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Postharvest regulated deficit irrigation in early- and intermediate-maturing loquat trees

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ABSTRACT

Postharvest deficit irrigation (DI) strategies have been proven to advance bloom, harvest dates and economic return in loquat ‘Algerie’ trees because an early harvest results in higher loquat fruit prices. This fact poses the question of whether postharvest DI strategies could have a similar effect on more precocious cultivars than *cv.* Algerie, providing thus a more profitable option to farmers. In this work, the response of an early- and intermediate-maturing loquat cultivars (*cv.* Cardona and Algerie, respectively) to a summer early (DI_{early}) and late (DI_{late}) DI strategy was assessed in two parallel studies during three consecutive years. The effects of the DI_{early} and DI_{late} strategies on bloom date, percentage of fruit picked at harvest per picking date and yield of both loquat varieties were studied. Moreover, fruit quality of *cv.* Cardona at harvest was also assessed. Plant water status was monitored by midday stem water potential (Ψ_{stem}) measurements. Results showed that DI_{early} and DI_{late} strategies advanced bloom in both cultivars although a higher effect was observed with the DI_{early} than with the DI_{late} treatment. Water restrictions did not increase the percentage of fruit picked at any of the picking dates and did not affect yield or fruit quality in the early-maturing cultivar. In ‘Algerie’ trees, a higher percentage of fruit was generally picked during the first picking dates in the DI_{early} and DI_{late} treatments than in the control although differences were only statistically significant during the last experimental season. Yield was significantly higher in ‘Algerie’ DI_{late} trees than in control or DI_{early} trees two out of the three experimental seasons. Overall, results showed that the DI_{early} and DI_{late} strategies tested here did advance bloom in the early-maturing cultivar but did not have an effect on the percentage of fruit picked per picking date at harvest. Nevertheless, the fact that substantial water savings (>30%) were obtained with no detrimental effect on

yield presents the use of postharvest DI strategies as an interesting option to be followed in early-maturing cultivars for a more efficient crop production.

Keywords: regulated deficit irrigation; water savings; water stress; stem water potential

Introduction

Loquat (*Eriobotrya japonica* Lindl.) is an evergreen subtropical tree crop native from China, which is the first producing country in the world (Caballero and Fernández, 2003). Loquat requires humid and warm climate and therefore, its production has been well adapted to the Mediterranean climatic conditions (Llácer et al., 1995). In Spain, loquat is a minor crop in the country although its fruit is appreciated in other Mediterranean countries and exports are close to 50% of total production (Caballero and Fernández, 2003). Its interest lies in the fact that loquat trees are harvested during spring (loquat fruit ripens between March to May), when there is low competition with other fruit on the market. This characteristic makes loquat an interesting and profitable crop for growers, especially the most precocious cultivars, which usually reach higher value in the market.

Specific breeding programs have been design in Mediterranean countries to find new and early-maturing loquat cultivars (Badenes et al., 2013). Crop management practices have been also tested with success to advance full bloom and harvest dates in ‘Algerie’ trees. For instance, extensive work on loquat ‘Algerie’ trees has illustrated the suitability of this cultivar to regulated deficit irrigation (RDI) (Cuevas et al., 2007; Cuevas et al., 2009; Hueso and Cuevas, 2008, 2010; Rodríguez et al., 2007).

RDI is a water-saving strategy in which trees are deficit irrigated during certain phenological periods when trees are less sensitive to water scarcity while irrigation is

applied to meet full water requirements during the most sensitive stages of the crop (Behboudian and Mills, 2010; Chalmers et al., 1981). Postharvest RDI strategies have been proven to hasten both bloom date and harvest date in ‘Algerie’ trees, increasing then crop profitability.

