Irrigation scheduling and regulated deficit irrigation in stone fruits

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Abstract

In recent years the interest for applying irrigation techniques aiming to reduce water consumption has increased, mainly in areas with scarce water resources. We studied the effect of different regulated deficit irrigation (RDI) strategies on peach (*Prunus persica* (L.) Batsch cv. "Catherine") performance in Murcia (SE Spain) during three consecutive growing seasons. Three irrigation strategies were established: a control treatment, irrigated to fully satisfy the crop water requirements and two RDI treatments (moderate and severe) based on measurements of stem water potential (Ψ_s). Pruning weight, percentage of fruit categories, fruit diameter, crop load and yield were determined for each treatment. The results indicated that RDI treatments significantly reduced pruning weight. However, no significant differences were detected in terms of reproductive growth, fruit categories and yield. In the case of water productivity, the values for the RDI treatments were higher than those from the control. These results and water savings up to 50% indicate that RDI strategies constitute a possible solution against water shortages in areas such as the south-eastern region of Spain, although sustainability must be studied in the medium-long term.

Keywords: Stem water potential; Soil water content; *Prunus persica*; Yield

1. Introduction

Mediterranean regions are characterized by the shortage on water resources. This situation is aggravated by the strong competition for water between agriculture and other non-agricultural users like industry or increasing population. Consequently, new and precise tools for assessing crop water requirements are needed to cope with this water scarcity. One of the most promising techniques to attain this objective is the use of Regulated Deficit Irrigation (RDI). This technique consists of applying water in quantities below those necessary to satisfy crop evapotranspiration (ETc) requirements during certain periods of the crop cycle when production and crop quality are hardly affected, applying all the water needed during the rest of the cycle. Currently, Spain is the second largest producer of peach [*Prunus persica* (L.) Batsch]. Most peach tree plantations are located in the Mediterranean area. In particular, the Murcia Region ranks third in peach production in Spain, with an average annual yield for the last 5 years of about 246,500 t, approximately 20% of the Spanish total production [3].

Several studies have reported that stem water potential (Ψ_s) is more reliable than others indicators of water needs. For these reasons, the aim of this study was to evaluate the effect of different RDI strategies based on Ψ_s measurements on production in adult peach trees [*Prunus persica* (L.) Batsch cv “Catherine”] under Mediterranean conditions.

2. Materials and Methods

The experiment was conducted over three consecutive years (2008–2010) in a commercial orchard located in Murcia. The irrigation water was considered of good quality with a very low electrical conductivity (0.6 dS m^{-1}). Plant material consisted of peach trees (*Prunus persica* (L.) Batsch cv. ‘Catherine’) grafted on GF-677 rootstock, planted in 1999. Spacings were 4 m x 6 m. Trees were drip irrigated using three emitters per tree (4 L h^{-1}). The experiment was laid out in completely randomized blocks with 4 replications (16 trees each). Three irrigation treatments were established (Fig. 1): Control plants (treatment C) were daily irrigated above the estimated crop evapotranspiration in order to obtain non-limiting soil water conditions, and two RDI strategies: RDI I plants were irrigated to maintain Ψ_s values close to -1.5 MPa during stage II of fruit growth and postharvest, and RDI II plants were irrigated to maintain Ψ_s values close to -1.8 MPa at stage II of fruit growth and -2.0 MPa at postharvest.

The volumetric soil water content (θ_v) was measured using a neutron probe. Midday stem water potential (Ψ_s) was measured using a pressure chamber following the procedures described by [7]. Fruit diameter was measured perpendicularly to the fruit suture. Fruits from each tree were individually harvested according to market demands. The effect of the irrigation treatments on fruit size was studied evaluating marketable and non marketable production, according to Commission Regulation (EC) nº 1861/2004.

3. Results and Discussion

The amounts of water applied (Fig. 2A) compared to ETc gave rise to savings of 26-45 % in 2008, 49-55 % in 2009 and 64-65 % in 2010 for RDI I and RDI II treatments, respectively.

The average soil water content in the 0-1m layer during each growth stage is shown in Table 1. In the C treatment, θ_v remained close to field capacity over the three years of experiment, indicating that plants did not suffer from water deprivation. On the contrary, significant differences were observed among treatments during stage II and postharvest, RDI values being lower than those of C treatment especially during postharvest (summer period with high climatic demand).

An increase in the evaporative demand from May produced a decrease in Ψ_s, with a similar pattern for the three irrigation treatments, although of different intensity (Fig. 2B). In fact, Ψ_s values for control trees decreased from an initial value of -0.5 MPa (stage I) to -0.9 MPa (postharvest). The RDI treatments induced significant reductions in Ψ_s in all the stages during which water deficit was imposed. Water deprivation during postharvest did not negatively affect the following year production of the studied peach trees, suggesting the feasibility to save water during this period. During the stage I and stage III of fruit development the values of Ψ_s were very similar among treatments. This scheduling had a negative effect on vegetative growth as shown in figure 3 (Pruning weight).

