Postharvest Regulated Deficit Irrigation of Peach Tree in a Mediterranean Environment: Effects on Vegetative Growth and Yield

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Abstract

The aim of this paper was to verify the possibility to reduce irrigation water requirements by applying regulated deficit irrigation (*RDI*) during phenological stages less sensitive to water deficit. The effects of two different levels of *RDI* were studied in a peach orchard (cv Springcrest). From bud break to harvest, irrigation was managed by applying 100% ETc, while from harvest to early autumn, irrigation was equivalent to 100%, 50% and 25% ETc. During the trial, no significant reductions in yield or quality were found for the 50% *ETc* treatment, whereas about 1,000, 1,800 and 2,400 m^3 ha^{-1} of water were saved in the first, the second and the third year. The 25% treatment did reduce quality and yield significantly. Under scarce water supply conditions, a clear benefit can be obtained through the use of 50% RDI during the post-harvest period, especially for early harvest peaches.

INTRODUCTION

The use of water saving techniques in fruit-growing in southern Italy is crucial due to the increasingly limited water availability. The regulated deficit irrigation technique is an irrigation management method that allows reducing irrigation volumes at selected phenological stages (Behboudian and Mills, 1997). It aims at the partial re-establishment of crop evapotranspiration in order to reach specific water deficit thresholds in the soil and in the plant. The reduction in water supply is applicable at the phenological stages less sensitive to water deficit without affecting yield and quality. Numerous experiments showed that regulated deficit irrigation techniques can be beneficial for fruit trees (Shackel et al., 1997; McCutchan and Shackel, 1992; Naor, 2000).

For early harvest peach cultivars, irrigation in the stage from post-harvest until leaf drop (June – December) can be managed effectively to reduce irrigation volume supply. Such reduction, though applied at the post-harvest stage, has to be performed with care to avoid severe stresses, with detrimental effects both on the accumulation of reserve substances and on the quality of flowers and thus the production of the following year (Xiloyannis et al., 1995).

The objective of the trial was to check the possibility to reduce the use of water by applying regulated deficit irrigation during the post-harvest stage of cv Springcrest.

MATERIALS AND METHODS

The three-year trial was performed in southern Italy (Montescaglioso (MT), N 40° 20', E 16° 48'), in a hot-arid environment with average yearly rainfall of 500 mm, in a peach orchard of 0.48 ha grown with cv Springcrest/GF677, cross-Y trained with a 4.5 x 2 m spacing. The peach orchard was fertigated by drip irrigation (2 drippers per plant, 10 L h^{-1}) following the principle of reestablishing mineral nutrients taken up by the plant, so each treatment received the same amount of nutrients. The meteorological parameters were measured at the meteorological station of the Demonstration Agricultural Farm of "Pantanello" in Basilicata Region, located around 1 Km far away from the experimental site. The soil was sandy clay with the following hydrological characteristics: bulk density 1.3 g cm^{-3}, field capacity 0.28 cm^3 cm^{-3}, permanent wilting point 0.13 cm^3 cm^{-3} and available water 0.15 cm^3 cm^{-3}.

In the course of the three years of the research, in the bud break-harvest period, water supply was equal to 100% crop evapotranspiration (ET_c). During this phase, soil moisture in the wetted volume was kept to reach 70-80% of field capacity. During the post-harvest stage, three treatments were differentiated, each consisting of 30 plants. In the first treatment - the control - 100% ETc was re-established (100% ETc treatment) whereas in the two other treatments, 50 and 25% ETc respectively were re-established (50% ETc and 25% ETc treatments).

Crop water use was calculated through the evapotranspiration method (ETc = ETo x Kc x Kr), where Kc is a coefficient to adjust for the difference between the orchard and ETo and Kr adjusts for ground cover. ETo was calculated by averaging the values obtained through Blaney-Criddle, Radiation and Hargreaves equations (Hargreaves et al., 1985; Doorenbos and Pruitt, 1977).

In March, April, May and June, crop coefficients (Kc) values, respectively equal to 0.50, 0.75, 0.95 and 1.00 were considered (Allen et al., 1998). In the post-harvest period, a Kc value equal to 0.8 was assumed, taking into account the indirect reduction in leaf transpiration due to harvesting of fruits (Catania et al., 1994). The ground cover coefficients (K_r) were chosen referring to Fereres and Castel, (1981).