Studies on ‘Algerie’ trees by Cuevas et al. (2007) determined that the month of July is the most appropriate time to implement RDI strategies in order to do not harmless flower development. Cuevas et al. (2009), on the other hand, reported that short periods with severe water restrictions (0 to 25% ET_c) from mid-June to the end of July are more effective than sustained water stress strategies to advance bloom and harvest date. Therefore, implementation of this irrigation practice can lead loquat ‘Algerie’ producers to increase their incomes due to both a reduction in the costs associated with the water usage and an increase in the price reached by the fruit in the market (Hueso and Cuevas, 2010). This fact poses the question of whether postharvest DI strategies could have a similar effect on more precocious cultivars than *cv.* Algeria, providing thus a more profitable option to farmers.

The *cv.* Cardona is a somatic mutation from ‘Algerie’ (Carrera García et al., 2011). ‘Cardona’ trees reach full bloom and maturation around two weeks earlier than ‘Algerie’ trees (Martínez-Calvo et al., 2000) and for that reason its cultivation is an interesting option in loquat producing areas. Postharvest RDI strategies in this particular cultivar could even increase the gap with the *cv.* Algeria. Nevertheless, it is not rare to find differences between cultivars in their sensitivity to water stress or other abiotic factors (Salón et al. 2005) and thus, assessment of RDI strategies on cultivars with different ripening season are encouraged.

The main objective of this work was to study the response of early- and intermediate-maturing loquat cultivars to postharvest deficit irrigation with special interest in

blooming, percentage of fruit picked at each picking date at harvest and yield in order to explore whether summer DI strategies could be applied to early-maturing loquat cultivars to reach the market earlier in the season..

Material and methods

Experimental sites

Two contiguous sites were selected at Callosa d'En Sarrià (38°45'N, 0°08'W, elevation 247 m), Alicante (Spain) for studying the response of early- and intermediate-maturing loquat varieties to RDI strategies. One site was a 0.6-ha terraced orchard planted with 'Cardona' trees in 2000 in which summer RDI strategies were studied from the 2009/10 to the 2011/2012 seasons. The second site was a 0.5-ha terraced orchard planted with 10-year-old 'Algerie' trees where RDI strategies were studied from the 2010/11 to the 2012/13 seasons. At both sites, trees were planted at a spacing of 3 m between trees within the same terrace.

Soil at both sites was of clay texture (45% clay, 25% silt, 30% sand), stony and with an effective depth of 0.80 m and an organic matter content of 2.82%. Trees were drip irrigated with only one line per row and four emitters of 3.85 L h⁻¹ per tree. As a normal practice in the area, a shading white net was used throughout the entire experiment in both sites to reduce the solar radiation to approximately 65% of the global solar incident radiation reaching the net. Meteorological data during the study was obtained from a weather station installed under the net.

Field practices were those commonly applied for loquat tree culture in the area and included fruit thinning applied to retain only the more developed 4-5 fruits per panicle.

Irrigation treatments

As an early-maturing cultivar, 'Cardona' trees reach full bloom earlier than 'Algerie' trees (11-20 days before in this study over the three seasons) and thus, RDI strategies

were applied two weeks earlier in ‘Cardona’ than ‘Algerie’ trees. Two RDI strategies in which irrigation was withheld for four weeks were assessed at each site during three consecutive seasons, that is, from 2009 to 2012 at the ‘Cardona’ site and from 2010 to 2013 at the ‘Algerie’ site. Irrigation treatments consisted in an early (DI_{early}) and late (DI_{late}) deficit irrigation strategies. DI_{early} was applied from mid-June to mid-July to ‘Cardona’ trees and during the month of July to ‘Algerie’ trees. The DI_{late} strategy was applied from mid-July to mid-August to ‘Cardona’ trees and during August to ‘Algerie’ trees. Both RDI strategies were compared to a control treatment irrigated at 100% of the estimated crop evapotranspiration (ET_c).

The experimental design at each site was a randomized complete block, with three plots per treatment (a total of 9 experimental plots per site). Each experimental plot consisted in three rows of five trees each. The middle row was used for the plant determinations and perimeter trees were used as guards. All the experimental plots were instrumented with in-line water flow meters in order to record the volumes of water applied to the trees.

