively.

These results comes up from the fact that under Mediterranean climatic conditions in the region of Murcia, the early ripening peach variety "Flordastar" develops its fruits from full bloom to harvest with only 30% of its maximum leaf area index (Mounzer, 2005) lasting about 90 days and coinciding with mild climatic demand and frequent rain events. Therefore, an important amount of irrigation water applied in post harvest is lost due to evapotranspiration rather than being transformed into economic value.

Applied irrigation water, fruit yield and water use efficiency (WUE) were calculated for both treatments (Table 2). The three-year old peach trees in treatment T2 received 116 mm, while the amount of water applied to T1 was 222 mm. In spite of this difference, fruit yield was similar for both treatments. Hence, T2 showed higher WUE than T1, with 5.0 and 2.7 kg m^{-3}, respectively. This means that although T2 received half of the applied water to T1, the fruit yield was not significantly affected; being able to perform as well as the 100% ETc irrigated treatment. This fact agrees with the results obtained by O'Connell and Goodwin (2003), who found that peach trees irrigated at 50% of ETc were not affected in fruit yield, furthermore it increased WUE from 6.4 kg m^{-3} for 100% of ETc to 16 kg m^{-3} for 50% of ETo.

CONCLUSIONS

The soil water content within the active root zone of young early-ripening peach trees was continuously monitored with multisensor capacitance FDR probes under different irrigation amount regimes. The graphical analysis and interpretation of the soil water dynamic variations as affected by water flow in the continuum soil-plant-atmosphere, permitted *in situ* determination of the soil apparent saturation >145 mm 0.5 m^{-1}, the field capacity 130 mm 0.5 m^{-1} and the

Table 2. Fruit yield and water applied in the two irrigation treatments of 'Flordastar' peach trees, 2004.

Treatment	Water applied (mm)	Fruit yield (kg $tree^{-1}$)	Fruit number per tree	Water use efficiency (WUE, kg m^{-3})
T1	222.0	15.1	122.2	2.7
T2	116.5	14.6	121.7	5.0

corresponding upper 142 mm 0.5 m^{-1} and lower 128 mm 0.5 m^{-1} thresholds of the soil water content needed to schedule a drip irrigation that supplies the plant water requirements with the minimum of undesired water losses. Also, it was possible to reduce irrigation water from 222 to 116 mm, with no effect on plant productive potential; moreover, it increased the water use efficiency from 2.7 kg m^{-3} to 5.0 kg m^{-3}.

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