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ORIGINAL PAPER

Effects of post-harvest regulated deficit irrigation on carbohydrate and nitrogen partitioning, yield quality and vegetative growth of peach trees

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Abstract The aim of the present work was to evaluate the effects of regulated deficit irrigation (RDI) applied in the post-harvest stage of peach trees. The 3-year trial was carried out in Italy (N 40°20′, E 16°48′) on mature peach plants (cv "Springcrest") trained to transverse Y. From bud break to harvest, irrigation was carried out by applying 100% ET_c, while from harvest to early autumn, plants were separated into three groups and subjected to different irrigation treatments (100, 57 and 34% ET_c). The decrease in soil water content caused a reduction in the values of tissue water potential and gas exchange both in 57% ET_c and 34% ET_c treatments. RDI determined the reduction in the growth of waterspouts and lateral shoots but did not influence the growth of fruiting shoots. During the trial, no significant reductions in crop yield and quality were observed in the 57% ET_c treatment, whereas about 1,100, 1,800 and 2,500 m^3 ha^{-1} of water were saved in the first, the second and the third year, respectively. In the second year of the trial, the use of RDI in the post-harvest stage determined carbohydrate and nitrogen accumulation in roots, branches, shoots and floral buds. The results demonstrate that, under scarce water supply conditions, a clear benefit can be obtained through the use of RDI during the post-harvest stage. This confirms the possibility to reduce the irrigation water by applying RDI during phenological stages less sensitive to water deficit without negatively affecting peach growth and yield.

Keywords Crop yield and quality · Drought stress · *Prunus persica* · Starch · Water relations

Abbreviations

CP	Well-irrigated control plants
DOY	Day of year
E_r	Effective rainfall
ET_c	Crop evapotranspiration
ET_0	Reference crop evapotranspiration
K_c	Crop coefficient
K_r	Ground cover coefficient
MSP	Moderate-stressed plants
N	Nitrogen
RDI	Regulated deficit irrigation
SC	Soluble carbohydrates
SSP	Severe-stressed plants
ST	Starch
SWC	Soil water content
TC	Total non-structural carbohydrates
WR	Water requirement
ψ_{Wleaf}	Pre-dawn leaf water potential
ψ_{Wstem}	Midday stem water potential

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Introduction

The peach tree (*Prunus persica* L.) is one of the most common and economically important species of the Mediterranean basin, where drought periods are frequent and irrigation water is a limiting factor for productivity. Peach drought tolerance is mainly based on stomatal control (Arndt et al. 2000) and morphological characteristics (Rieger et al. 2003), together with some degree of osmotic adjustment (Escobar-Gutiérrez et al. 1998; Arndt et al. 2000). Recent works in this species covered subjects from the physiological processes adopted to regulate water status under drought conditions (Arndt et al. 2000; Rieger et al. 2003) to the biochemistry underlying plant response to water deficits and oxidative stress (Escobar-Gutiérrez et al. 1998; Sofo et al. 2005).

Regulated deficit irrigation (RDI) is the practice of reducing applied water at selected phenological stages less sensitive to water deficit, thus imposing plant water stress in a controlled manner, and can be a feasible water saving practice for arid areas. The success of RDI strongly depends on the appropriate use of localized irrigation techniques, which allows the control of soil water content (SWC) and plant water status. Moreover, an efficient use of irrigation water is important for water uptake dynamics by root system (Clothier and Green 1994).

Peach trees are highly sensitive to drought stress at particular phenological stages, such as flowering and fruiting, and during stem extension and fruit growth (Berman and DeJong 1997; Xiloyannis et al. 2005). In this species, the application of RDI during the early stages of fruit growth until the end of shoot growth slightly influences fruit size and number (Boland et al. 2000) and a water deficit treatment during the final stage of rapid fruit growth causes decreases in fruit size and increases in total fruit soluble solids (Crisosto et al. 1994; Besset et al. 2001).

Nevertheless, little is known about RDI application in the stage from post-harvest until leaf abscission. Withholding irrigation applied after harvest reduces vegetative growth of early maturing peach trees (Larson et al. 1988; Johnson et al. 1992; Ghrab et al. 1998) and improve fruit quality (Gelly et al. 2004). Moreover, RDI extended over a long period lead to adaptation of peach tree to dry conditions due to a better extraction of water from deeper soil (Johnson et al. 1992). The technique of RDI, though applied during the post-harvest stage, has to be performed avoiding high levels of drought stress, which could negatively influence the accumulation of reserve carbohydrates, flower development and thus, indirectly, crop yield (Xiloyannis et al. 2005).