Plant water status

Effect of treatments on plant water status was determined by measuring the stem water potential (Ψ_{stem}) in two trees per replicate (six trees in total per treatment) with a Scholander pressure chamber (Model 600 Pressure Chamber, PMS Instrument Company, Albany, USA). Measurements were performed weekly at solar noon in two leaves per tree located in the north side of the canopies and bagged with aluminum foil at least two hours previous to the measurements.

Flowering determinations

The possible effect of the DI strategies on flowering was evaluated on ten panicles of two trees per plot (20 panicles per plot; 60 panicles per treatment). Panicles were

properly labeled and flower opening was monitored weekly to determine the percentage of open flowers on a panicle basis thorough the season.

Yield determinations and fruit quality

Yield was determined at harvest by picking all the fruit from three trees per plot (nine trees per treatment in total). At both sites, fruit were picked in several days (over the tree seasons, 7-8 days for 'Cardona' trees and 4-6 days for 'Algerie') because of the uneven development of fruit ripening within each tree. The percentage of fruit picked during each picking date was then calculated for each treatment. For each sampled tree, the number of fruits collected were counted and total production weighted in order to calculate the average fresh fruit weight per treatment.

Fruit quality was assessed on 'Cardona' trees only during the 2009/10 and 2010/11 season. Considering the results obtained and the lack of human resources available for fruit composition determinations, in the last experimental season fruit analyses were not performed. For that, a minimum of 12 fruits were sampled at harvest from the three selected trees per plot and fruit weight, external color, firmness, titratable acidity and total soluble solids content determined. Fruit skin color was evaluated using a Minolta Colorimeter (Model CR-300, Ramsey, NY, USA). The 'L', 'a', 'b' Hunter parameters were measured and the results were expressed as a Skin Colour Index (CI) = $(1000a) / (Lb)$ (Jimenez-Cuesta et al. 1981). Flesh firmness was determined after removing peel by a texturometer instron universal machine model 4301 (Instron Corp., Canton, MA, USA) using an 8-mm flat plunger. The results are expressed as the load in Newtons (N) required for breaking fruit flesh. After taking the texture measurements, each fruit was cut into four longitudinal pieces. Two opposite quarters were used to determine titratable acidity and total soluble solids; to this end, two juices were obtained (six fruits per juice) by grounding the samples in a mortar and filtered through cheesecloth. Total

soluble solids content of each juice was measured twice with a digital refractometer (model PR1, Atago, Tokyo, Japan) and the results were expressed as °Brix. Titratable acidity was determined by allowing the acids present in the juice to be neutralized with a 0.1 N sodium hydroxide solution at a chosen end point, while the required volume was used to estimate acidity, reported as the equivalent g of malic acid per 100 mL of juice.

Data analysis

Statistical analysis was performed using the SAS statistical package (version 9.0; SAS Institute, Cary, NC). On a first attempt, data from all three seasons were pooled together. But because for some of the variables the interaction between the irrigation treatments and the year factor was statistically significant ($p < 0.05$), data from each site and year were analysed separately using analysis of variance (ANOVA) procedure where means were separated by Duncan's test. For fruit quality determinations, peel colour was initially added as a co-variate in the ANOVA, but because its effect was statistically not significant ($p > 0.05$), all fruit quality variables were then analysed without any co-variate.

Results

Meteorological conditions and irrigation volumes

The ET_o and rainfall recorded at both sites during each growing season (from harvest to harvest) are shown in Table 1. Similar values of total ET_o were recorded from the 2010/11 to the 2012/13 seasons, which ranged from 717 to 777 mm. However, total ET_o during the 2009/10 season, the first experimental season for 'Cardona' trees, was 994 mm. Total precipitation recorded ranged from 280 mm in the 2012/13 season to 559 mm in the 2011/12.