Water requirements (WR) of the peach orchard were calculated on daily basis through the relationship of the simplified water budget WR = ETc – Er, where Er stands for effective rainfall calculated by the Soil Conservation Service (SCS) method – USA (Dastane, 1974). For calculating the irrigation volume, an efficiency of 0.9 of the drip irrigation method was considered (Xiloyannis et al., 1995). Irrigation was performed whenever water requirements were close to 18 mm that represent the amount of readily available water in the wetted volume.

The second year of the trial was characterized by scarce rainfall in winter, therefore, in managing irrigation, the irrigation volumes of the stressed treatments were respectively increased for the plant not to exceed the threshold values of the pre-dawn leaf water potential equal to -0.7 MPa in the 50% ET_c treatment and to –1.2 MPa in the 25% ET_c treatment.

The plant water status was monitored using predawn leaf water potential, Ψ_{wpd} and the stem water potential, Ψ_{wstem} at the hottest hours of the day (01:00 p.m. - 02:00 p.m.) as indicated by Naor (2000). The measurement of Ψ_{wpd} and Ψ_{wstem} was taken in the same days as those of the gas exchanges and on mature leaves samples on fruiting shoots situated in the median zone of the plant and in shadowed areas, using Scholander pressure chamber (PMS Instrument Co).

Leaf photosynthesis and transpiration was evaluated by the open system, ADC-LCA4 with 200 ml min-1 flow rate. The measurements taken in clear sky days referred to 15 well-lightened leaves (>40% available PAR) for treatments distributed over 3 plants. Assessments were made every twenty days (June-August) and at 10.00 a.m. when the leaves of the well irrigated plants reached their maximum photosynthetic rate.

The vegetative growth of watersprouts, lateral shoots and fruiting shoots were measured by a non-destructive method on 50 samples for each organ (5 trees and 10 samples per tree) per treatment in the period from the end of June till early October. Average yield was evaluated by measuring the fruit size, the average weight, the soluble solids content (° Brix), the firmness of the flesh and the color of 15 plants per treatment.

RESULTS AND DISCUSSION

Water Volumes

The irrigation volumes supplied at the different growth stages are reported in table 1. The irrigation volume at the post-harvest stage ranges from 66 to 78% of the seasonal irrigation volume. The 50% ET_c treatment received irrigation volumes equal to 2,447, 5,730 and 4,193 $m^3\,ha^{-1}$ for the three years, respectively.

Plant Water Status and Gas Exchanges

In the first year the predawn leaf water potential (Ψ_{wpd}) ranged from –0.2 to –0.3 MPa in the control, whereas in the 50% ET_c and the 25% ET_c treatments it reached maximum values of –0.5 and -0.75 MPa (Fig.1), respectively. In the two subsequent years, the Ψ_{wpd} in the 50% ET_c and 25% ET_c treatments reached, in the order, values close to –0.7 and –1.2 MPa (data not shown).

The comparison between the Ψ_{wpd} and of Ψ_{wstem} values measured at the hottest hour of the day showed a good correlation (r^2=0.88) between the two parameters (Fig. 2) similarly to plums, apples, nectarines and grapevines, (Shackel et al., 2000; Naor, 2000). As reported in the literature, the values of Ψ_{wstem} were correlated with the photosynthesis activity of the plant (data not shown). The correlation between the values of Ψ_{wstem} and some important physiological parameters is particularly useful to identify the critical stages of the crop and the threshold depletion values to irrigate.

At the post-harvest stage, the well irrigated plants, with Ψ_{wpd} values between –0.3 and – 0.4 MPa, had average values of Ψ_{wstem} from –0.9 to –1.0 MPa, whereas the plants with Ψ_{wstem} values variable from –1.5 to -1.7 MPa, the 50% ETc treatment, did not show negative effects on the production of the subsequent years. The previously reported Ψ_{wstem} values could be used as threshold values for the well irrigated plants subjected to mild regulated water deficit.

The drop in water potential as a result of the reduced water supply at the post-harvest stage caused a clear-cut reduction in photosynthesis (A) in the stressed treatments with respect to the control associated with a lesser water use efficiency (WUE) (Fig. 3). As indicated by Shackel et al., (2000), under moderate stress conditions (Ψ_{wstem} –1.5 MPa), a slight reduction in photosynthesis of the single leaf with respect to the whole plant, can be compensated by the reduction in the growth rate of the vegetative apexes that are the major users of carbohydrates at the post-harvest stage.