In peach trees there is a direct correlation between water availability and carbohydrate synthesis (Girona et al. 2002a), and between photosynthetic rate and types of carbohydrates synthesized (Escobar-Gutiérrez et al. 1998). During fruit growth, high photosynthetic rates are necessary for growth requirements of this species (Besset et al. 2001). Sorbitol and sucrose are the two main photosynthetic carbohydrates of peach plants and their function depends on the organ of utilization and its developmental stage (Lo Bianco et al. 2000). In well-watered peach plants, these sugars are translocated from their sources, mainly mature leaves, and then absorbed by sink organs, such as shoot apices (Lo Bianco et al. 2000), developing fruits (Grossman and DeJong 1995), and buds during dormancy release (Marquat et al. 1998).

Peach leaves are the main sink for nitrogen (N) in summer while roots represent the main storage organ for this element after summer, but also fruits use a significant fraction of absorbed nitrogen until ripening (Tagliavini et al. 1999; Policarpo et al. 2002). Moreover, Crisosto et al. (1997) demonstrated that an excessive level of N in peach fruits negatively affects post-harvest storage life and quality.

A better understanding of the effects of water deficit on peach plants has a primary importance for improved management practices (Girona et al. 2002a), breeding programmes (Rieger et al. 2003) and for predicting fruit growth and quality (Besset et al. 2001). On this basis, the aim of this research was to determine if the application of different irrigation treatments applied during the post-harvest stage can influence carbohydrates and nitrogen partitioning in the different organs of mature peach trees, as well as to study the influence of RDI on physiological and yield responses of the plants.

We hypothesize that the application of RDI in the post-harvest stage could reduce the vegetative growth and increase carbohydrate and N accumulation in the reserve organs (roots, branches, shoots) but also in floral buds, without negatively affecting crop yield and quality.

Materials and methods

Plant material and irrigation volumes

The 3-year trial (from 1999 to 2001) was conducted at Montescaglioso (southern Italy—Basilicata Region—N 40°20′, E 16°48′), in a hot-arid environment with an average yearly rainfall of 500 mm, on *Prunus persica* (L.) Batch cv "Springcrest", on *P. persica* × *P. amygdalus* "GF677", planted at distances of 4.5 × 2 m and trained to transverse Y, according to Xiloyannis et al. (2005).

The soil was sandy clay (46% sand, 12% silt and 42% clay), with the following hydrological characteristics: bulk density 1.38 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 cm^{-1}. Trees were irrigated by two drip emitters per plant discharging 10 L h^{-1} each, following the principle of re-establishing mineral nutrients taken up by the plant, so each treatments received the same amount of nutrients. During the experimental period, for each year, an optimal irrigation equal to 100% of crop evapotranspiration (ET_c) was applied in the period between bud break and harvest. During such stage, soil moisture in the wetted volume was kept at 70–80% of field capacity. In the post-harvest stage, from harvest to early autumn, plants were divided in three groups, each consisting of 30 plants: well-irrigated control plants (CP; irrigation = 100% ET_c), plants subjected to a moderate drought stress (MSP, moderate-stressed plants; having a mean irrigation volume of 57% ET_c during the 3-year experimental period) and plants subjected to a severe drought stress (SSP, severe-stressed plants; having a mean irrigation volume of 34% ET_c).

Crop water use was calculated according the evapotranspiration method by the following equation:

$$ET_c = ET_0 \cdot K_c \cdot K_r \quad (1)$$

where ET_0 is the reference crop evapotranspiration and K_c is the crop coefficient. K_r is a reduction coefficient accounting for the percentage of the ground surface covered by the crop. K_r values were assumed to be equal to 0.7, 1.0, 1.0 for the first, second and third year of experiment, according to Fereres and Castel (1981) and Girona et al. (2002b).

ET_0 was calculated by averaging the values obtained through Blaney-Criddle and Hargreaves equations (Hargreaves et al. 1985; Dorenbos and Pruitt 1992). In March, April, May and June, K_c values, respectively, equal to 0.5, 0.75, 0.95 and 1.0 were considered, according to Allen et al. (1998). In the post-harvest stage, a K_c value equal to 0.8 was assumed, taking into account the indirect reduction in leaf transpiration due to harvesting of fruits.

Water requirement (WR) of the peach orchard were calculated on daily basis through the relationship of the simplified water budget using the following equation:

$$WR = ET_c - E_r \quad (2)$$

where E_r stands for effective rainfall calculated by the Soil Conservation Service (SCS) method—USA (Dastane 1974).

The irrigation volumes were calculated by considering an efficiency of 0.9 of the drip irrigation method. Irrigation was applied whenever water requirements were close to 18 mm, at 2–3 day intervals. This value represents the amount of readily available water in the wetted volume. Since the second year of the trial was characterized by scarce rainfall in winter, irrigation volumes of drought-stressed plants were, respectively, increased for the plant not to exceed the threshold values of the pre-dawn leaf water potential (ψ_{Wleaf}) equal to –0.7 MPa in MSP and to –1.2 MPa in SSP.