Mean irrigation volumes applied to the ‘Cardona’ control treatment during the three seasons of study ranged from 234 to 390 mm (Table 1). ‘Cardona’ DI_{early} trees received 24, 20 and 34% less water than control trees during the first, second and third experimental seasons, respectively. Similar reductions in water applied were obtained in the DI_{late} treatment in 2009 (22%) and 2010 (18%). However, during the last and most rainy experimental season, DI_{late} trees received just 8% less water than control trees.

Over the three seasons, irrigation applied to the control ‘Algerie’ trees ranged on average between 291 and 342 mm. Water restrictions in the DI_{early} treatment in this site led to water savings of 10, 38 and 37%, in the 2010/11, 2011/12 and 2012/13 seasons, respectively. In the DI_{late} treatment, however, water savings ranged from 18 to 33% of the water applied to control trees.

Plant water status

Similar Ψ_{stem} values were recorded in control, DI_{early} and DI_{late} trees before the imposition of the water restrictions in each treatment. Once treatments began, Ψ_{stem} dropped in DI_{early} and DI_{late} trees at both sites, reaching significantly lower values than the control treatment (Figure 1).

In ‘Cardona’ trees, the lowest Ψ_{stem} values recorded in the DI_{early} treatment were obtained in 2011 (-1.84 MPa). In 2009 and 2010, the average minimum Ψ_{stem} values reached were -1.46, and -1.71 MPa, respectively. Lower Ψ_{stem} values were recorded during the first growing season in the DI_{late} than in the DI_{early} treatment when irrigation water was withheld. Minimum Ψ_{stem} values reached on average in DI_{late} trees were -1.75, -1.66 and -1.73 MPa in the first, second and third experimental seasons, respectively.

‘Algerie’ DI_{early} and DI_{late} trees reached lower Ψ_{stem} values than ‘Cardona’ trees when water restrictions were applied in these treatments (Figure 1). Minimum Ψ_{stem} values measured in ‘Algerie’ DI_{early} trees were -1.75, -1.93 and -1.84 MPa in 2010, 2011 and

2012. In the DI_{late} strategy, water restrictions led to minimum Ψ_{stem} values of -1.63 MPa in 2010, -1.83 MPa in 2011 and -2.06 MPa in 2012.

Flowering

At both sites and in all the experimental seasons, trees from the DI_{early} treatment had a significantly higher percentage of open flowers than control trees at some measurement dates (Figure 2). DI_{late} trees also had a significantly higher percentage of open flowers than control trees at some dates although not as in the DI_{early} treatment and only during the 2010/11 season in ‘Cardona’ trees and the 2010/11 and 2011/2012 seasons in ‘Algerie’ trees. During the first and third experimental seasons on ‘Cardona’ trees (2009/2010 and 2011/2012), statistically significant differences were also found between the DI_{early} and DI_{late} treatments with trees from the DI_{early} strategy having the highest percentage of open flowers (Figure 2A, C).

Due to lack of human resources available for field determinations, flowering in ‘Algerie’ trees was only monitored during the 2010/11 and 2011/12 seasons (Figure 2). At both seasons, trees from the DI_{early} and DI_{late} treatments had a significantly higher percentage of open flowers than control trees at some measurement dates. Differences between DI_{early} and control trees were statistically significant on November 4th, 11th and 18th, 2010, and on October 18th and 26th, 2011. The percentage of open flowers in ‘Algerie’ DI_{late} trees was higher than that of control trees on November 4th and 11th, 2010, and October 26th, 2011. No statistically significant differences were observed in this cultivar between DI_{early} and DI_{late} trees.

Yield and its components

In the case of ‘Algerie’ trees, the effects of the irrigation regimes imposed on some of the yield components were slightly different among seasons (Table 2). As a consequence, in Table 3, data from each season were reported separately. DI_{early} and

DI_{late} treatments did not have a significant effect on the total number of fruit picked per tree, average fruit weight or yield at any of the three experimental seasons on ‘Cardona’ trees (Table 3). That was also the case in ‘Algerie’ trees during the second experimental season (2011/12), when no statistically significant differences in yield or its components were observed among treatments. During the 2010/11 and 2012/13 seasons, on the other hand, yield was significantly higher in the DI_{late} treatment than in both DI_{early} and control treatments (19 and 21% higher than control in the 2010/11 and 2012/13 seasons, respectively) due to a higher number of fruit (Table 3).

