FEASIBILITY OF TRUNK DIAMETER FLUCTUATIONS IN THE SCHEDULING OF REGULATED DEFICIT IRRIGATION FOR TABLE OLIVE TREES WITHOUT REFERENCE TREES.

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Abstract

Regulated deficit irrigation (RDI) results are affected by the actual water stress level reached during the treatments. The irrigation scheduling based on water status measurements, such as trunk diameter fluctuations, can control in an accurate way the water restrictions. However, the number of works that use these indicators as isolate parameter to control the schedule is scarce in general, and very scarce in olive trees. Building on previous works, the aim of this article is to schedule an RDI strategy in olive trees based on threshold values of maximum daily shrinkage (MDS) and trunk growth rate (TGR) without reference trees. The experiment was performed in a 40 years-old table olive orchard (cv Manzanillo) in Seville (Spain) for three years (seasons from 2011 to 2013). Three different irrigation treatments were considered in a completely randomized block design. Control trees were over-irrigated (125% crop evapotranspiration, ETc) in order to obtain fully irrigated conditions. Water stress conditions were applied during phase II (pit hardening) in the RDI-2 treatment or during phase II and phase I (full bloom) in RDI-12. In both RDIs, a treatment recovery (phase III) was performed before harvest. The trunk diameter fluctuation indicator was selected according to the phenological stage. TGR was used in conditions of full irrigation or moderate water stress level, such as phase I and phase III. TGR threshold values based on previous works were selected: 20µm day^{-1}, RDI-2; 10µm day^{-1}, RDI-12 (phase I) and -5µm day^{-1}, both treatments, phase III. Only in one season RDI-2 was scheduled with TGR values (-10µm day^{-1}) during phase II. MDS threshold values were determined as the ratio between measured MDS and fully irrigated MDS (the so called MDS signal). The latter was estimated from a baseline. During phase II, RDI-2 was irrigated with a threshold value of 0.9, while RDI-12 was irrigated with a threshold value of 0.75. MDS signal was not useful for most of the period considered and it did not agree well with fruit drop or fruit size. Conversely, the average of TGR during phase II was significantly linked to fruit drop and fruit size, and so were the midday stem water potential and stress integral. Recommendations about the management of TGR are discussed. The water stress level in the experiments was moderate and no significant differences in yield were found. However, the trend of yield reduction in RDI-12 was likely related with a fruit drop and a reduction in crown volume. The yield quality did not decrease in the RDIs treatments, on the contrary, pulp:stone ratio improved significantly in some of the seasons.

INTRODUCTION

Water scarcity around the world has been reduced the irrigation availability. Deficit irrigation scheduling has been suggested in most of the fruit trees. Regulated deficit irrigation (RDI) and partial root drying (PRD) are two different options of water deficit management. In some fruit trees such as olive orchard, PRD has not improved the results of RDI (Fernández et al. 2006). Since PRD needs more labor force, farmers commonly prefer RDI scheduling. Regulated deficit irrigation (RDI) is an irrigation scheduling method first reported in the 70's, based on differences in water stress sensibility during the season (Chalmers et al., 1975). Traditional RDI works reduce the amount of water provided during the most resistant phenological stages using the percentage of crop evapotranspiration (Behboudian and Mills, 1997). Such strategy has produced contradictory results. Similar recommendations in RDI scheduling caused clear differences when they were performed at different sites (for instance, Girona (2002) in peaches; Johnstone et al (2005) in tomato).

The irrigation season in olive trees could be divided into four different periods according to water stress sensibility. The full bloom/fruit set period is considered the most sensitive to drought conditions (Moriana et al, 2003), while the pit hardening period is the most resistant (Goldhamer, 1999) in relation to yield. Oil accumulation is also considered a sensitive period (Lavee and Wodner, 1991) though several works suggest that moderate water stress increases oil production (Moriana et al, 2003; Lavee et al., 2007). The postharvest period has not been studied, probably because in the main producing zone this is the rainfall season. The results of irrigation works in olive trees strongly suggest that different levels of water stress during the same phenological stage change the effect on yield (Goldhamer, 1999; Moriana et al. 2003; Lavee et al., 2007).

Irrigation scheduling based on water status measurements could provide a useful tool to control the water stress level in RDI. In this way, water stress conditions in different sites will be comparable and RDI strategies could be easily performed out of the experimental orchards. Trunk diameter fluctuations are daily cycles of swelling and shrinking suggested in several fruit trees as an irrigation scheduling tool (Ortuño et al., 2010). There are two indicators obtained from daily curves: maximum daily shrinkage (MDS) and trunk growth rate (TGR) (Goldhamer and Fereres, 2001). In olive trees, MDS is not reported as a useful indicator, while TGR is considered an early water stress detector (Moriana and Fereres, 2002). There are only a few works using these parameters in olive RDI. Recently, Moriana et al (2013) suggested a threshold value of -5μm day^{-1} of TGR during pit hardening and recovery in table olive trees and concluded that MDS is not an easy tool in these conditions. However, Corell et al. (2013) suggested a different approach to estimate MDS in order to reduce the influence of the environment. Moriana et al (2013) used the reference tree approach (Goldhamer and Fereres, 2001) which, in brief, requires trees to be fully irrigated at the orchard in order to eliminate the environmental effect. These “reference trees” could affect the results obtained. Threshold values based in previous experiments could change the usefulness of some indicators such as MDS. The aim of this work is to combine previous results in order to obtain an irrigation approach that uses only threshold values of MDS and TGR without reference trees. This objective will be studied from two points of view. First, the present work considers the ease of data interpretation. Secondly, the robust relationship between both indicators and processes relate to yield results, such as fruit drop or fruit size, will be studied as well.

MATERIAL AND METHODS

Site description and experimental design

Experiments were conducted at La Hampa, the experimental farm of the Instituto de Recursos Naturales y Agrobiología (IRNAS-CSIC), located in Coria del Río near Seville (Spain) (37º17’’N, 6º3’W, 30 m altitude). The experiment was performed on 40-year-old table olive trees (*Olea europaea* L cv Manzanillo) from the 2011 to the 2013 seasons. Tree spacing followed a 7m x 5m square pattern. Age and density of the experimental orchard is the common of the zone in commercial orchards. The sandy loam soil (about 2m deep) of the experimental site was characterised by a volumetric water content of $0.33m^3\ m^{-3}$ at saturation, $0.21m^3m^{-3}$ at field capacity and $0.1m^3m^{-3}$ at permanent wilting point, and 1.30 (0-10cm) and 1.50 (10-120cm) g cm^{-3} bulk density. Pest control, pruning and fertilization practices were those commonly used by growers and weeds were removed chemically within the orchard, only in the last season no pruning was performed. Drip irrigation was carried out at night using one lateral pipe per row of trees and five emitters per plant, spaced 1m and delivering 8L h^{-1} each. Micrometeorological data were obtained using an automatic weather station located around 40 m from the experimental site. Although some recent works suggest simple approaches for estimated daily reference evapotranspiration (ETo) (i.e. Valipour 2014 and 2015), daily reference evapotranspiration (ET_o) was calculated using the Penman-Monteith equation (Allen et al., 1998).

The experimental design was a completely randomized block experiment with 3 blocks and 3 irrigation treatments. Each treatment was carried out in a plot with two trees located in a single row and two adjacent guard rows. There were 6 trunk diameter fluctuation sensors per treatment and 1 sensor per tree.

Irrigation phases considered

The seasonal cycle of the trees was divided in 4 phases according to Rallo (1997):

- Phase I occurred from the shoot flush (around mid-February, day of the year (DOY) 45) until the beginning of the period of massive pit hardening (around DOY 169).
- Phase II occurred from massive pit hardening until the last week of August. We considered that massive pit hardening began when a decrease in the growth rate of the longitudinal diameter of the fruit was measured (Rapoport et al., 2013). There is no morphological indicator to establish the end of this phase. Therefore the end of this phase was established in order to obtain a complete rehydration before harvest (around DOY 240).
- Phase III was the period of rehydration and occurred from the end of August until harvest (around DOY 275).
- Phase IV. Postharvest. The typical date of the beginning of postharvest is the beginning of October.

Treatment description

The water stress levels were estimated according to the trunk diameter fluctuation indicators. Maximum daily shrinkage (MDS) was calculated as the difference between the maximum daily diameter and the minimum daily diameter (Goldhamer et al., 1999). Trunk growth rate (TGR) in day "n" was calculated as the difference between the maximum daily diameter in day "n+1" minus that in day "n" (Cuevas et al., 2010).

Severe water stress conditions reduce MDS in comparison to fully irrigated trees (Moriana et al., 2000). Therefore, MDS was used only during phase II. Since MDS is strongly related with evaporative demand, the parameter considered was the MDS signal, which is the ratio between the measured MDS and the MDS in fully irrigated conditions (Goldhamer and Fereres, 2001). Moriana et al (2011) reported that the maximum temperature is the best meteorological measurements in order to estimate the seasonal baseline in olive trees. The fully irrigated MDS was estimated from a baseline obtained with the Corell et al (2013) approach. Corell et al (2013) suggested that seasonal changes in the baseline are in the y-interception, while the slope is similar for different years. Therefore, a small numbers of MDS data at the beginning of the irrigation season could be used to estimate the seasonal baseline (Corell et al., 2013).