Water status and gas exchange

The plant water status was determined on 10 plants per treatment by measurements of leaf water potential at pre-dawn (04:00 h) (ψ_{Wleaf}) and stem water potential in the central hours of the day (13:00 h) (ψ_{Wstem}). The values of ψ_{Wleaf} and ψ_{Wstem} were measured on five fully expanded leaves selected from each plant on fruiting shoots situated in the median zone of the plant and in shadowed areas using a pressure chamber (PMS Instrument Co., Corvallis, OR, USA, model 600). For the determination of ψ_{Wstem}, leaves were covered with aluminium foil 1 h before each measurement.

For each treatment, 10 plants were chosen to measure gas exchange on five fully-expanded and well-lightened leaves (PAR > 40%) selected from each plant on fruiting shoots situated in the median zone of the plant. Measurements were carried out in the first 2 years of the experimental period using the leaf chamber analyzer LCA-4 (ADC, Hoddesdon, Herts., UK) operated at 200 μmol s^{-1} flow rate, under clear sky conditions. The measurements of net photosynthesis and transpiration rates were taken in the same days as those of the water potentials at 10:00 h, when the leaves of the well-irrigated plants reached their maximum photosynthetic rate.

The values of SWC during the second year of the experimental period were determined from the weight differences of soil samples before and after drying at 105°C for 24 h and expressed as percentages of water on dry weight. Soil samples were taken in different points of the soil at three levels of depth (0–30 cm, 30–60 cm, and 60–90 cm).

All ψ_{Wleaf} and gas exchange/SWC measurements were taken at 6–12 h and 12–18 h, respectively, after the end of the irrigation.

Vegetative growth and fruit quality

During the whole experimental period, the vegetative growth of watersprouts, lateral shoots and fruiting shoots were measured by a non-destructive method on 50 samples for each organs (5 trees and 10 samples per tree) per treatment in the period from the end of June till early October. In the 3 years, the amount of material removed by pruning was recorded from 15 plants per treatment.

In the last 2 years of the experimental period, in 15 plants per treatment, average yield and fruit quality was evaluated by measuring fruit size, average weight, and soluble solids content (Brix), the firmness of the flesh and the percentage of fruit size classes.

Soluble carbohydrates, starch and nitrogen

In the second year of the experimental period, 15 plants for each drought treatment were selected for excavation and the following tissue sampling. Samples were taken from 1-year branches, roots (with a diameter between 1 and 5 mm), leaves and new shoots. Tissues were collected at the end of the harvest (21 June) and at the end of the irrigation period (20 October), i.e. before and after the drought treatment, respectively. Floral buds were sampled at the end of the winter (15 February).

All the samples were washed with distilled water, dried with filter paper, oven-dried at 65°C for 48 h and then mashed into fine powder. Soluble carbohydrates (SC) concentration was spectrophotometrically determined at 625 nm on 100 mg aliquots of powder with anthrone reagent within 30 min, using glucose as calibration standard (Yemm and Willis 1966). Starch (ST) in the tissue residual was converted to glucose with amyloglucosidase (Sigma, St. Louis, MO, USA), and then glucose concentration was spectrophotometrically measured at 450 nm by mixing the sample with peroxidase-glucose oxidase-*o*-dianisidine dihydrochloride reagent color solution after 30 min incubation at 25°C. The concentrations of total non-structural carbohydrates (TC) were calculated by adding the values of SC and ST. Nitrogen (N) concentration was determined by Kjeldhal method on 500 mg aliquots of powder. The values of TC, SC, ST and N were expressed as mg per g of dry weight.

Results

Irrigation volumes, plant water status and gas exchange

In CP, the irrigation volumes during the post-harvest stage ranged from 66 to 78% of the seasonal irrigation volume, whereas the values in MSP and SSP fluctuated within a range from 51 to 65% and from 37 to 54%, respectively (Fig. 1). CP received irrigation volumes equal to 3,561, 7,539 and 6,662 m^3 ha^{-1} for the 3 years, respectively, whereas the relevant volumes in MSP were equal to 2,447, 5,730 and 4,193 m^3 ha^{-1} (Fig. 1).

The values of SWC, recorded at different levels of depth during the second year of the experimental period, gradually decreased with decreasing irrigation volumes: in fact, the values were generally higher in CP than in MSP and SSP, in particular at depths of 0–30 cm and 60–90 cm (Fig. 2). A decrease of SWC occurred at the end of the irrigation period in all the treatments (Fig. 2).