Our results showed that RDI treatments reduced vegetative growth (pruning weight) compared to trees under full irrigation conditions, similarly to what has been previously reported [1], thus demonstrating the high sensitivity of peach vegetative growth to water deficit [4]. In contrast, the stress imposed did not cause any significant reduction in fruit growth (Fig. 4). According to [6], fruits act as sinks for photosynthates that help a faster recovery during the periods of full irrigation. The irrigation treatments had no significant effects on crop load and yield (Table 2).

With respect to fruit size, water stress did not result in significant differences in fruit category (Fig. 5) in contradiction to the findings of [2] for the same cultivar. The peach trees with high load fruit have proven to be more sensitive to water stress than trees with low loads [7]. In our case, in 2009 the industrial destination of the fruit allowed a minor thinning which caused a higher crop load in this year respect to that of 2008 and 2010. During that year, Ψ_s values were lower compared to those from other years with a lower crop load. This effect of water deprivation on fruit growth did not limit subsequent crop yield, most of the fruits reaching marketable fruit size.

4. Conclusions

The results obtained suggest that the RDI treatments were able to considerably reduce the seasonal water applied without affecting yield components of peach trees. The RDI treatments tested, showed significant differences regarding vegetative growth, but these differences were not found in the yield of both crops. Nevertheless, sustainability of these results must be studied at the medium-long term. The reduction of tree size can be considered beneficial because it allows light to enter inside the tree canopy and also reduces pruning time, with the consequent economic savings for the farmer. These reasons, together with irrigation water savings around 50%, emphasize the RDI strategies as a possible solution in areas with water shortage, like the south-eastern region of Spain.

5. Acknowledgements

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6. References

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Tables and Figures

Table 1. *Average soil water volumetric content in different stages of fruit growth for the three studied growing seasons. Each data point is the mean of all values in the corresponding stage. Different letters next to a value in each year indicate significant differences according to Tukey´s multiple range test ($p < 0.05$).*

	Stage I	Stage II	Stage III	Post-Harvest
2008				
C	0.24a	0.25a	0.25a	0.25a
RDI I	0.25a	0.22b	0.25a	0.20b
RDI II	0.24a	0.20b	0.24a	0.17c
2009				
C	0.26a	0.25a	0.26a	0.25a
RDI I	0.26a	0.21b	0.26a	0.19b
RDI II	0.24a	0.18c	0.25a	0.17c
2010				
C	0.25a	0.24a	0.24a	0.25a
RDI I	0.25a	0.22b	0.24a	0.19b

Table 2. *Crop load (number of fruits tree^{-1}), yield (kg tree^{-1}) and water productivity (WP, kg m^{-3}) for the experimental period 2008-2010. Different letters next to a value in each year indicate significant differences according to Tukey´s multiple range test ($p < 0.05$).*

	Crop load (Fruits tree^{-1})	Yield (Kg tree^{-1})	WP (Kg m^{-3})
2008			
C	170a	29.87a	1.29a
RDI I	137a	26.99a	2.47ab
RDI II	160a	29.78a	3.75b
2009			
C	489a	67.23a	3.30a
RDI I	523a	66.54a	9.73b
RDI II	488a	63.18a	10.63b
2010			
C	173a	30.16a	1.77a
RDI I	197a	33.79a	6.61b
RDI II	244a	40.40a	8.15b

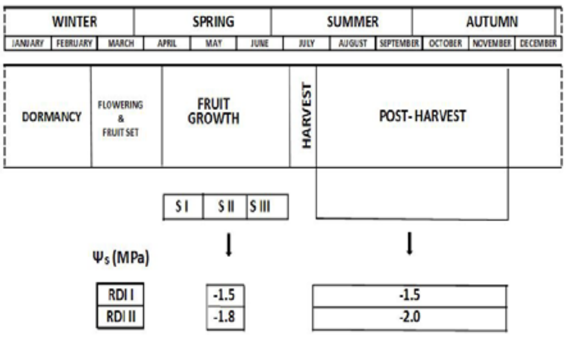

Fig. 1. *Regulated deficit irrigation strategies based on threshold values for midday stem water potential (Ψ_s), applied in stage II (S II) of fruit growth and postharvest.*