The TGR was used when moderate water stress levels were imposed because it was reported as the most sensitive indicator to water deficit conditions (Moriana and Fereres, 2002). Thresholds values from Moriana et al (2013) were used for phase I and phase III. During the first two seasons, the MDS approach permitted a small amount of irrigation in the RDIs and then both treatments presented a similar water status. For this reason, only in the last year, the TGR was used in the irrigation scheduling of phase II in one of the RDIs treatment.

All the treatments stopped the irrigation after harvest. During the rest of the season irrigation treatments were:

- *Control treatment*. Irrigation requirements were determined according to daily crop evapotranspiration (ET_c) calculated using the FAO method (Allen et al., 1998). Crop coefficient values (K_c) were previously estimated in the orchard (Fernández et al. 2006). In addition, a reduction according to tree size was considered (Kr=0.7). Trees were irrigated daily with 125% crop evapotranspiration (ET_c) until harvest.
- *Regulated Deficit Irrigation 2 (RDI-2).* No water stress was performed in phase I. In this phase, a TGR threshold value of 20µm day^{-1} was

considered. The objective of this treatment during phase II was to create moderate water stress conditions and a threshold value of 0.9 of MDS signal was considered. Phase III was used as a rehydration period and the objective was to perform a slow recovery with a -5μm day^{-1} of TGR. Only during the 2013 season, phase II was scheduled with TGR values, using -10μm day^{-1}.

- *Regulated Deficit Irrigation 12 (RDI-12).* Water stress conditions were applied during phase I and II. During phase I, a moderate water stress level was applied with a TGR threshold value of 10μm day^{-1}. In phase II, severe water stress conditions were the objective and the threshold values were 0.75 of the MDS signal. No water stress was applied in phase III and the management was the same in this phase as in RDI-2.

Estimation of irrigation needs

Water needs in RDI trees is depended the water status of the tree. In water stress conditions, crop evapotranspiration in these treatemnts is lower than the ones of Control. Then, irrigation in RDI treatments was changed daily according to the variation of the threshold value considered (MDS signal or TGR depending on the phenological stage). Three levels of irrigation rate were estimated in relation to the maximum average daily ET_c of the orchard. When the deviation of the threshold was very high, water applied was around the maximum needs estimated in order to maintain water status around the threshold. Otherwise, water applied was reduced in comparison to this maximum or even no irrigated if the values obtained were higher than the threshold considered. These estimations were calculated for the last ten years with the K_c and K_r values used in the Control treatment. The percentages of variations selected were based in previous works (Moriana et al., 2013). The irrigation rate varied as follows:

- The selected parameter changed less than 15% of the threshold value; 1mm (a quarter of the maximum daily ET_c) of irrigation was applied on this date.
- The selected parameter changed 15-30% of the threshold value; 2mm (half the maximum daily ET_c) of irrigation was applied on this date.
- The selected parameter changed more than 30% of the threshold value; 4mm (the maximum average daily ET_c) of irrigation was applied on this date.

Measurements

All the measurements were made on the two measured trees located on each plot. Trunk diameter fluctuations were measured throughout the experimental periods using a set of linear variable displacement transducers (LVDT) (model DF±2.5mm, accuracy ±10µm, Solartron Metrology, Bognor Regis, UK) attached to the main trunk, with a special bracket made of Invar, an alloy of Ni and Fe with a thermal expansion coefficient close to zero (Katerji et al., 1994). Trunk diameters were very similar between treatments; Control 0.24±0.01m, RDI-2 0.24±0.01m, RDI-12 0.23±0.01m. According to Corell et al (2013) such differences would not affect to the indicators derivate from trunk diameter fluctuations. The height and position of the sensor was similar in all the trees around 0.5 m height and in the north side of the trunk. Measurements were taken every 10s and the datalogger (model CR10X with AM 416 multiplexer, Campbell Sci. Ltd., Logan, USA) was programmed to report 15 min means. Since TGR daily data are very variable between days, the maximum diameter (accumulative values of TGR) was used in the graphs. In addition, the average TGR during the three periods considered were used in order to better describe the tree water status.

The soil moisture was measured with a portable FDR sensor (HH2, Delta-T, U.K.) with a calibration obtained in previous works. The measurements were made in three plots per treatment. The access tubes for the FDR sensor were placed in the irrigation line at about 30cm from an emitter, which is the distance where root activity is higher (Fernández et al., 1991). The data were obtained at 1m depth with 10cm intervals.

The water status of trees for each treatment was characterised by the midday stem water potential (Ψ) and maximum leaf conductance. The leaves near the main trunk were covered in aluminium foil at least one hour before measurements were taken. The water potential was measured at midday in one leaf per tree, using the pressure chamber technique (Scholander et al., 1965). The abaxial leaf conductance was measured at around 10 a.m. in order to estimate the maximum daily value in two fully expanded sunny leaves per tree with a steady state porometer (LICOR 1600, Lincoln, Nebraska, U.S.A).

In order to describe the accumulative effect of the water deficit, the water stress integral was calculated from the Ψ data (Myers, 1988) during the period of water stress (equation 1). Equation 1 used a reference of -1.4MPa, which is the threshold value suggested by Moriana et al (2012) in fully irrigated olive trees. All the values higher than the reference were considered as equal to this. The expression used was:

$$S\varphi = |\sum(\Psi - (-1.4)) * n| \qquad (1)$$

where: $S\varphi$ is the stress integral

Ψ is the average midday stem water potential for any interval

n is the number of the days in the interval

At the beginning of each season, ten shoots per tree were selected randomly. For each shoot, the length, number of inflorescences and fruits were measured periodically.

The fruit volume was estimated from a survey of ten fruits per tree in the same trees where trunk diameter fluctuations were measured. Fruits were randomly selected on each date of measurement. Two measurements were made for each fruit: the longitudinal dimension and the transversal dimension (at the equatorial point).

The irrigation treatments were also evaluated from the point of view of quantity and quality of yield. In table olives, the quality of the fruit is related to three parameters: the pulp-stone ratio (PS ratio), mature index (MI) and the fruit size. High values of PS ratio are considered an indicator of better quality fruits. A sample of 18 fruits per plot was measured. Fruits were deboned and the fresh weight of the pulp and the stone were measured. Pulp and stone were put into a stove at 70ºC during 24 hours. Dry weight was then measured. The fruit size was estimated in 6 trees per treatment with the number of fruits per kilogram. The mature index (MI) of the fruits estimated the colour of the fruits (Hermoso et al., 1997). A sample of 100 fruits in each plot were classified in 4 groups according to the fruit colour: 0 green, 1 yellow-green, 2 lower than 50% of purple, 3 higher than 50% purple, 4 purple fruit. MI is calculated as a weighted average. In table olive for green style, fruit at harvest should be an index around 1.

Productivity of irrigation was estimated with the irrigation water used efficiency (WUE). WUE was calculated as the ratio between yield (in Kg ha^{-1}) and the amount of water applied (in m^3 ha^{-1}).

Data analyses were performed with ANOVA and the mean separation was made via a Tukey's test using the Statistix (SX) program (8.0). Significant differences were considered when p-level<0.05 in both tests. Calculations of the p-level were performed considering the F-test of equality of variance. When conditions of equality of variance were not obtained, a decrease in the degree of freedom and, therefore, more restrictive p-value was calculated. The number of samples measured is specified in the text and figures.

RESULTS

Water relations

The climatic and water data applied along the three years of experiment are presented in Table 1. The duration of the different phenological stages was similar for all seasons (Table 1). Phase II, the pit hardening period, was shorter but with less rain than phase I, which is the common seasonal pattern. The amount of irrigation in Control trees was almost linear from the end of phase I throughout the seasons, with the greatest consumption during phase II. During this period, phase II, the daily water consumption in Control trees was clear lower in 2011 (2.8 mm day^{-1}) than 2012 and 2013 (3.8 and 3.4 mm day^{-1}, respectively) likely related with the lower fruit load in this season. The greatest seasonal volume of water applied during 2012 (540mm) in comparison with 2011 (299mm) and 2013 (369mm) was related to an important reduction of rainfall. During 2012, the seasonal amount of rain was 302mm (only 94mm during spring), while in 2011 and 2013 there were 521mm (211mm in spring) and 418mm (173mm in spring), respectively. The Control values higher than field capacity and the horizontal pattern of soil moisture (Fig. 1) suggest that this treatment was over-irrigated during part of the seasons, mainly in phase II. RDI treatments provided a similar irrigation amount in both treatments during 2011 and 2012 (Table 1), though there was a slightly greater amount of water in RDI-2 during phase I. Such results were related to the threshold value of MDS signal which was not reached during phase II in most of the dates for both seasons. The change in the irrigation scheduling of RDI-2 during the last year, the 2013 season, increased the amount of water of this treatment during phase II

(Table 1). There was no significant differences between RDI-2 and Control in this season, but the pattern of soil moisture suggest no drainage but also no water stress conditions in RDI-2.