Vegetative Activity

The vegetative growth by elongation is more sensitive than photosynthesis activity to water deficit conditions (Mills et al., 1996). In the period from June through October, the 50% ET_c and 25% ET_c treatments showed a significant reduction in the growth of watersprouts and lateral shoots with respect to the control treatment (Fig. 4). Whereas the growth of fruiting shoots, that represent the productive potential of the plant for the following year, was not significantly different in the three treatments. The total amount of pruning residues was about 30% lower in the 50% ET_c and 25% ET_c treatments with respect to the control (data not shown).

In agreement with Boland et al., (2000), the regulation of vigor due to moderate water stress could reduce the competition for assimilates between reserve tissues and the vegetative apexes, could improve light interception and reduce summer pruning.

Yield and Quality

In the second year of the trial, the average yield per hectare was lower in the 25% ET_c treatment with respect to the control and the 50% ET_c treatment, whereas statistically non significant differences were observed in the production of the third year (Table 2). The fruit size was not affected by the treatment (Fig. 5) therefore, the reduction of yield in 25% ET_c treatment was probably due to the total number of fruit per tree. The firmness of the flesh, and °Brix didn't exhibit statistically significant differences in the different years (data not shown).

CONCLUSIONS

The treatment re-establishing 50% ET_c is the one that globally gave the most interesting results. The satisfactory yield obtained with this type of irrigation management associated with the reduction in the seasonal irrigation volume of 1,000 m^3 ha^{-1}, 1,800 m^3 ha^{-1} and 2,400 m^3 ha^{-1} for the first, the second and the third year, with respect to the control, suggests to adopt it as a model to impose water deficit for early ripening peach cultivars, to optimize irrigation and save water.

ACKNOWLEDGMENTS

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Tables

Table 1. Irrigation volumes (m^3 ha^{-1}) supplied in the three years.

Year	Bud Break Harvesting	Post-harvest			Seasonal irrigation volume		
		control	50% ETc	25% ETc	control	50% ETc	25% ETc
	(m^3 ha^{-1})						
1999	1,195	2,366	1,252	694	3,561	2,447	1,889
2000	2,112	5,427	3,618	2,486	7,539	5,730	4,598
2001	1,447	5,215	2,746	1,388	6,662	4,193	2,835

Table 2. Yields obtained in the two years of the trial in the three compared treatments. Each value represents the mean of 15 measurements. Statistical analysis was performed using ANOVA. Significant differences from treatments were determined at $P \leq 0.05$, according to Duncan's mean separation test.

	Yield (t ha^{-1})		
Year	Control	50% ETc	25% ETc
2000	22.6 a	21.0 ab	18.1 b
2001	19.2 a	16.6 a	17.1 a
Total	41.8	37.6	35.2

*Values in the same line followed by the same letter are not significantly different at P≤0.05.

Figures

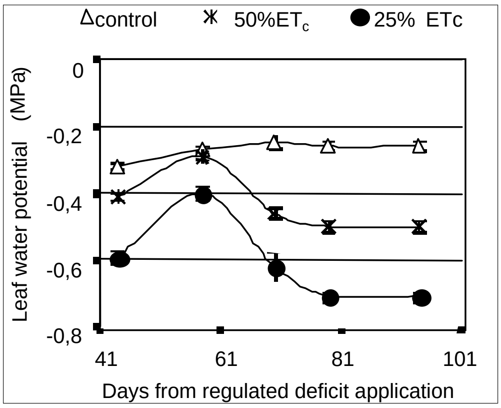


Fig. 1. Pattern of the pre-dawn leaf water potential during the first experimental year.

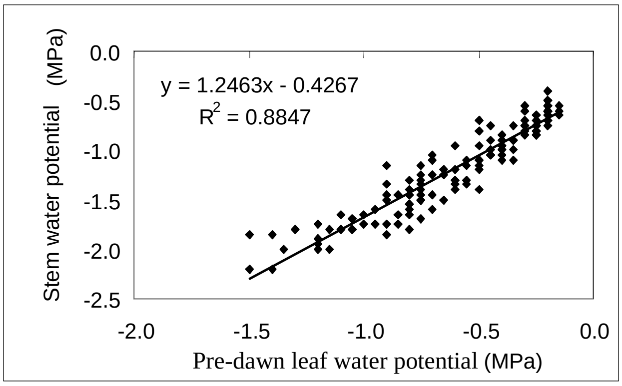


Fig. 2. Correlation between the pre-dawn leaf water potential and the stem water potential at the hottest hours of the day (values of the three years).