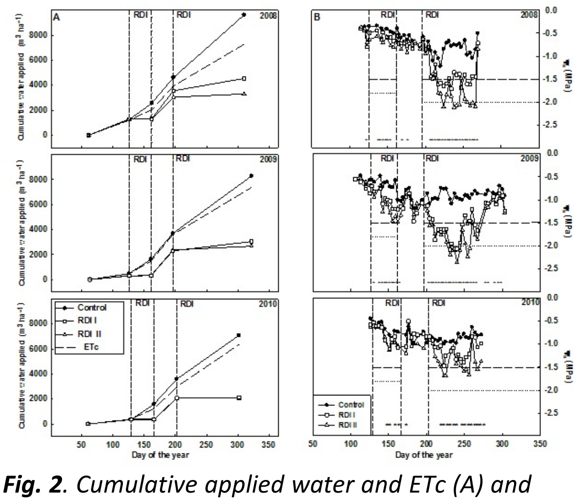

Fig. 2. *Cumulative applied water and ETc (A) and midday stem water potential (B), in C (closed circles), RDI I (open squares) and RDI II (open triangles) plants for the three studied growing*

seasons. Asterisks indicate significant differences among treatments ($p < 0.05$). The interval between vertical lines, from left to right, represents the beginning of stages II and III of fruit growth and postharvest. Horizontal lines represent threshold values in each phenological stage for both RDI treatments.

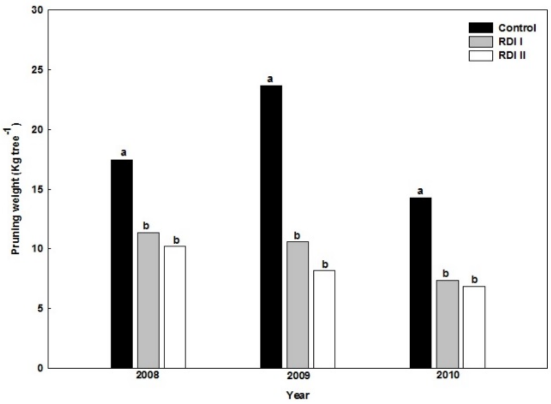

Fig. 3. *Pruning weight as a function of the irrigation treatment, control (black bars), RDI I (gray bars) and RDI II (white bars) in the 2008, 2009 and 2010 growing cycles. Each bar corresponds to the mean of sixteen trees. Different letters on top of bars indicate significant differences according to Tukey´s multiple range test ($p < 0.05$).*

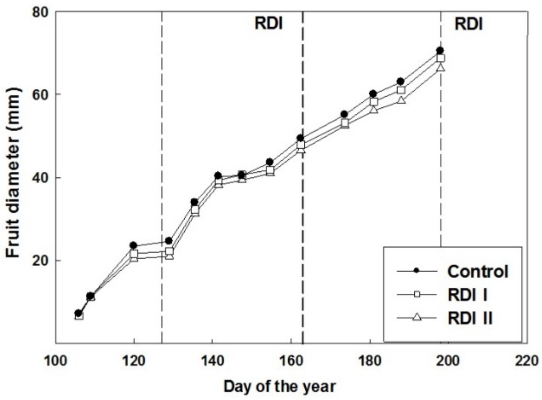

Fig. 4. *Fruit diameter (mm) evolution in C (closed circles), RDI I (open squares) and RDI II (open triangles) plants for the average of the three studied growing seasons. The interval between vertical lines, from left to right, represents the beginning of stages II and III of fruit growth and postharvest. Each value is the mean of 160 measurements.*

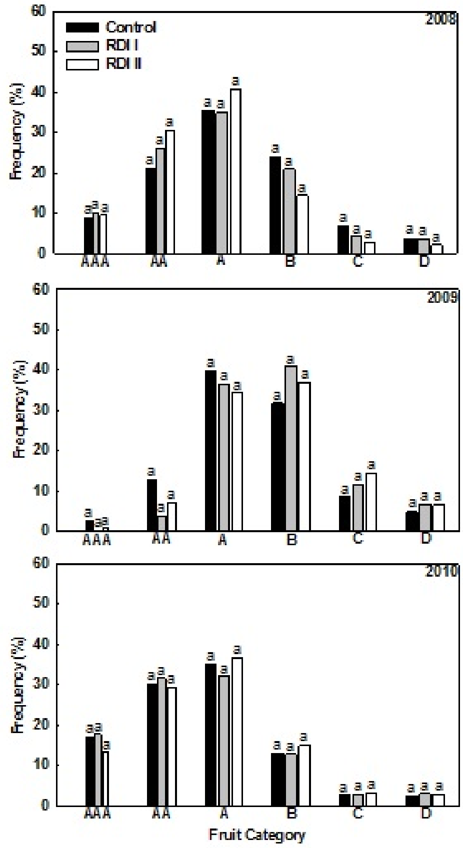

Fig. 5. *Percentage of fruit categories for each irrigation treatment, control (black bars), RDI I (gray bars) and RDI II (white bars) in the 2008, 2009 and 2010 growing cycles. Each bar corresponds to the mean of eight trees. Different letters on top of bars indicate significant differences according to Tukey´s multiple range test ($p < 0.05$).*