The soil moisture was affected by the irrigation treatments (Fig. 1). The control treatment slightly increased soil moisture from phase I to phase II, though values were similar along the season and between years. On the other hand, RDI treatments decreased sharply during phase II, with significant differences when compared to Control, but not between RDIs (Fig. 1). Only in the 2013 season, when the irrigation approach in RDI-2 was changed, significant differences between this and RDI-12 were measured (Fig. 1c). In this season, there were no significant differences between Control and RDI-2 (Fig. 1c).

Stem water potential (Ψ) data showed clear differences between the seasonal water stress levels (Fig. 2). Control trees presented similar values in all the seasons with a minimum value around -1.5MPa. Significant differences were found mainly between Control and RDI-12, most of them during phase II. In most of the dates, RDI-2 was an intermediate treatment, though in the 2011 and 2012 seasons, RDI-2 was very similar to RDI-12 (Fig. 2a and b). Only during the 2013 season, when the irrigation approach was changed in RDI-2, this treatment was nearer to Control than to RDI-12 (Fig. 2c).

The maximum leaf conductance (g) data presented clear differences between seasons (Fig. 3). In 2011 (Fig. 3a), a low fruit load year, g was lower in all the treatments in comparison with 2012 and 2013 (Fig. 3b and c), when the yield was around the orchard average. As in previous parameters, most of the significant differences were obtained between Control and RDI-12 and during phase II (Fig. 3). However, throughout the season RDI-2 was significantly lower than Control at the end of the stress period (Fig. 3). Only in the 2011 season, g data in RDIs treatment were not significantly different to the Control ones at the end of the experiment. In 2013, RDI-2 was completely recovered at the end of the experiment according to g; while RDI-12 was still significantly lower (Fig. 3c).

The Stress Integral (SI) data indicated clearly the differences between seasons and treatments (Fig. 4). SI at Control treatments was lower than 10MPa*day in all the seasons, while the values in RDIs were at their maximum during 2012 and at their minimum during the 2011 season. In all the seasons RDI-12 was significantly greater than Control, while RDI-2 was significantly different to Control in 2011 and 2012 but not in 2013. RDI-2 data were clearly lower than RDI-12 in all the seasons. The smallest differences between RDI-2 and Control occurred during 2013.

The trunk growth rate (TGR) graph is difficult to read when a large number of data are included. In order to improve the clarity of the results, the Maximum diameter graph is presented (Fig. 6.), where the slope are TGR data. The average TGR values in each phenological stage are included in Table 2. Seasonal patterns of Maximum diameter were affected by fruit loads and spring rainfall. In 2011 and 2012, the rains during phase I reduced the TGR in all the treatments (Table 2) and produced large cycles of increase and decrease (Fig. 5). In these periods, irrigation scheduling based on this parameter was extremely difficult because negative TGR were not related to water stress. The significant differences in TGR during phase I for the two first seasons, 2011 and 2012, were not clearly related to the irrigation treatment (Fig. 5a and b). The rain effect was similar in the 2013 season but since the wet period was concentrated at the beginning of the year, a growth period was measured during phase I in all the treatments. In the 2013 season, during this period there were clear trends of lower values in TGR and RDI-12 than in Control and RDI-2 (Fig 6c). In 2013, TGR averages were around the values suggested in the methodology for each treatment (Table 2).

Most of the significant differences in TGR were found during pit hardening, phase II, in all the seasons (Fig. 5 and Table 2). In the 2011 season, TGR in Control was clearly greater than in the rest of the years because of the low fruit load conditions (Fig 6a and Table 2). For the rest of the seasons and treatments, the TGR was around zero during phase II, when water stress was not severe or clearly negative in severe conditions of water stress, mainly during 2012 when the highest level of water stress was detected (Fig. 5b, Table 2). No significant differences in TGR were found in 2011 and 2012 between RDIs treatments. In 2013, the TGR during phase II was significantly different between RDI-2 and RDI-12 because of the changes in the irrigation scheduling in the former (Fig. 5c). In this season, the average TGR of RDI-2 tended to greater values than Control and it was clearly greater than -10μm day^{-1}, the suggested threshold value in the methodology (Table 2).

In the recovery period, the average TGR was not around the threshold suggested in the methodology for RDIs (-5μm day^{-1}) in any of the seasons (Table 2), though there was a daily TGR value in these treatments lower than this value (Fig. 5). In this recovery phase, although no significant differences were found in the average values, there were actually some differences in the daily TGR values between Control and RDIs and a clear trend of greater values in RDIs than in Control (Fig. 5 and Table 2).

The Maximum Daily Shrinkage signal (MDS signal) was the indicator for the irrigation scheduling during phase II in the RDI treatments (except RDI-2 in the 2013 season). According to the approach for the estimated MDS signal (see Materials and Methods), only MDS signal data for phase II and phase III are presented because the ones for phase I were used for estimating the baseline. Although some significant differences between Control and RDIs were measured, mainly at phase III, the seasonal pattern of MDS signal was very confusing (Fig. 6). Even daily Control data were clearly higher than 1 mainly during the 2011 season (a low fruit load year) (Fig.7), although the average values of MDS signal in Control during the 2012 and 2013 seasons were around 1 (Table 3). However, the clear deviations of daily data from 1 for the Control MDS signal suggest that the baseline did not represent accurately enough the environmental effect. An example of this is the period from DOY 207 to DOY 212 in the 2012 season, when a large increase in the MDS signal was measured. Since these large values occurred in all the treatments, they can be most probably attributed to the environment. One of the possible reasons are the large changes in maximum temperature, from 32ºC in DOY 207 to 27ºC in DOY 209 and the later increase to 35º C in DOY 211.

The MDS signal did not reflect easily the effect of the water stress. The threshold values considered in the methodology were not usually reached (Fig. 6) and this produced small irrigation amounts, which were very similar between RDI treatments. During short periods in phase II of the 2011 and 2012 seasons, the daily MDS signal in RDI treatments tended to show greater values than Control and only at the end of 2012 RDI-12 presented lower values than Control. The average MDS signal values also were greater during RDI treatments than during Control in both seasons. In the 2013 season, the MDS signal pattern for both RDIs tended to show clearly much greater daily and average values than Control during phase II (Fig. 6c and Table 3). Moreover, during this season RDI-12 presented a decrease in MDS signal at the end of Phase II that was reversed during the rehydration phase (Fig. 6c).

Vegetative growth

Shoot elongation presented a similar seasonal pattern in all the years of the experiment with an active growth during phase I and almost no growth in the rest of the season

(Fig. 7). The increase in fruit load reduced the shoot elongation; thus the growth during the lowest yield season (2011, Fig. 7a) was half that of the highest (2013, Fig. c). During the 2011 (Fig. 7a) and 2012 (Fig. 7b) seasons, shoot elongation was not affected by the water stress and the maximum values of growth were not significantly different between treatments. Only during the 2013 season, RDI-2 was significantly greater than RDI-12 during most of phase I, while Control was an intermediate treatment without such differences (Fig. 7c). In this season, there were significant differences between treatments at the end of the period of active growth. During phase II, period without active growth, the maximum elongation was significantly different, just as it happened during phase I (Fig. 7c). In all the seasons, there was no active growth during the recovery phase in any of the treatments.

The percentage of soil cover was estimated only at the beginning and the end of the 2013 season (Fig. 7c). No significant differences were found in this parameter. The Control values (42%) tended to show a greater soil cover than the RDIs treatment, which were almost equal at the beginning of the season (36% RDI-2 and 37% RDI-12). The increase of soil cover at the end of the season was similar in all the treatments and around 20%, slightly higher in Control and RDI-2 (22%) than in RDI-12 (18%).

Fruit development

Numbers of inflorescences per shoot were measured along the season and from pit hardening (phase II) the number of fruit per inflorescence was counted. There were no significant differences between treatments in both parameters (data not shown). The fruit drop was estimated as the different between the number of fruit per inflorescence at the beginning and the end of pit hardening. The percentage of fruit drop data were compared to the minimum midday stem water potential (Fig. 2), stress integral (Fig. 4) and average TGR data (Table 2) obtained during phase II (Fig. 8). All the relationships were significant, though the ones with the midday stem water potential (Fig. 8a) and stress integral (Fig. 8b) were the most robust. In all the indicators, the increase of water stress enlarged the percentage of fruit drop. However, since the best fit was a quadratic adjustment, the rate of fruit drop increased with water stress. No multi-variable adjustment presented best fit. Data of fruit drop in RDI-2 in the 2013 season were greater than expected for all three indicators, while the ones for RDI-12 in the same season were not (data circled in Fig. 8).