No statistically significant differences were found among treatments in the percentage of fruit picked for any of the picking dates in the ‘Cardona’ study (Figure 3A, B, C). In ‘Algerie’ trees, a higher percentage of fruit was generally picked in both the DI_{early} and DI_{late} treatments than in the control during the first picking dates. Nevertheless, statistically significant differences were only obtained between the DI_{late} and control trees, with the former having the highest percentage of fruit picked on April 22nd, 2013 during the last experimental season (Figure 3D, E, F).

Fruit quality

Quality of ‘Cardona’ fruit at the different harvests carried out during the season 2009/10 is shown in Figure 4. The external colour was the maturity index used for harvesting, and the pale orange tones characteristic of this cultivar were reflected in colour index values that ranged from IC=+5 to IC=+6 (Figure 4A). The values of firmness and the titratable acidity importantly decreased at the end of the season; firmness values declined from 6 to 4.8 N while the acidity dropped from 2.2 to 1.2 g malic acid/100 mL (Figure 4B and 4C). Neither firmness nor acidity were significantly affected by the different irrigation strategies assayed. Regarding the content of soluble solids, it remained quite constant during the harvest season, all the fruit showing a content around

12 °Brix irrespective of the irrigation conditions (Figure 4D). As described for the rest of the quality parameters, there was not effect of the irrigation strategies on fruit weight. All the fruit gained weight as the season advanced to reach 60 g weight at the end of April (Figure 4E).

These results were confirmed by the data collected during the season 2010/2011 (data not shown), since the irrigation practices did not affect any of the quality parameters evaluated. Thus, at the last harvest carried out during the second season (123 DOY) when fruit showed a colour index close to +7, all the treatments resulted in firmness values close to 4N, acidity values of 1.1 g malic acid/100mL and a content of soluble solids around 10.5 °Brix. However, it must be mentioned that in the second season all the fruit showed a weight slightly higher than in the first season.

Discussion

In the present work, summer water restrictions in the DI_{early} strategy advanced flowering in both the early- and intermediate-maturing cultivars during all the experimental seasons although this effect was not reflected in a higher percentage of fruit picked at the first picking dates at harvest. The main advantage of implementing postharvest RDI strategies on the early-maturing cultivar Cardona was the water savings obtained respect to the treatment irrigated at 100% of the estimated ET_c , which ranged between 18 and 34% and did not detrimentally affect yield.

The DI_{late} strategy also had an advancement effect on flowering in both cultivars although only during one of the experimental seasons (2010/11) in the early-maturing cultivar and not as marked as in the DI_{early} strategy in ‘Algerie’ trees. In fact, in the case of the early-maturing cultivar Cardona, control trees had a significantly higher percentage of open flowers than trees from the DI_{late} strategy in the 2011/12 season. This

result is in agreement with Cuevas et al. (2009), who reported that water restrictions during late summer were less effective than earlier strategies in hastening bloom date in *cv.* *Algerie* trees. This different response between the early and late strategies was attributed to a slowing down effect on normal flower development when DI is applied later in summer (Rodríguez et al., 2007).

The advancement effect on flowering observed in ‘Cardona’ DI_{early} trees, however, was not reflected in a higher percentage of fruit picked earlier in the DI_{early} strategy than in the control treatment. In fact, no statistically significant differences in the percentage of fruit picked was found at any picking date and season in the early-maturing cultivar (Figure 3A, B and C). Similar results were obtained in the study on ‘Algerie’ trees, in which just the DI_{late} strategy and during the last experimental season significantly increased the percentage of fruit picked on April 22nd compared to the control treatment (Figure 3F).