In the first year, ψ_{Wleaf} of CP ranged from –0.2 to –0.3 MPa, whereas in MSP and SSP it reached minimum values of –0.5 and –0.7 MPa, respectively (Fig. 3A). During the post-harvest stage of the first year, ψ_{Wstem} in MSP and SSP reached the values of –1.4 and –1.7 MPa, respectively (Fig. 3B). In the second year, ψ_{Wleaf} of CP fluctuated within a range from –0.2 to –0.5 MPa, and the minimum values in MSP and SSP were –0.8 and –0.9 MPa, respectively (Fig. 3A). The values of ψ_{Wstem} during the second year reached –1.5 MPa in MSP and –1.8 MPa in SSP (Fig. 3B).

The drop in ψ_{Wleaf} and ψ_{Wstem} as a result of the reduced water supply during the post-harvest stage, caused a clear-cut reduction in net photosynthesis and a decrease in transpiration in SSP, if compared to CP (Fig. 3C, D).

Vegetative activity and yield

During the period from June to October, MSP and SSP had significantly reduced the growth of waterspouts and lateral shoots with respect to CP, whereas the growth of fruiting shoots was not significantly different in the treatments (Table 1).

In the second year, SSP had an average yield per hectare significantly lower if compared to CP and MSP, whereas non-significant differences were observed in the production of the third year (Table 2). The firmness of the flesh and the soluble solids content in the three treatments did not exhibit statistically significant differences (Table 2). Finally, fruit distribution in size classes was not statistically affected by water treatment (Table 3).

Soluble carbohydrates, starch and nitrogen

In roots, TC in all the treatments was higher after RDI than before, with higher differences in stressed plants than in CP (Fig. 4A). In all the treatments, the rose in TC in roots is mainly due to the marked increase of ST after RDI (from 8.4% before RDI to 23.6% after RDI in MSP) (Fig. 4A). The trend of N in roots were similar to that of TC, increasing after RDI in particular in the stressed treatments (11.0 mg g^{-1} in MSP and 13.5 mg g^{-1} in SSP) (Fig. 4A).

TC in the wood of branches had the same patterns observed in roots (17.6, 18.4 and 19.4% in CP, MSP and SSP after RDI, respectively) and

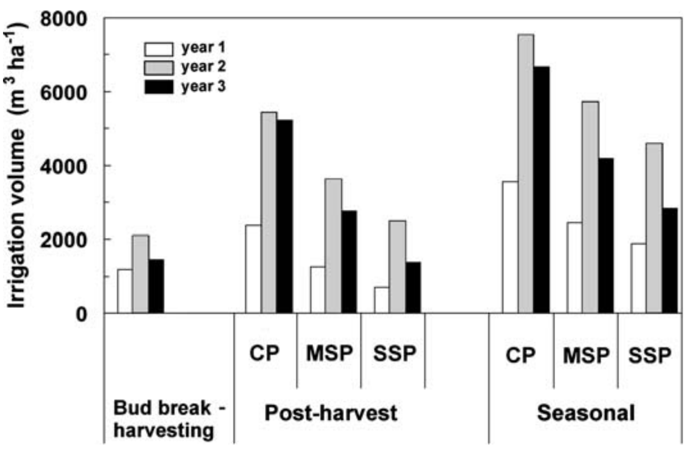

Fig. 1 Irrigation volumes supplied in the first (white columns), second (gray columns) and third year (black columns) of the experimental period. CP, control plants; MSP, moderate-stressed plants; SSP, severe-stressed plants