The fruit volume increased in Control trees almost linearly in the three seasons of the experiment (Fig. 9). The differences in fruit volume between seasons in Control trees were lower than expected according to the fruit load. During 2011, with around 30% of historical average fruit load, the fruit volume was similar to 2013, around 115% of the fruit load. In all the years, significant differences were measured between Control and RDIs during phase II (always lower than 15%), but at the end of the rehydration period, the fruit volume was completely recovered. Only in the RDI-12 in the 2013 season, slightly but significant differences were found (Fig. 9c). No significant differences were found between RDIs. When the fruit volume at the end of the phase II is normalized for the Control treatment, on that day there was a robust relationship between the data and the three indicators used in Fig. 8. The best fit in the three indicators was linear and there was a reduction of the relative fruit volume with the increase in water stress (Fig. 10). The multi-variable fit was not better than the ones presented in Fig. 10. Although significant relationships were found with the three indicators, Stress integral (SI) and average TGR (Fig. 10 b and c) were better than the minimum midday stem water potential (Ψ, Fig. 10 a). In addition, the slope of the relationship in SI and Average TGR was sharper than the ones of the Ψ.

Yield quality and quantity

Table 4 presents the main features of the yield in the three years of the experiment. Yield in Control trees was increased along the experiment. In 2011 season, the Control yield was around 30% of the average yield of the orchard (8MT ha^{-1}), which then was considered a low fruit load in this season. In the 2012 and 2013 seasons, the yield was around or slightly greater than the average in Control trees. There were no significant differences in yield between irrigation treatments. In the 2011 season, RDI-2 produced the greater yield, while RDI-12 and Control were almost similar. The 2012 season was, in theory, a high fruit load season according to the fruit load of the previous year. However, the attack of *Spilocaea oleagina* (Cast.) Hughes reduced the fruit load in all the treatments. During the 2012 season, RDIs tended to lower yield values than Control. In 2013, RDI-2 was closer to Control yield than to RDI-12.

Fruit size is an important feature of the yield quality in table olives. Changes in fruit load did not clearly affect the fruit size (Table 4). There were no significant differences between treatments according to water stress conditions. Only in the 2011 season, RDI-2 presented significantly smaller fruit than Control and RDI-12. These latter results were not confirmed in the following years, nor were there clear trends suggesting a reduction in the fruit size at the end of the rehydration period.

The Pulp/Stone ratio is other important characteristic in table olives. A large pulp/stone ratio is valued in the industrial processing after harvest. The Pulp/Stone ratio was sensitive to the fruit load. In conditions of low fruit load (2011 season), Control trees had a greater ratio than in high fruit load (2013 season). Only in the 2013 season, the water stress increased significantly the pulp/stone ratio of RDIs in comparison to Control (in dry weight), although a similar trend was measured in the 2012 season in dry and fresh weight (Table 4). Differences in the 2011 season could be due more to the low fruit load than to the water stress.

The Mature Index (MI) estimates the fruit color. An MI higher than 1, indicates that there is a purple zone in the fruit which is not valued in “green table olives”. There were no significant effects of water stress on MI. The irrigation water use efficiency (WUE) was greater in RDIs than in Control trees in all the seasons. There were no clear differences between RDIs in 2011 and 2012. Only in the 2013 season, when RDI-1 irrigation scheduling was changed, RDI-12 tended towards clearly greater values than RDI-1.

DISCUSSION

Irrigation scheduling based on trunk diameter fluctuations indicators.

Changes in the methodology of MDS signal did not improve the usefulness of the indicator in comparison to previous work (i.e. Moriana et al 2013). The baselines calculated according to Corell et al (2013) generated values in Control trees that, on average, were near to 1 only in high fruit load seasons, although they changed widely in daily values. On the other hand, in the high fruit load season the MDS signals were clearly higher than 1 in both RDIs. Only in an isolated period at the end of phase II, RDI-12 presented an MDS signal lower than 1. These values slightly higher than 1 indicate, in most cases, moderate water stress conditions. However, according to the present result, the MDS signal as a unique indicator is not reliable.

The trunk growth rate (TGR) could be a useful indicator in irrigation scheduling. According to the present data, the average TGR is a good tool for predicting the water stress conditions, similarly to the stem water potential, but using daily TGR and Maximum diameters could also facilitate irrigation scheduling. Rains are the main problem in the use of this methodology and produce long periods, even on the dry days, when trunk diameter fluctuations are useless because there is a trunk shrinkage unrelated to the water stress conditions. Such response has been reported previously in Moriana et al (2013).

The averages TGR obtained in the experiments were generally very different for the daily TGR threshold used in the irrigation scheduling, mainly during the rehydration periods, but also when RDI-2 was scheduled with this parameter during phase II of the 2013 season (Table 2 and Materials and Methods). Such results are related to the response with a great increase of TGR to isolated irrigation events, mainly in the rehydration period. Therefore, during rehydration the daily TGR marked the moment when irrigation is needed but it was not possible to control TGR around these values yet. According to the present data -5μm day^{-1} of daily TGR was an efficient threshold which provided a slow but progressive rehydration. Then, in rehydration periods such as the ones presented here, irrigation scheduling based only on daily TGR seems to be adequate. Having said that, the daily TGR was not as useful during a period when a water stress level is going to be performed. During the 2011 and 2012 seasons, the almost no irrigation in RDIs in phase II produced a continuous decrease in maximum diameter with nearly constant TGR. When RDI-2 was controlled during the 2013 season using the daily TGR, the average TGR and maximum diameter showed a completely different pattern than expected (the objective was -10μm day^{-1}, see Materials and Methods). Although water potential in this treatment and period suggests low water stress conditions, the maximum diameter and average TGR data indicated that “false positives” were considered during this period. Giron et al (2015a) reported a decrease in TGR with vapor pressure deficit (VPD) variations not related to water stress. Therefore, when water stress is imposed, the daily TGR could be useful, but only if used in addition to maximum diameter and average TGR. Daily TGR values below the threshold should be the alert signal but this should be confirmed for the trend of maximum diameter and average TGR.

Maximum diameters, in addition, permits the estimation of the beginning of pit hardening when there is a significant fruit yield. TGR values around 0 as in 2012 and 2013 seasons, produces a period of no trunk growth in full irrigated conditions which has been related with maximum endocarp size and the beginning of massive pit hardening (Pérez-López et al., 2008).

Effect of regulated deficit irrigation in table olive yield

The yield response in RDI scheduling could be evaluated for the short and long term. In the present work, there were no significant differences in yield, although there was a clear trend towards a reduction in RDI-12 in comparison to Control and this could be related to both effects. Long-term effects are mainly associated with floral induction and tree growth. According to present data, the level of water stress did not affect the floral induction in any of the treatments. On the other hand, data of soil cover at the end of the experiment suggested that there was a slight reduction in crown volume, which could explain part of the trends towards yield reductions in 2013 in the RDI-12 treatment. Caruso et al (2013) suggested that, in young olive trees, the most important differences between irrigation treatments were related to crown volume. In the present work, the absence of pruning during 2012 and 2013 allowed estimating the influence of growth. RDI-2 almost had a similar water status to Control during virtually the entire 2013 season and the reduction in yield could be likely related only to differences in crown volume at the beginning of the season, this reduction was only around 9%. Therefore, this level of water stress could be sustainable because the differences in yield are low and in mature trees, pruning could level out the differences in seasonal growth.

Yield effects in the short term are processes that occur during the current season. In the present work, the fruit growth and fruit drop are the two main effects described. The fruit volume reduction in the RDIs treatments was recovered during the rehydration period and the data suggest no effect on this yield component. Such results suggest that the water stress level did not have a significant impact on the capacity of the fruit to recover. In phase II, when these differences were measured, only the mesocarp was growing and the reduction in fruit size was likely related to a reduction in mesocarp cell size or in the number of cells. Rapoport et al (2004) reported differences in the cell size but not in the cell number in olive trees during water stress conditions. Girón et al (2015b) suggest that in olive trees, fruits are a stronger water sink than leaves at the end of a moderate drought period, which could facilitate a complete recovery even in a slow and/or short rehydration period. Such response is likely related with the traditional recommendation of reduction of irrigation during pit hardening (Goldhamer, 1999).

Olive trees are very sensitive to drought conditions during phase I, when a severe fruit drop could be caused by low levels of water stress (Moriana et al., 2003). However, according to the present data of water status, number of inflorescences and fruits, there was not fruit drop during this period. In this work, the fruit drop was affected during phase II at shoot level, although the reduction was not always in agreement with the one measured in the final yield. These differences between fruit drop at shoot and total tree level could be related to sampling problems, since the level of radiation was lower at the sampling height than at the upper part of the tree, especially during 2012 or 2013, when there was no pruning. Radiation is an important factor in the location of fruits in the tree. Several authors reported that olive trees tend to accumulate fruit in the best illuminated part of hedgerow olive orchards (Pastor et al., 2007; Cherbiy-Hoffmann et al., 2013).