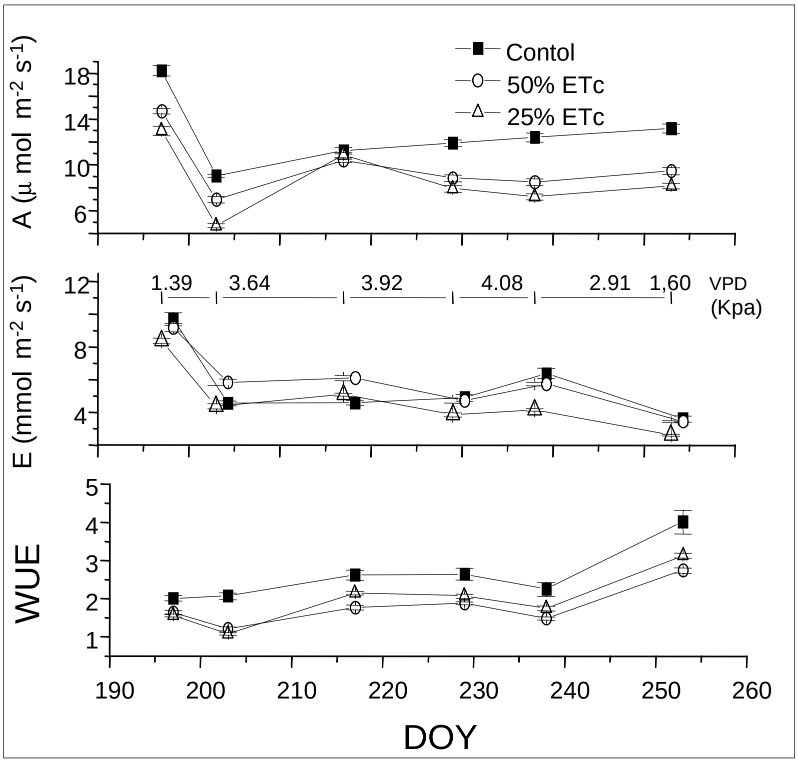
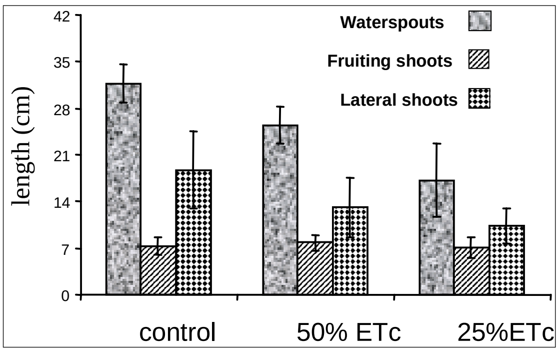


Fig. 3. Pattern of photosynthesis (A), transpiration (E) and water use efficiency (WUE) measured at 10:00 a.m. in peach trees subject to different water regimes.



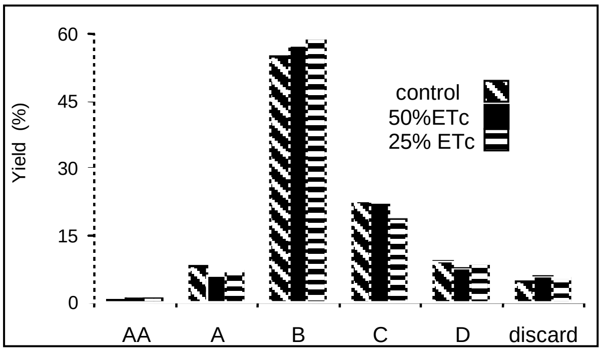


Fig. 4. Growth of watersprouts, fruiting shoots and lateral shoots in the three compared treatments, from the end of June to early October (average of the three years).

Fig. 5. Percentage of fruit size classes in the compared treatments (average of two years).