Water stress applied to loquat trees during postharvest has been reported to have a greater effect on advancing bloom date than harvest date because of the need of loquat fruit to satisfy specific heat unit requirements to ripen (Fernández et al., 2010). This greater effect of the RDI treatments on flowering advance than on fruit ripening was observed in the present study in both cultivars but particularly in the early-maturing cultivar Cardona. It is reasonable to think that an earlier blooming date in deficit-irrigated trees should lead to an advance in fruit maturity and, thus, picking date at harvest. However, studies performed on ‘Algerie’ trees by Hueso et al. (2007) and Stellfeldt et al. (2012) reported that trees submitted to water stress during flower development required more growing degree days than well-watered trees in their transition from bloom to harvest to ripen their fruits. These authors (Hueso et al., 2007;

Stellfeldt et al., 2012) attributed this developmental limitation to a carry-over effect of the imposed water stress.

It is also possible that the fruit thinning practice applied as a conventional strategy buffered the possible initial differences in fruit growth and development among treatments, because growers tend to keep on the panicle only the more advanced fruits. The low effect of the RDI strategies on fruit ripening could also be related with the severity and duration of the water stress imposed to the trees, which have been pointed out as key factors in the success of loquat RDI strategies (Fernández et al., 2010). Average minimum Ψ_{stem} values reached in this study in ‘Algerie’ DI_{early} and DI_{late} trees over the three seasons ranged from -1.63 to -2.06 MPa. These values are similar to those reported in other studies in which DI strategies were successful at hastening bloom and harvest dates in ‘Algerie’ trees (Cuevas et al., 2009). In Cuevas et al. (2009), however, water restrictions lasted at least two more weeks than in this study, which could explain the low effect of the DI strategies on fruit ripening.

The level of stress reached in trees from the DI_{early} and DI_{late} treatments applied to the early-maturing cultivar Cardona was lower (minimum Ψ_{stem} ranged from -1.46 to -1.84 MPa) than that reached in ‘Algerie’ trees (Figure 1). Further research on early-maturing cultivars would be needed to study whether a larger period of water restrictions with a more severe level of water stress could lead farmers to reach the market earlier in the season.

Water restrictions did not have a negative effect on yield in ‘Algerie’ trees. Indeed, yield was significantly higher in DI_{late} trees than in control trees during two out of the three experimental seasons (Table 3). This result is in agreement with Hueso and Cuevas (2010), who also reported higher yields in ‘Algerie’ trees under a postharvest DI

strategy (water restrictions from early June to the end of August) than trees irrigated to fully meet their water requirements.

The DI_{early} and DI_{late} strategies tested on ‘Cardona’ trees did not detrimentally affect yield or have an effect on fruit quality (assessed during two of the three growing seasons) as has been also reported for ‘Algerie’ trees (Hueso and Cuevas, 2008). This result *per se* is of great value since postharvest in loquat (June-August) coincides with a period of high water requirements for other valuable crops in the area. Implementation of postharvest RDI strategies on early-maturing cultivars, thus, could leave a substantial amount of water available for other surrounding crops in which water stress at that particular time of the season would definitely compromise productivity.

Conclusions

The DI_{early} treatment had an advancement effect on bloom in both the early- and intermediate-maturing loquat cultivars. Flowering, on the other hand, was less influenced by the DI_{late} strategy, particularly in the early-maturing cultivar Cardona. In spite of the higher percentage of open flowers observed in trees from the DI_{early} treatment with respect to the control, no differences were observed in the percentage of fruit picked at any picking date at harvest in ‘Cardona’ trees.

A similar effect was observed in the intermediate-maturing cultivar Algerie, suggesting that the level of stress reached by the trees was not enough to have the desired advancement effect on fruit ripening. Further research in this sense, testing longer summer DI strategies than those implemented here as well as the combination of late pruning management with postharvest DI treatments would be of interest in loquat early-maturing cultivars to meet this objective.