The quantification of total fruit drop in relation with water stress is not easy. Fruit drop in 2011 was negligible in all the treatments. During the 2013 season, the reduction in yield in RDI-12 was probably related to differences in crown volume and fruit drop. Since the yield reduction due to crown volume was around 9% in RDI-2 and both RDIs have similar tree sizes, the fruit drop would produce around 16% of yield reduction in RDI-12. During 2012, the moderate defoliation of the trees due to the Spilocaea attack could have leveled the differences in crown volume and most of the yield reduction in both RDIs could have been related to fruit drop. In this season, the yield reduction was lower than expected in RDI-12 based on to the water stress level and fruit drop at shoot level, while the opposite occurred at RDI-2. Unidentified factors probably related to locations of the Spilocaea defoliation could be linked to these disagreements. Considering all the data, the water stress level of the 2012 season and RDI-12 in the 2013 season would be not advisable because of the excessive fruit drop. However, further works will be performed in order to quantify the total fruit drop related to water stress.

Yield quality was not significantly deteriorated in RDIs treatments, in fact, the pulp:stone ratio improved. Since during the endocarp growth, phase I, the water stress level was not significant, such differences should be related to mesocarp growth. In addition, clearer trends for improvements in the pulp:stone ratio were measured in dry weight than in fresh weight. Such results suggest that a moderate water stress level, likely to occur during the recovery period, could enhance the accumulation of dry matter. In other species the accumulation of carbohydrate is commonly reported when a period of water stress is imposed before harvest (i.e., tomato, Johnstone et al., 2005; vineyards, Girona et al. 2006). In olive trees, although the oil accumulation has been reported as sensitive to water stress (Lavee and Wonder, 1991), some authors have suggested that moderate water stress conditions could increase oil accumulation (Lavee et al., 2007)

Sustainable water stress levels and indicators in table olive trees

Trunk growth rate (TGR), midday water potential (Ψ) and water stress integral (SI) were sustainable indicators in the present work with a good correspondence with fruit drop and fruit growth. Several authors described these indicators as useful in olive trees, mainly Ψ (among others, Goldhamer, 1999, Moriana and Fereres, 2002, Gucci et al., 2007, Iniesta et al 2009) but also TGR (Moriana and Fereres, 2002; Moriana et al., 2013). However, there are few publications about threshold values, even in Ψ. In the present work there was no clear results during phase I, because of the weather during this period (which affected the TGR values) and the very small differences, if any, of water stress level in the trees. The TGR threshold value during the recovery ($-5 \mu m\ day^{-1}$) provided a similar response for the different years in all the RDIs treatments with a slow, sometimes even incomplete, recovery of water status. Having said that, the recovery was still sufficient, according to the previous discussion and no clear differences in yield related to fruit size were observed. Moriana et al (2013) suggested that this threshold value was useful during recovery and even phase II.

The water stress level during phase II was more variable between seasons and the relationship with fruit drop would allow selecting a threshold value for future works. According to data of the 2011 season, a fruit drop at the shoots of around 5% could be acceptable, mainly when these values usually over-estimated the yield reduction. Then, values of -2.2MPa in Ψ and -2.0MPa*day in SI could be useful as a first approach. Dell’Amico et al (2012) and Girón et al (2015b) suggested water stress values between -1.8MPa and -2.5MPa for olive trees. Rosecrance et al (2015) reported that a Ψ around -

2.2MPa increased oil yield and reduced shoot growth in olive trees. Although Girón et al (2015b) suggested that SI could be complementary information to Ψ in the description of water stress in olive trees, the present work suggests that, at least in relation with fruit drop, both indicators provided similar information. Although TGR vs fruit drop was weaker than in the other two indicators, values around -10μm day^{-1} of TGR average could be useful in future works.

Environment around the tree is a common source of error in all the water status measurements. Although Control Ψ values in the three seasons were commonly very similar around the threshold suggested, several dates in all the season, even in low fruit load conditions, were lower than expected likely related with the extreme climatic conditions. Moriana and Fereres (2004) and Moriana et al (2012) suggested though there was an effect of evaporative demand in the Ψ values, such variations were small and constant values could be used. This strategy is easy for commercial orchard management but it could be over-estimated the water stress level of the trees. Fruit load is other factor which could affect the values of these indicators, mainly TGR seasonal patter according to the present work but also Ψ and, then, the stress integral. This response in all these indicators has been reported in different works (Moriana et al 2003; Martín-Vertedor et al., 2011) and could avoid with a good selection of the trees at the orchard.

Usefulness of each indicator could be also analyzed according to the present data. Although the present work suggests thresholds and management of TGR, further works are needed to confirm such recommendations in other orchards. On the other hand, the utility and ease of Ψ measurements and its capacity for using at commercial orchard is clearly greater than TGR. Even for the present data, some conclusions of previous work such as Moriana and Fereres (2002) about the higher accuracy of TGR vs

Ψ are not clearly demonstrated. However one of the main advantages of the TGR which is the continuous monitoring, suggest that it is advisable to continue with the line of research in order to improve this methodology.

CONCLUSIONS

MDS was not a clear indicator of water stress in most of the dates in the three seasons. Isolated values of MDS were difficult to interpret, even with the changes included in the calculation. On the opposite, the average TGR presented good fit with fruit drop and fruit size and could be useful for irrigation scheduling during phase II. However, although the daily TGR should be used in the daily scheduling, the pattern of maximum diameter and average TGR should be considered in a deficit approach as well. During the recovery period, the daily TGR was a simple approach that permitted a good management of the rehydration, although the average TGR was clearly different from daily TGR due to the tree response to irrigation events.

Water stress level during the three years of experiments reduced fruit size during the period of stress, but it was recovered during rehydration. The most severe water stress levels increased fruit drop at shoot level, although it was not possible to quantify exactly the effect on the total yield. According to the relationship obtained between fruit drop and water stress indicators, the threshold values of midday stem water potential around -2.2MPa, stress integral around -2.0MPa*day and average TGR around -10µm day^{-1} during phase II could be sustainable in a RDI strategy. During the recovery period, a daily TGR of -5µm day^{-1} provided a slow but adequate rehydration in relation to fruit size.

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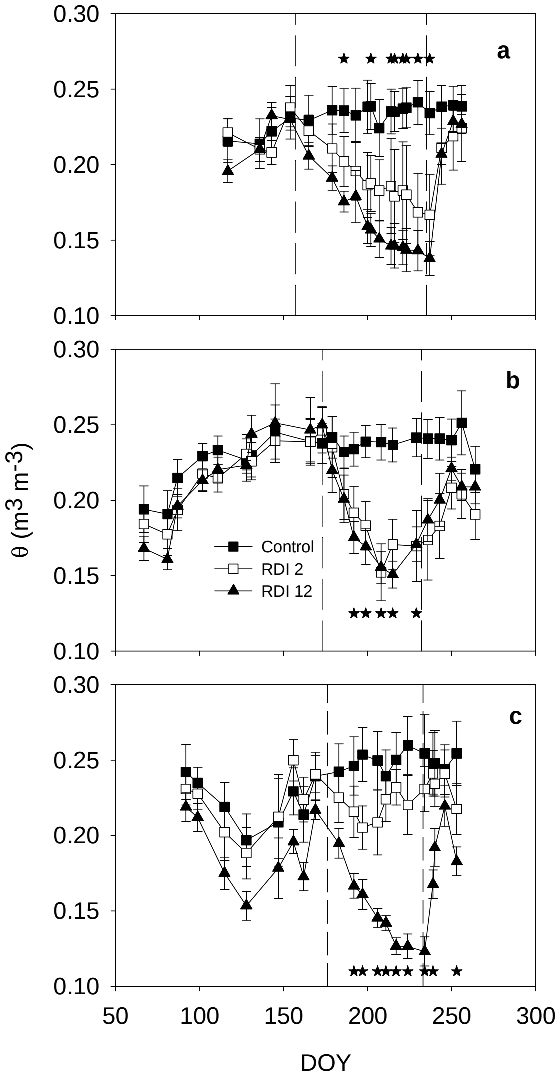

Fig. 1. Soil water content (θ, m^3m^{-3}) in 1 m depth along the season during the three years of the experiment. (a) 2011, (b) 2012, (c) 2013. Each point is the average of 3 measurements. Vertical bars represent standard error. Vertical lines delimitate the pit hardening period (phase II). Asterisks at the bottom indicate significant differences at that date.