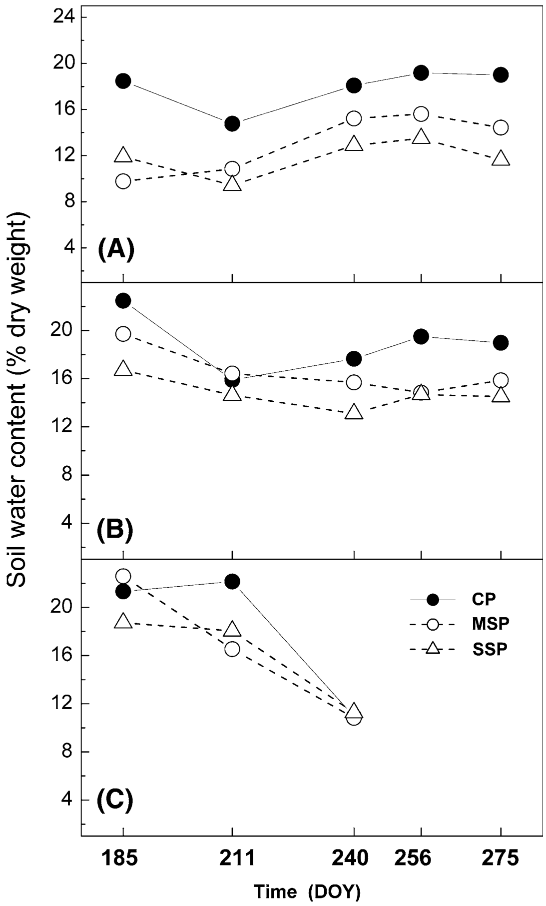

Fig. 2 Soil water content during the second year of the experimental period measured at depths (**A**) of 0–30 cm, (**B**) 30–60 cm and (**C**) 60–90 cm in well-irrigated (continuous line = ●: CP, control plants) and under regulated deficit irrigation (dashed lines: MSP, moderate-stressed plants = ○; SSP, severe-stressed plants = △) treatments. DOY = day of year

its increase was parallel to the increase of SC (Fig. 4B). ST in branches before and after RDI did not differ significantly among the three treatments, whereas N increased after RDI in particular in stressed plants (7.1 mg g^{-1} in MSP and 8.5 mg g^{-1} in SSP) (Fig. 4B).

In shoots, the levels of TC after RDI were markedly higher than those found before RDI both in CP and drought-stressed plants and this trend was due to the increase of SC (13.8, 15.6 and 18.6% in CP, MSP and SSP after RDI, respectively) (Fig. 4C). In all the treatments, the values of N concentration after RDI were similar to those before RDI (Fig. 4C).

After RDI, TC in leaves increased in all the treatments and in particular in CP (Fig. 4D). The same trend was observed for SC, whereas ST content was very low (Fig. 4D). N concentration in leaves was lower after RDI than before in all the treatments (Fig. 4D).

The values of TC and SC in floral buds were higher in SSP (16.4 and 16.0%, respectively) than in the stressed treatments (15.3 and 15.0% in CP; 15.9 and 15.5% in MSP, respectively) (Table 4). The levels of N in floral buds of SSP was significantly higher than those in the other treatments (Table 4).

Discussion

The values of SWC (Fig. 2) resulted in a reduction of ψ_{Wleaf}, ψ_{Wstem} and gas exchange both in MSP and SSP if compared to 100 ET_c treatment (Fig. 3). Moreover, the values of ψ_{Wstem} were related with the photosynthetic activity of the plant (Fig. 3) and this could be particularly useful to identify the critical stages of the crop and the threshold depletion values to irrigate.

The vegetative growth by elongation is more sensitive than photosynthesis activity to water deficit conditions (Mills et al. 1996). Shackel (2000) found that at ψ_{Wstem} of about –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, which are the major users of carbohydrates during the post-harvest stage. This regulation of vigor due to moderate water stress can decrease the competition for assimilates between reserve tissues and the vegetative apexes, improves light interception and reduce summer pruning (Boland et al. 2000). In fact, during the whole experimental period, the total amount of pruning residues was about 19% lower in MSP and 25% lower in SSP if compared to the values of CP. Our values are higher than those of Larson et al. (1988), who found that pruning weights of peach trees grown in arid areas of California were 13% less in dry treatments than wet treatments. Considering that pruning influences the balance between vegetative growth and cropping, and reduces canopy shading, the