This work illustrated that substantial water savings (>30%) can be obtained by implementing postharvest DI strategies (either early or late) in early-maturing cultivars

such as Cardona with no detrimental effects on fruit quality and yield. Thus, we suggest the DI_{early} treatment here presented as an interesting strategy to follow in order to save water resources for co-existing crops in which water stress at that time of the season could have substantial negative effects on productivity.

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Table 1 Irrigation amounts applied (mm from harvest to harvest) to ‘Cardona’ and ‘Algerie’ trees in the control, early deficit irrigation (DI_{early} ;) and late deficit irrigation (DI_{late} ;) treatments along with the reference evapotranspiration (ET_o , mm) and precipitation (P, mm) recorded during each of the experimental seasons. Water savings (%) for each DI treatment and season are shown between brackets.

<i>Cultivar</i>	Season	Control	DI_{early}	DI_{late}	ET_o	P
Cardona	2009-2010	234	177 (24)	183 (22)	994	532
	2010-2011	252	202 (20)	206 (18)	768	403
	2011-2012	390	256 (34)	358 (8)	736	559
Algerie	2010-2011	291	263 (10)	237 (19)	777	403
	2011-2012	342	210 (38)	281 (18)	717	557
	2012-2013	273	173 (37)	184 (33)	721	280

Table 2 Statistical significance from two-way (irrigation (Irr) x year) analysis of variance (ANOVA) of the main factors included in the analysis for the ‘Cardona’ ‘Algerie’ experiments.

	Irr	Year	Irr x Year	Irr	Year	Irr x Year
		Cardona			Algerie	
Yield	0.075	<0.001	0.092	0.034	<0.001	0.048
Tree crop load	0.093	<0.001	0.088	0.046	<0.001	0.052
Fruit weight	0.453	<0.001	0.134	0.043	<0.001	0.029

Table 3. Yield (kg tree⁻¹), tree crop load (# fruit tree⁻¹) and mean fruit weight (g) data in the control, early deficit irrigation (DI_{early}) and late deficit irrigation (DI_{late}) treatments applied to ‘Cardona’ and ‘Algerie’ trees within each experimental season.

	Season	Control	DI_{early}	DI_{late}
Yield				
‘Cardona’	2009/10	37.2a	36.5a	38.9a
	2010/11	48.8a	47.4a	55.5a
	2011/12	30.4a	29.8a	28.0a
‘Algerie’	2010/11	73.2a	74.3a	88.6b
	2011/12	89.2a	84.2a	93.4a
	2012/13	87.1a	79.7a	105.6b
Tree crop load				
‘Cardona’	2009/10	711a	750a	740a
	2010/11	751a	740a	781a
	2011/12	461a	466a	418a
‘Algerie’	2010/11	915a	940ab	1081b
	2011/12	1103a	1054a	1178a
	2012/13	1116ab	1008a	1280b
Fruit weight				
‘Cardona’	2009/10	49a	48a	50a
	2010/11	65a	64a	71a
	2011/12	66a	64a	67a
‘Algerie’	2010/11	80a	79a	82a
	2011/12	81a	80a	79a
	2012/13	78a	79a	82a

Different letters within columns denote significant differences at $P < 0.05$ among treatments