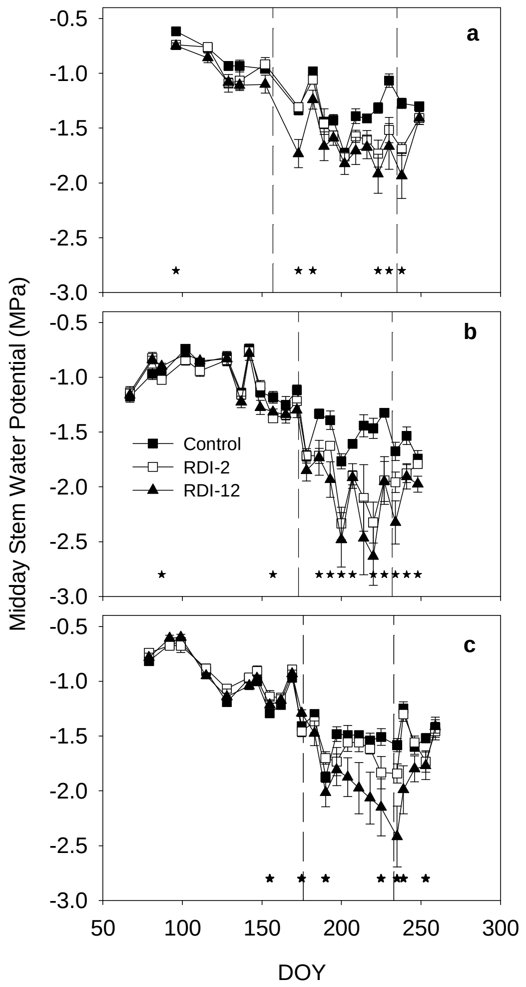

Fig. 2. Midday stem water potential (MPa) along the season during the three years of the experiment (a) 2011, (b) 2012, (c) 2013. Each symbol is the average of 6 data. Vertical bars represent standard error. Vertical lines delimitate the pit hardening period (phase II). Asterisks at the bottom indicate significant differences at that date.

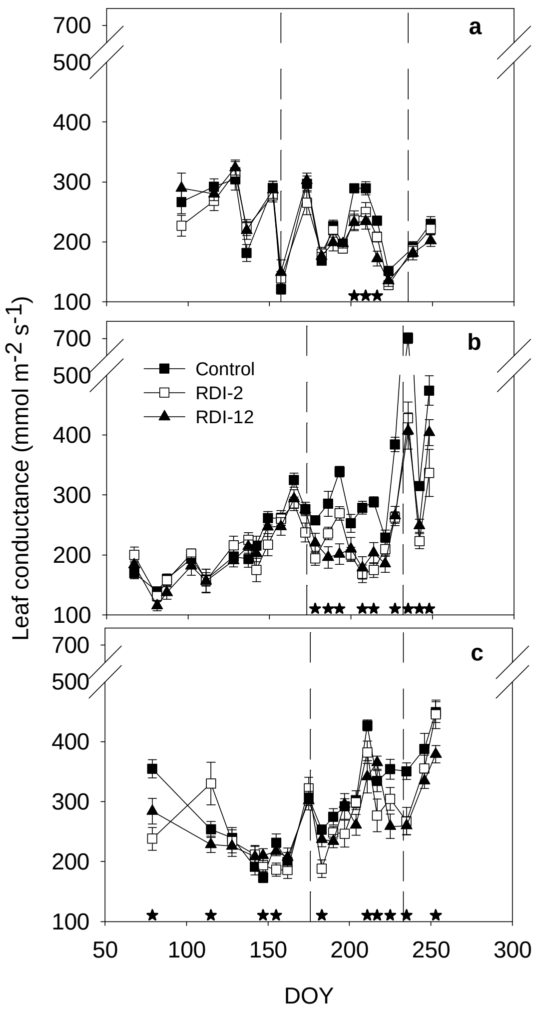

Fig. 3. Maximum leaf conductance during the three years of the experiment (a) 2011, (b) 2012, (c) 2013. Each symbol is the average of 12 data. Vertical bars represent standard error. Vertical lines delimitate the pit hardening period (phase II). Asterisks at the bottom indicate significant differences at that date.

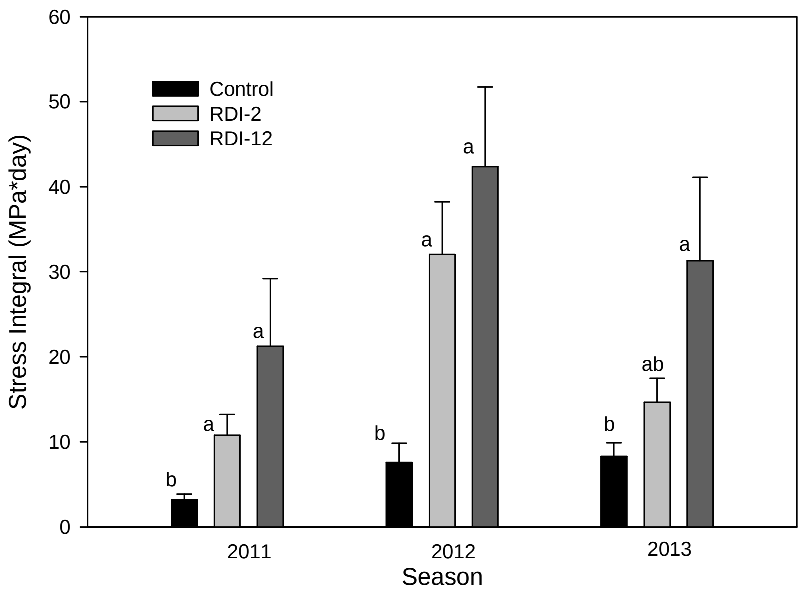

Fig. 4. Stress integral (SI) during the three years of the experiment. Each bar is the average of 6 data. Vertical lines represented standard error. Different letters at the same season indicate significant differences (p<0.05, Tukey Test).

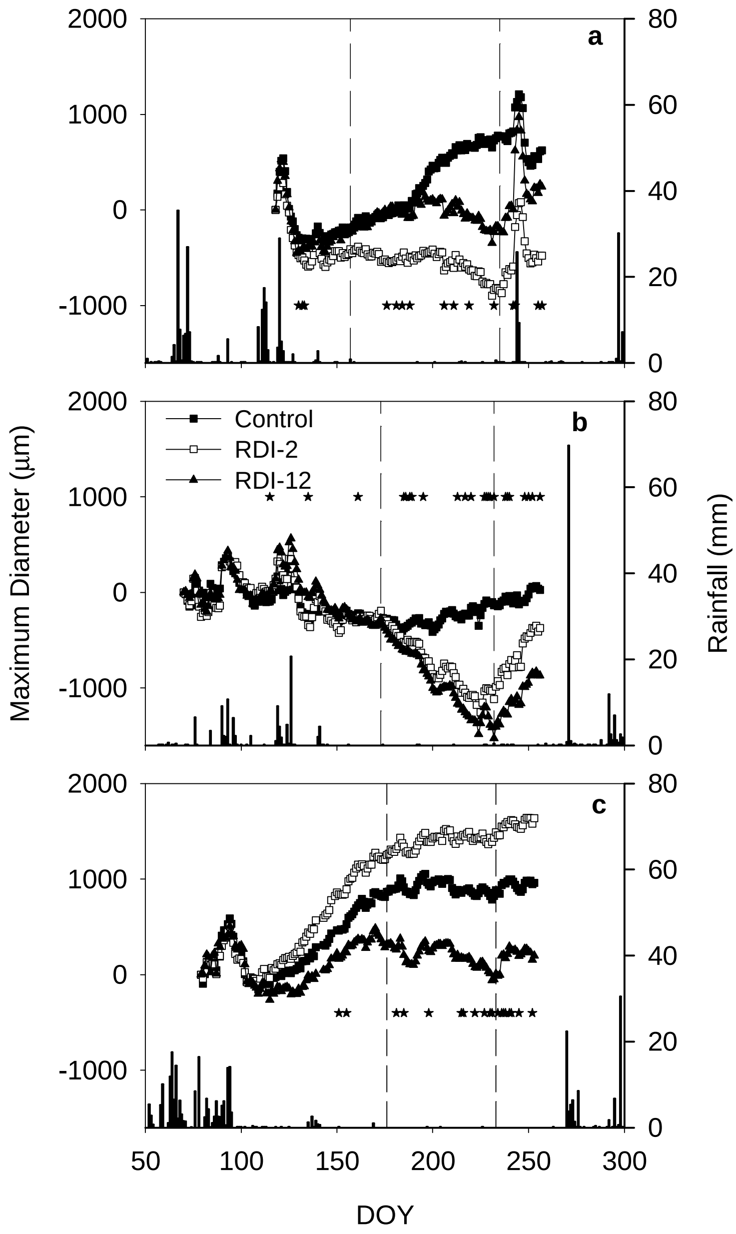

Fig. 5. Seasonal pattern of Maximum diameter in the three years of the experiment (a) 2011, (b) 2012, (c) 2013. The slopes of these data are the Trunk growth rate (TGR). Each symbol is the average of 6 data. Vertical bars at the bottom represent rainfall. Vertical lines limited the period of pit hardening. Asteriks indicated the date when significant differences between TGR values were measured.