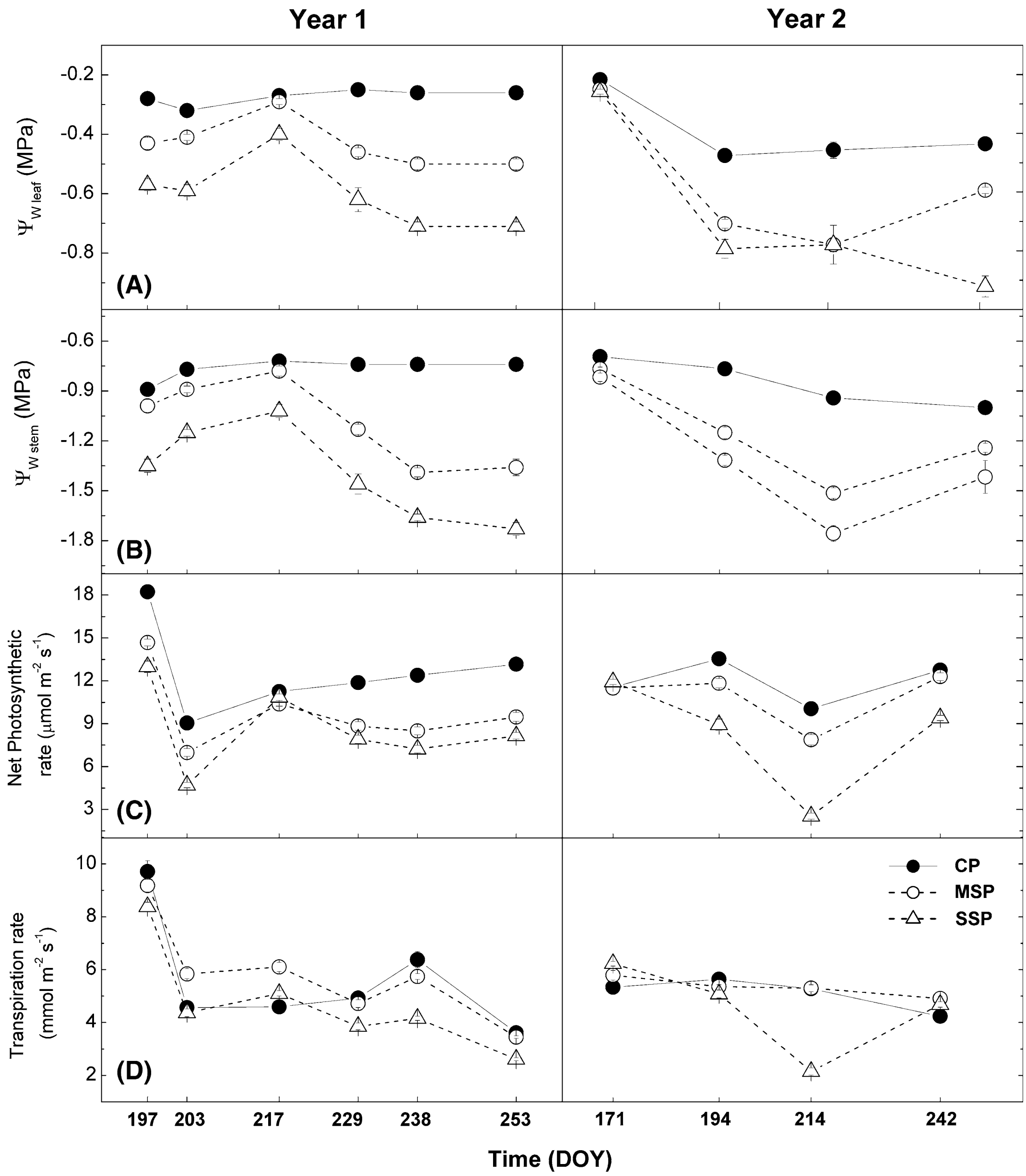

Fig. 3 Trends of (**A**) pre-dawn leaf water potential, (**B**) midday stem water potential, (**C**) net photosynthetic rate and (**D**) transpiration rate in well-irrigated (continuous line = •: CP, control plants) and under regulated deficit irrigation (dashed lines: MSP, moderate-stressed plants = ○; SSP, severe-stressed plants = △) treatments. Each value represents the mean of 10 measurements (±SD) taken during the first (left) and second year (right) of the experimental period. DOY = day of year

application of RDI could thus facilitate peach orchard management.

In peach, a period of drought stress reduces stem elongation and sorbitol utilization in sinks (Lo Bianco et al. 2000). Our results demonstrate that RDI causes the reduction in the growth of waterspouts and lateral shoots (Table 1). On the contrary, both in MSP and SSP, the decrease in photosynthesis was not accompanied by the reduction in the growth of fruiting shoots, which represents the productive potential of the plant for the following year (Table 1).

Table 1 Growth of waterspouts, fruiting shoots and lateral shoots in the three irrigation treatments, from the end of June to early October

	Length (cm)		
	CP	MSP	SSP
Watersprouts	32 ± 3 a	25 ± 2 b	17 ± 5 c
Fruiting shoots	8 ± 1 a	9 ± 1 a	8 ± 1 a
Lateral shoots	19 ± 5 a	13 ± 4 b	10 ± 2 c

Each value represents the mean of 50 measurements taken during the whole experimental period. Significant differences between the treatments were determined according to Duncan's mean separation test. Values in the same line followed by the same letter are not significantly different at $P \leq 0.05$

Table 3 Percentage of fruit size classes in the three irrigation treatments

Fruit class	Yield (%)		
	CP	MSP	SSP
AA	0.4 a	1.4 b	1.0 b
A	8.1 a	6.0 a	7.1 a
B	54.9 a	57.3 a	59.1 a
C	22.6 a	21.9 a	18.8 b
D	9.1 a	7.7 a	8.6 a
Discard	4.9 a	5.7 a	5.5 a

Each value represents the mean of 15 measurements taken in the last 2 years of the trial. Statistical analysis was performed using ANOVA. Statistical analysis and significant differences between the treatments as in Table 1

