peach trees

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Introduction

Regulated deficit irrigation (RDI) is an irrigation strategy designed to save water with a minimum impact on yield and fruit quality (Chalmers, 1989). In stone fruits trees two critical periods have been defined. The first one corresponds to the second rapid fruit growth period (stage III), when water stress induces a reduction in yield due to the smaller fruit size at harvest. The second critical period is the early postharvest period, in which water stress affects flower bud induction and/or the floral differentiation processes that occur at this time (Ruiz-Sánchez et al., 1999).

It is important to bear in mind that in peach trees RDI can reduce yield if the recovery of tree water status is delayed after deficit irrigation, particularly when the water stress extends into the stage III of fruit development (Girona et al., 1993). For this reason, in early maturing peach trees, with their very short period from fruit set to harvest and a very long post-harvest phenological period, deficit irrigation should be applied only during the post-harvest period in order to avoid any effect on yield and fruit quality.

Under deficit irrigation conditions, the continuous control of tree water status is crucial in order to prevent a moderate, potentially beneficial, water stress from becoming too severe and ending in a reduction of yield (Domingo et al., 1996). In this sense, LVDT sensors are able to measure daily trunk diameter fluctuations (TDF) with great precision, generating sensitive parameters which strongly correlate with established plant water status parameters (Ortuño et al., 2010). The most common TDF parameter for the irrigation scheduling is the maximum daily trunk shrinkage (MDS). Absolute MDS values registered without considering the evaporative demand might be meaningless, and for irrigation scheduling it is better to use the concept of signal intensity (SI) (actual MDS/reference MDS) (Goldhamer and Fereres, 2001). MDS SI values above unity indicate water stress levels, while SI values of unity indicate the absence of irrigation-related stress (Ortuño et al., 2010).

The research reported in this paper was conducted to test the hypothesises that RDI scheduling can be based exclusively on MDS measurements, and that by maintaining MDS SI values close to unity during fruit growth, a moderate water deficit during early postharvest period and a more severe water stress during late postharvest period, it is possible to save water without affecting yield and fruit components.

Materials and methods

Experimental conditions, plant material and treatments

The experiment was performed during three growing seasons (2007, 2008 and 2009). The soil was stony (33% w/w) and shallow, with a clay-loam texture. The volumetric soil water content at field capacity and permanent wilting point were 0.35 and 0.15 m^3 m^{-3}, respectively. The plant material was 6 year old early maturing peach trees (*Prunus persica* (L.) Batsch cv. Flordastar) grafted on GF-677 peach rootstock. Tree spacing followed a 5 m x 5 m square pattern.

ET_C was estimated according to Allen et al. (1998). T0 plants were irrigated daily above the estimated ETc ($\approx$ 130%). Before fruit thinning, the regulated deficit irrigation (RDI) treatment (T1) was irrigated at 100% ET_C. From fruit thinning to 2 weeks after, RDI plants were irrigated to maintain MDS SI at values close to unity (no irrigation-related stress). During the early postharvest period, RDI plants were irrigated to maintain MDS SI values close to 1.3. Finally, during the late postharvest period RDI plants were irrigated to maintain MDS SI values close to 1.6. In T1, the irrigation rate was decreased by 3% when the MDS SI did not exceed the threshold value on the previous day, and increased by 3% when the MDS signal intensity exceeded the threshold value.

Measurements

The soil volumetric water content (θ_v) of the top 150 mm of the soil profile was measured by time-domain-reflectrometry (TDR). The θ_v content of the soil from 0.2 m down to a maximum depth of 0.80 m was measured using a neutron probe, in access tubes installed 1.0 m from the trees and next to the emitters (10 cm).

Midday (12.00 h solar time) stem water potential (Ψ_{stem}) was measured in leaves enclosed in a small black plastic bag covered with aluminium foil for at least 2 h before measurements in a pressure chamber.

TDF were measured throughout the experimental period in four trees per treatment, using a set of linear variable displacement transducers (LVDT) attached to the trunk, with a special bracket made of Invar and aluminium. MDS was calculated daily as the difference between maximum and minimum daily trunk diameter.

Results and discussion

The fact that MDS SI values from fruit thinning to 2 weeks after harvest in T1 plants showed low variability and remained close to the selected MDS SI threshold value (unity) (Fig. 1) and that their Ψ_{stem} values were similar to those of T0 plants (data not shown) indicates that the irrigation water amounts applied were suitably adjusted and able to satisfy the plant water requirements while saving irrigation water compared with the amount estimated by ET_C (Conejero et al., 2007). The difference between the applied water rate in the MDS signal intensity-driven schedule (T1) and peach evapotranspiration (ET_C) during this period (Table 1) could be attributed to the fact that the crop factors used to calculate ET_C (FAO 56, Allen et al., 1998) were not developed for a early maturing peach cultivar as the used in the experiment.