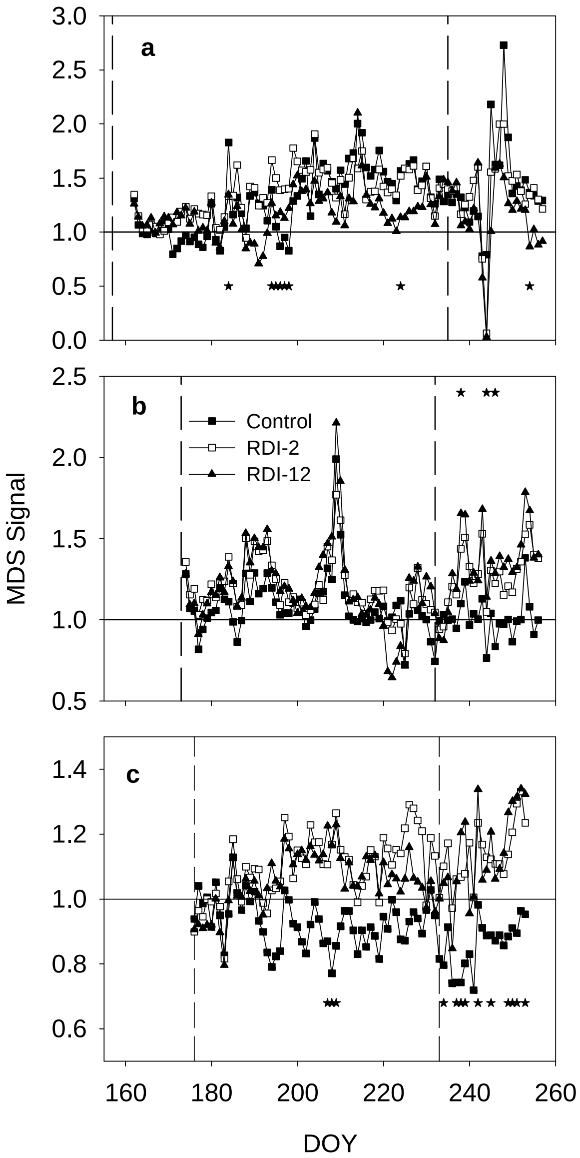

Fig. 6. Seasonal pattern of Maximum daily shrinkage signal (MDS signal) in the three years of the experiment (a) 2011, (b) 2012, (c) 2013. Each symbol is the average of 6 data. Vertical lines limited the period of pit hardening. Asteriks indicated the date when significant differences between treatments were measured.

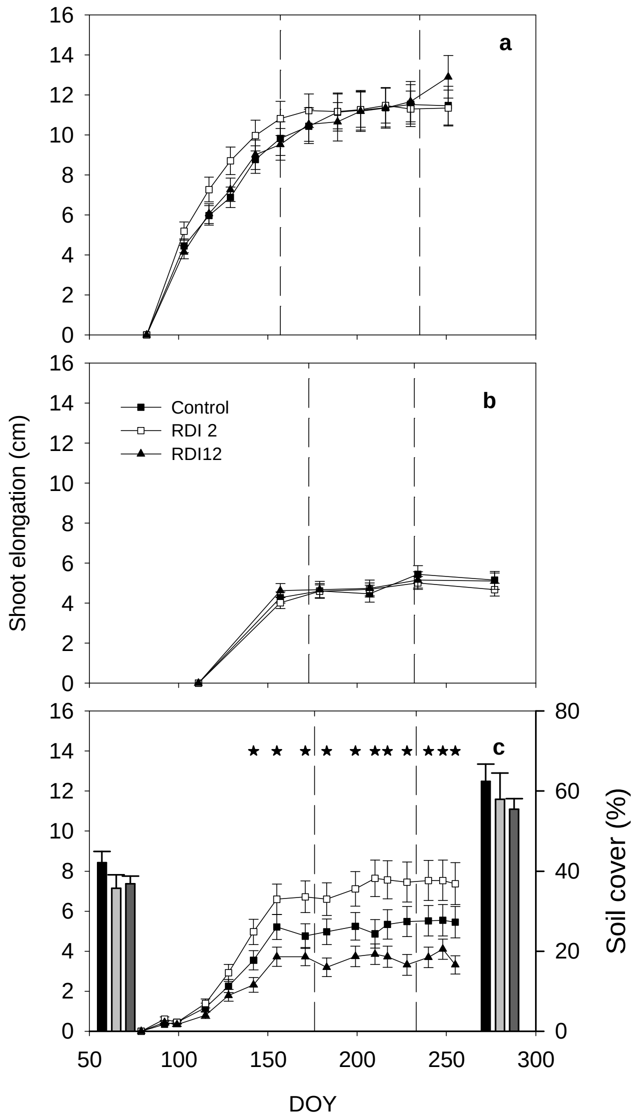

Fig. 7. Shoot elongation during the three seasons of the experiment (a) 2011, (b) 2012, (c) 2013. Vertical bars represent percentage of soil cover at the beginning and the end of 2013 season (c). Left bars are Control data, center bars are RDI-2 data and right bars are RDI-12 data. Each symbol is the average of 60 data and each bar is the average of 6 data. Small vertical lines represent standard error. Long dash vertical lines delimitate phase II. Asteriks represent significant differences in shoot elongation data at that date ($p<0.05$, Tukey Test). No significant differences were found in the percentage of soil cover.

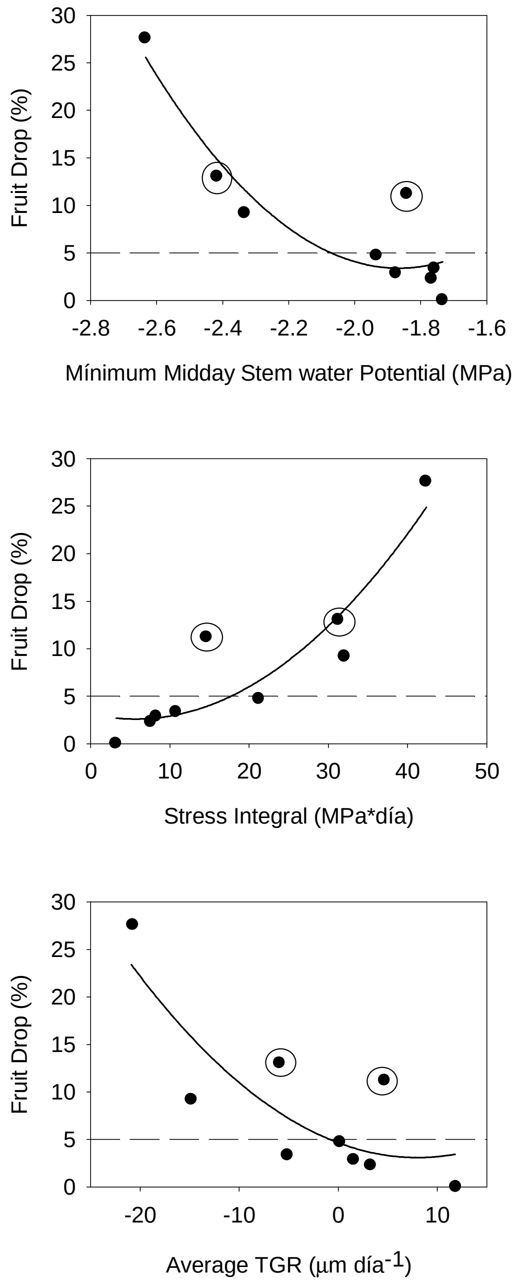

Fig. 8. Relationship between fruit drop (%) and three different indicators. (a) Minimum Midday Stem Water Potential (Ψ) during phase II (% Fruit Drop=134.4+140.4*Ψ+37.6*Ψ^2, R^2=0.84**, Standard Error=3.96%, n=9) (b) Stress Integral (SI) during phase II (% Fruits Drop=3.1-0.19IS+0.02SI^2, R^2=0.84**, Standard Error=3.99%, n=9) (c) Average TGR. During phase II (% Fruit Drop=4.74-0.41TGR+0.02TGR^2, R^2=0.68*,Standard Error=5.5, n=9). Horizontal line represents an

acceptable percentage of fruit drop. Data with a circle are the ones measured during 2013 season at RDIs treatments.

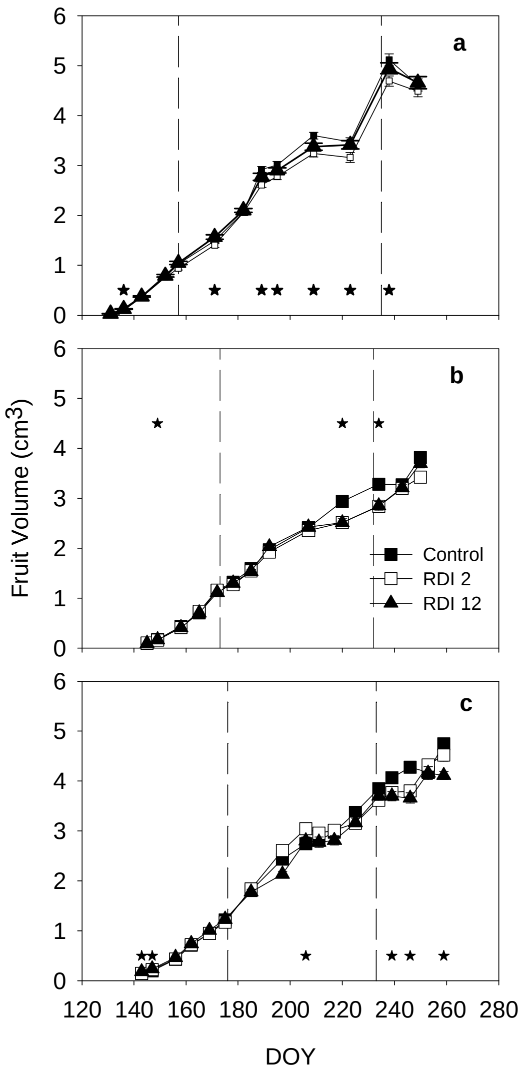

Fig. 9. Seasonal pattern of fruit volume during the three years of the experiment. (a) 2011, (b) 2012, (c) 2013. Vertical lines limited the period of phase II. Vertical bars are standard error. Asterisks indicate significant differences at that date ($p<0.05$, Tukey Test).