In almond, the application of RDI in the kernel-filling stage does not significantly influence crop yield and improves water use efficiency (Romero et al. 2004), whereas in pear, RDI within the latter part of fruit growth stage I is linearly correlated with lower fruit size and smaller cell size in the fruit cortex (Marsal et al. 2000). Withholding irrigation in non-critical periods can be also used in apricot (Ruiz-Sánchez et al. 2000) and apple (Kilili et al. 1996) production to improve fruit quality and save water. Finally, in olive tree, RDI accelerates ripening (Alegre et al. 1999) and does not influence fruit load, weight and value (Goldhamer 1999). In our study, the application of RDI in the post-harvest stage did not cause significant differences in fruit yield (Table 2) and size (Table 3) between the stressed treatments and CP, in accordance to the results of similar experiments conducted by Larson et al. (1988) and Johnson et al. (1992). During our experiment, there was not evidence for significant differences in fruit firmness and soluble solids concentration among the three treatments (Table 2), whereas Gelly et al. (2004) found an improvement in quality in terms of high soluble solid content and skin coloration in fruits of peach trees subjected to post-harvest deficit irrigation. Finally, The reduction in SSP yield in the second year was probably due to the total number of fruit per tree and not related to water treatment (Table 2).

It is well-known that buds of deciduous trees take up and use nutrients during dormancy, from summer to the following spring, when they act as sinks of soluble carbohydrates. The results of the second year of the trial confirm that TC levels after fruit harvest are higher than those before harvest in all the organs of the three treatments (Fig. 4). This was likely due to the competition for carbohydrates between fruits and other plant organs. In fact, vegetative growth of peach trees is resource-limited shortly after bud break and fruits reduce the amount of carbohydrate available for stem growth (Grossman and DeJong 1995) but, after fruit removal, the total sugar content of

Table 2 Yields, flesh firmness and soluble solids concentration in the three irrigation treatments

	Year 2			Year 3		
	CP	MSP	SSP	CP	MSP	SSP
Yield (t ha^{-1})	22.6 a	21.0 a	18.1 b	19.2 a	16.6 a	17.1 a
Flesh firmness (kg cm^{-2})	7.2 ± 0.8 a	5.6 ± 1.3 a	5.8 ± 1.2 a	7.9 ± 0.5 a	6.6 ± 0.7 a	8.0 ± 0.7 a
Soluble solids concentration (°Brix)	10.9 ± 0.4 a	11.3 ± 0.3 a	10.8 ± 0.4 a	9.1 ± 0.4 a	9.1 ± 0.8 a	9.2 ± 0.7 a

Each value of flesh firmness and soluble solids concentration represents the mean of 15 measurements. Statistical analysis and significant differences between the treatments as in Table 1