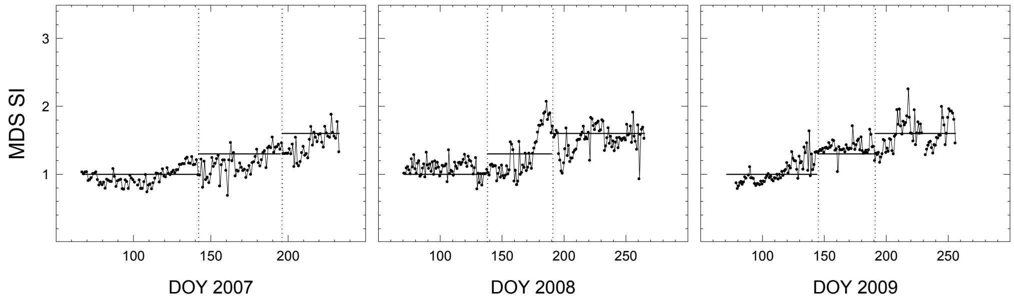

Fig. 1. MDS SI values in T1 treatment plants. Horizontal lines indicate the MDS signal intensity threshold values (1, 1.30 and 1.60). Vertical dotted lines from left to right represent the beginning of early and late postharvest periods, respectively. Each data point is the mean of four values.

The moderate variability of MDS SI values during the early and late postharvest periods (Fig. 1) also indicated that the information generated in this way under RDI was sufficient to adjust the irrigation schedule to maintain MDS signal intensity close the selected threshold values and that peach tree irrigation scheduling can be based on MDS measurements alone (García-Orellana et al., 2007). Nevertheless, the fact that the average MDS SI values during the early and late postharvest period of 2007, and during the late postharvest period of 2008, were lower than the threshold value (Fig. 1) suggests that it is necessary to modify the proposed irrigation protocol in order to obtain the new water stress level faster. So, when an RDI schedule involves a change from one MDS SI threshold value to higher one, the decrease in the irrigation rate during the first days of this change should be greater than 3%.

The fact that the θ_v in T0 remained close to field capacity during the 3 years of the experimental period (data not shown) indicated that irrigation scheduling in this treatment kept the plants under non-limiting soil water conditions. The deficit irrigation during early and late postharvest (T1) resulted in a progressive reduction in θ_v values, which, in turn, induced a decrease in Ψ_{stem} values, reflecting a moderate water stress during the early postharvest period and a more severe water stress during late postharvest period (data not shown).

The fact that the only vegetative growth component affected by deficit irrigation was pruning weight may be related with the fact that apex elongation is more sensitive than other physiological parameters to water deficit (Dichio et al., 2007) (Table 2). Also, the absence of a significant effect of RDI on the yield/ΔTCA ratio could indicate similar carbon partitioning schemes during fruit growth. However, taking into consideration that vegetative apexes are the main users of carbohydrates during the postharvest period, vigor regulation in T1 plants may decrease the competition for assimilates between vegetative apexes and reserve tissues, reducing pruning (Boland et al., 2000).

Although the seasonal irrigation water applied in RDI was 35-42% lower than the estimated ET_C, no effect on total yield, yield efficiency components or the distribution of different peach fruit categories was observed (data not shown). This behaviour could be related to the fact that during the early postharvest period the water stress achieved was moderate, and that the late postharvest period is not a critical period for yield and fruit quality. Moreover, Ruiz Sánchez et al. (1999) indicated that in stone fruit trees severe water stress for one and a half months after harvest, when floral bud induction and/or bud differentiation processes take place, leads to a lower germination potential in the pollen and the following year also encourages young fruit to drop.

Table 1. Precipitation (mm), estimated crop evapotranspiration (ETc, mm) and irrigation applied (mm) to T0 (control) and T1 (RDI scheduled using different maximum daily trunk shrinkage signal intensity (MDS SI) threshold values) treatments during different phenological periods (DOY). Values in parenthesis indicate obtained average MDS SI values.

Year	Period	MDS SI	Rainfall	ETc	Irrigation applied	
					T0	T1
2007	67-141	1 (0.96)	156.3	147.5	195.6	117.5
	142-195	1.3 (1.16)	3.4	214.0	286.1	158.4
	196-233	1.6 (1.44)	1.7	142.9	195.1	53.0
2008	71-137	1 (1.09)	46.8	184.4	261.5	164.4
	138-190	1.3 (1.27)	76.8	257.1	335.0	147.6
	191-265	1.6 (1.51)	18.2	355.7	461.5	173.4
2009	79-144	1 (1.03)	104.4	194.6	261.9	80.3
	145-190	1.3 (1.39)	3.8	256.7	345.1	131.2
	191-256	1.6 (1.58)	5.0	326.3	424.6	241.5

Table 2. Effect of irrigation treatments on pruning weight (kg tree^{-1}), fruit load efficiency (number of fruits per tree divided by trunk cross sectional area (TCA, cm^2)), yield efficiency (Yield/TCA, kg cm^{-2}), yield per increase in trunk cross sectional area (Yield/ΔTCA, kg cm^{-2}) and water use efficiency (WUE, kg m^{-3}) during the experimental period. Means for each year within a column that do not have a common letter are significantly different by LSD$_{0.05}$ test.

Year	Treatment	Pruning	Fruit load efficiency	Yield/TCA	Yield/ΔTCA	WUE
2007	T0	24.5a	1.15a	0.14a	0.80a	1.06a
	T1	16.4b	1.12a	0.14a	0.99a	1.96b
2008	T0	30.8a	1.72a	0.21a	1.34a	1.24a
	T1	17.7b	1.62a	0.21a	2.07a	2.41b
2009	T0	35.2a	2.12a	0.26a	1.45a	1.90a
	T1	21.2b	1.88a	0.24a	1.66a	3.54b

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