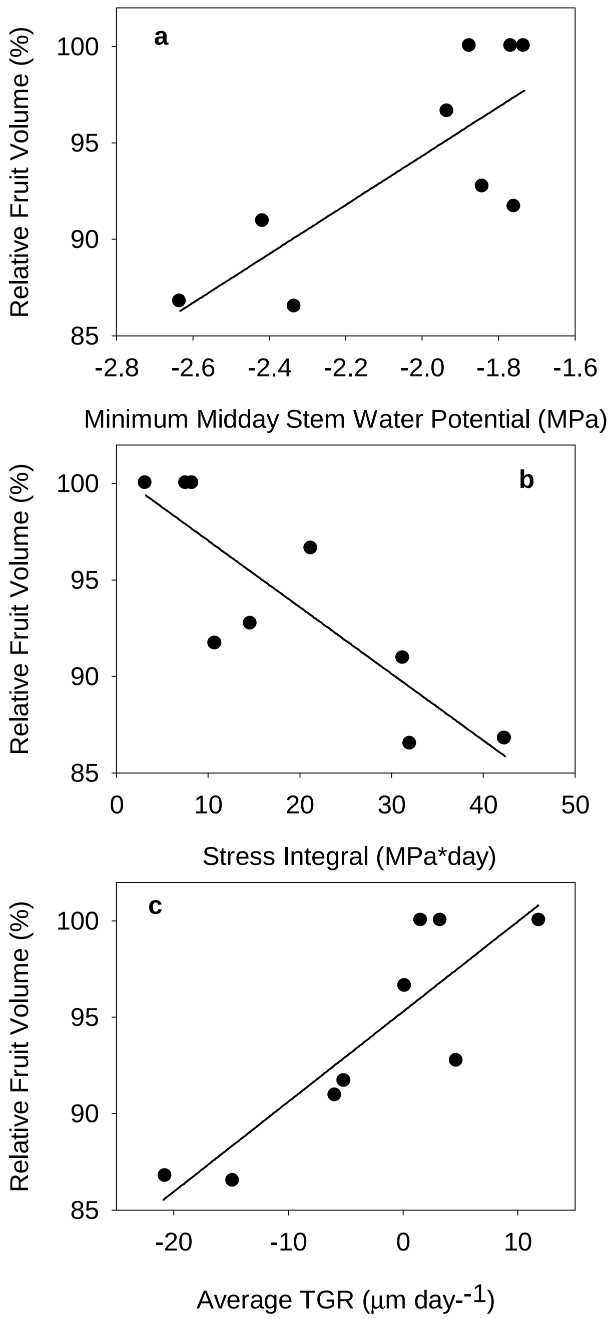

Fig. 10. Relationship between three different indicators and the relative fruit volume of each treatment at the end of the phase II. (a) Minimum Midday Stem water potential during phase II (Ψ); Relative Fruit Volume=119.7+12.7 Ψ; R^2=0.61*; Error Standard=3.6%; n=9 (b) Stress Integral (SI) during phase II; Relative fruit Volume=100.5-0.35IS; R^2=0.72**; Error Standard =3.1 (c) Average TGR during phase II; Volume Relative Fruit =95.2+0.47 TCT; R^2=0.75**; Error Standard =2.9; n=9. For

each season, the relative fruit volume is the rate between the fruit volume of each treatment at the end of the phase II and the one of the Control.

Table 1. Irrigation amount (mm), reference evapotranspiration (ETo, mm) and rainfall (mm) during the corresponding phenological stages of the three seasons experiments.

The duration of each phenological stage is presented between brackets. The beginning of phase I was considered in all the seasons at DOY (day of the year) 60. In the columns ETo and rainfall, between brackets, the values of each variable from the beginning of the irrigation period. Ph I (Phase I), Ph II (Phase II), Ph III (Phase III), Postharv (Postharvest). Description of each phenological stage is provided in Materials and Methods.

			Irrigation		**ETo**	**Rain**
		Control	**RDI-2**	**RDI-12**		
2011	Ph I (97)	40	34	28	444 (130)	211(5)
	Ph II (78)	216	33	12	513	3
	Ph III (28)	43	78	75	137	37
	Postharv	0	0	0	270	163
2012	Ph I (113)	229	128	111	484 (425)	94(86)
	Ph II (60)	230	13	9	368	0
	Ph III(30)	81	30	41	147	1
	Postharv	0	0	0	137	115
2013	Ph I (116)	108	72	62	440(279)	173(9)
	Ph II(57)	193	89	0	361	0
	Ph III (30)	68	46	44	139	0
	Postharv	0	0	0	212	152

Table 2. Average trunk growth rate (TGR) during each phenological phase along the experiment.

			Average TGR (µmday^{-1})		
	Fruit load		Control	RDI-2	RDI-12
2011	30%	Phase I	7.9±5.6	7.3±8.8	16.7±2.2
		Phase II	11.9±4.5	-5.1±3.0	0.2±6.4
		Phase III	14.1±9.1	23.6±12.2	26.8±9.1
2012	83%	Phase I	-2.1±2.3	-2.6±5.5	-6.3±2.7
		Phase II	3.3±3.1a	-14.8±5.7b	-20.7±2.9b
		Phase III	6.1±3.4	31.5±12.4	28.2±7.1
2013	113%	Phase I	15.1±2.5	19.0±4.4	6.2±4.5
		Phase II	1.6±1.2	4.7±2.8	-5.9±4.8
		Phase III	3.8±1.9	7.4±3.2	9.8±6.0

The column "fruit load" indicated the rate between the Control yield of each year and the average biennial Control yield in the last 8 seasons (8 MT ha^{-1}). When different letters are presented in the same row indicates significant differences between treatments ($p<0.05$, Tukey Test).

Table 3. Average maximum daily shrinkage signal (MDS signal) during each phenological phase along the experiment.

The column “fruit load” indicated the rate between the Control yield of each year and the average biennial Control yield in the last 8 seasons (8 MT ha^{-1}). When different

			MDS Signal		
	Fruit Load		Control	RDI-2	RDI-12
2011	30%	Phase II	1.39±0.08	1.40±0.07	1.21±0.05
		Phase III	1.31±0.13	1.33±0.08	1.12±0.11
2012	83%	Phase II	1.08±0.14	1.19±0.07	1.20±0.16
		Phase III	1.00±0.14	1.28±0.07	1.33±0.13
2013	113%	Phase II	0.92±0.08	1.10±0.06	1.06±0.07
		Phase III	0.86±0.09b	1.14±0.08a	1.15±0.08a

letters are presented in the same row indicates significant differences between treatments ($p<0.05$, Tukey Test).

Table 4. Features of the yield in the three seasons of the experiments.

		Control	RDI 2	RDI 12
2011	Yield	2.5±0.5	4.1±0.6	2.9±0.6
	Fruit per Kg	188±5 b	206±5 a	190±4 ab
	PS Fresh	6.2±0.1 a	5.7±0.1 b	6.1±0.1 a
	PS Dry	2.8±0.1	2.5±0.1	2.8±0.1
	M.I	2.9±0.2 a	1.6±0.1 b	2.3±0.2 a
	WUE	0.8	2.8	2.5
2012	Yield	6.6±0.7	5.0±0.8	5.9±0.7
	Fruit per Kg	233±13	249±10	240±10
	PS Fresh	4.1±0.1	4.1±0.2	4.4±0.2
	PS Dry	1.9±0.1	2.2±0.1	2.3±0.1
	M.I.	0.8±0.2	0.8±0.1	0.9±0.1
	WUE	1.2	2.9	3.7
2013	Yield	9.0±1.1	8.2±0.6	6.7±0.7
	Fruit per Kg	229±13	209±7	208±11
	PS Fresh	4.6±0.3	5.2±0.2	5.0±0.3
	PS Dry	2.1±0.1 b	2.5±0.1 a	2.3±0.1 ab
	M.I.	1.0±0.1	1.3±0.2	1.1±0.1
	WUE	2.4	4.0	6.3

Yield (MT ha^{-1}), Number of fruit per Kg (fruits Kg^{-1}), Pulp/stone ratio in fresh weight (PS fresh), pulp/stone ratio in dry weight (PS dry), Mature Index (M.I.), Irrigation Water Use Efficiency (WUE, Kg m^{-3}). Different letter indicates significant differences at the same season and feature ($p<0.05$, Tukey Test). No statistical analysis were performed at the WUE