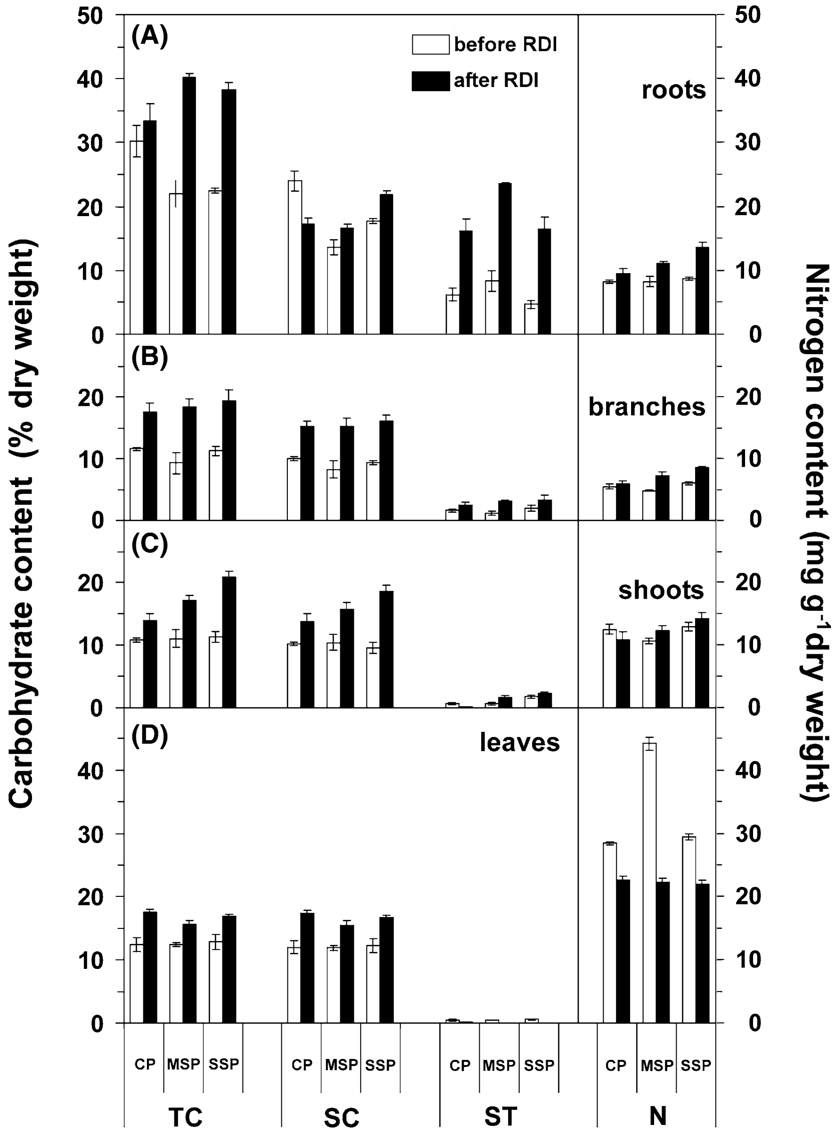

Fig. 4 Total non-structural carbohydrates (TC), soluble carbohydrates (SC), starch (ST) and nitrogen (N) in (**A**) roots, (**B**) branches, (**C**) shoots and (**D**) leaves in the three irrigation treatments. Each value represents the mean of 15 measurements (±SD) taken in the second year of the experimental period, before (white columns) and after (black columns) the application of regulated deficit irrigation. CP = control plants; MSP = moderate-stressed plants; SSP = severe-stressed plants

leaves increases (Nii 1997). Furthermore, in peach plants, hexose accumulation can play a key role in bud development and in triggering the onset of bud break (Maurel et al. 2004). The results show that the use of RDI in the post-harvest stage did not negatively affect carbohydrate

Table 4 Total non-structural carbohydrates (TC), soluble carbohydrates (SC), starch (ST) and nitrogen (N) in floral buds of the three irrigation treatments

	Floral buds		
	CP	MSP	SSP
TC (% of dry weight)	15.3 ± 0.25 a	15.9 ± 0.19 a	16.4 ± 0.16 b
SC (% of dry weight)	15.0 ± 0.22 a	15.5 ± 0.16 a	16.0 ± 0.14 b
ST (% of dry weight)	0.3 ± 0.03 a	0.4 ± 0.03 a	0.4 ± 0.02 a
N (mg g^{-1} of dry weight)	20.0 ± 1.11 a	19.8 ± 0.56 a	20.5 ± 0.34 b

Each value represents the mean of 15 measurements. Statistical analysis and significant differences between the treatments as in Table 1 accumulation in reserve organs and, in many cases, TC values in MSP were higher than those observed in CP (Fig. 4A–C), so confirming our hypothesis. A similar trend was observed by Lo Bianco et al. (2000), which observed sorbitol accumulation in mature leaves (source) and shoot tips (sink) of drought-stressed peach plants. On the contrary, Esparza et al. (2001) found that in mature almond trees, water shortage during the harvest period causes a reduction in TC and can negatively influence fruit-bearing capacity. Our data on floral buds indicate that RDI caused an increase in carbohydrate and N levels (Table 4), in accordance to our hypothesis.

The results show that in leaves, N concentration in the post-harvest stage was lower than those observed before harvest in all the treatments (Fig. 4D). This behavior is likely due to the after-summer mobilization of nitrogen from leaves to other organs of peach plants, such as twigs, trunk and roots (Policarpo et al. 2002). Moreover, in the post-harvest stage of the second year, RDI determined a higher N accumulation in roots, branches and shoots of all the three treatments, with the only exception in shoots of CP (Fig. 4A–C). In roots, the levels of N after RDI were similar in the three treatments (Fig. 4). This is in accordance to the results of Esparza et al. (2001), which observed that irrigation deprivation in the harvest stage of almond do not cause the reduction in N content in root system. Since shoot and fruit growth of peach mainly relies on N remobilized from reserves, which account for 72–80% of total N in new growth (Policarpo et al. 2002), and in particular from roots (Tagliavini et al. 1999), the application of RDI could have positive effects on growth resumption in spring and cropping potential.

Our results show that RDI applied in the post-harvest stage has positive effects on crop yield of peach plants. Irrigation treatment for moderate stressed plants allowed the reduction in the seasonal irrigation volume of about 1,100, 1,800 and 2,500 $m^3\ ha^{-1}$ for the first, second and third year of the trial, respectively, if compared to well-irrigated plants. The satisfactory yield obtained with this type of irrigation management suggests to adopt it for early ripening peach cultivars grown in semiarid areas with limited water resources to improve irrigation efficiency and save water while maintaining top yields of high quality.

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