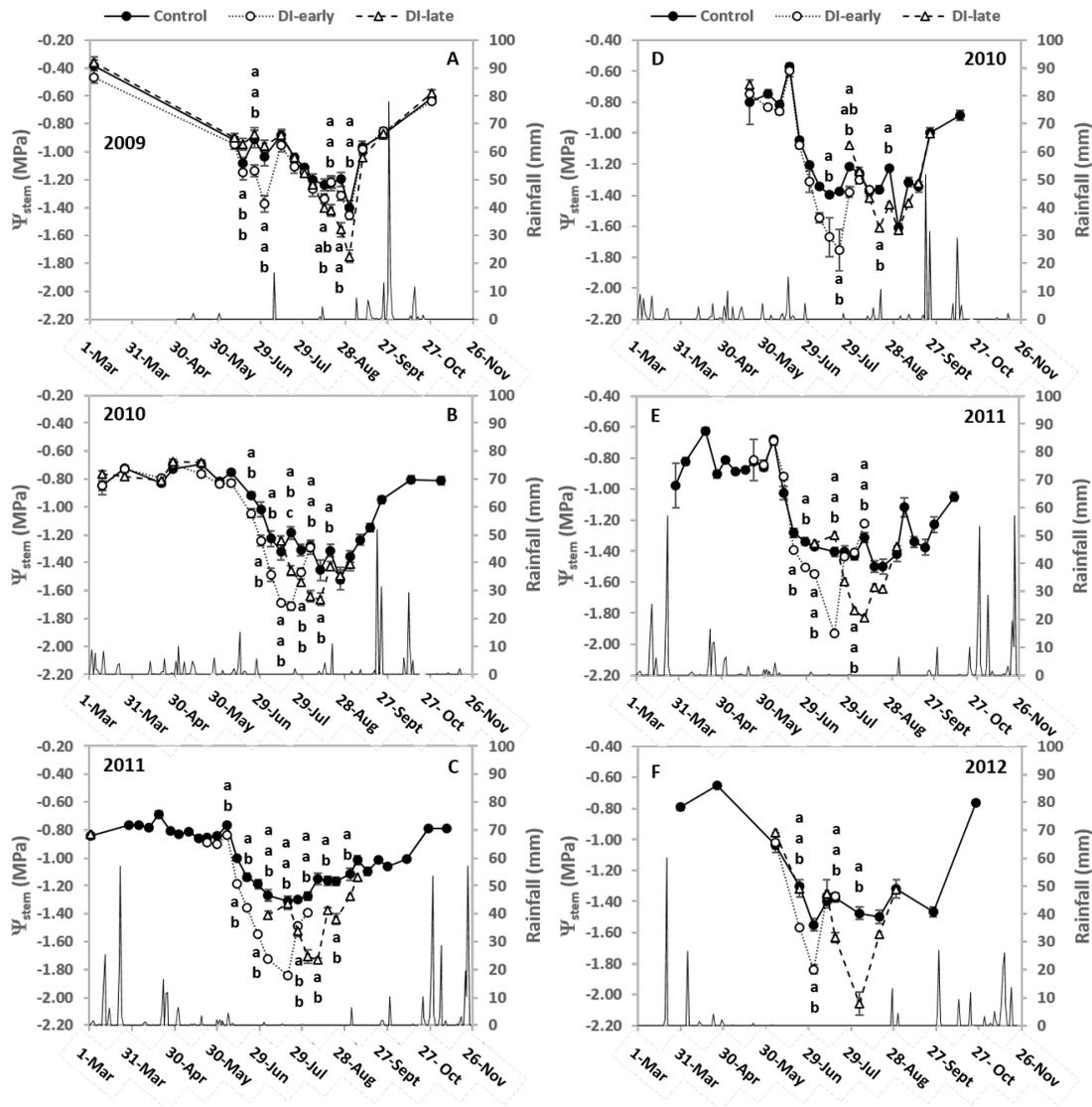


Figure 1 Stem water potential (Ψ_{stem}) determinations in the control, early deficit irrigation (DI-early) and late deficit irrigation (DI-late) treatments applied to ‘Cardona’ trees during the 2009/10 (A), 2010/11 (B) and 2011/12 (C) seasons, and to ‘Algerie’ trees during the 2010/11 (D), 2011/12 (E) and 2012/13 (F) seasons. Vertical bars indicate the standard error for each measurement date. Within each specific date, different letters denote statistically significant differences at $p < 0.05$ among treatments, indicating the letter ‘a’ the highest value. In those dates when letters are not included no statically significant differences at $P < 0.05$ among treatments were recorded. Rainfall recorded on each season and site is also indicated.

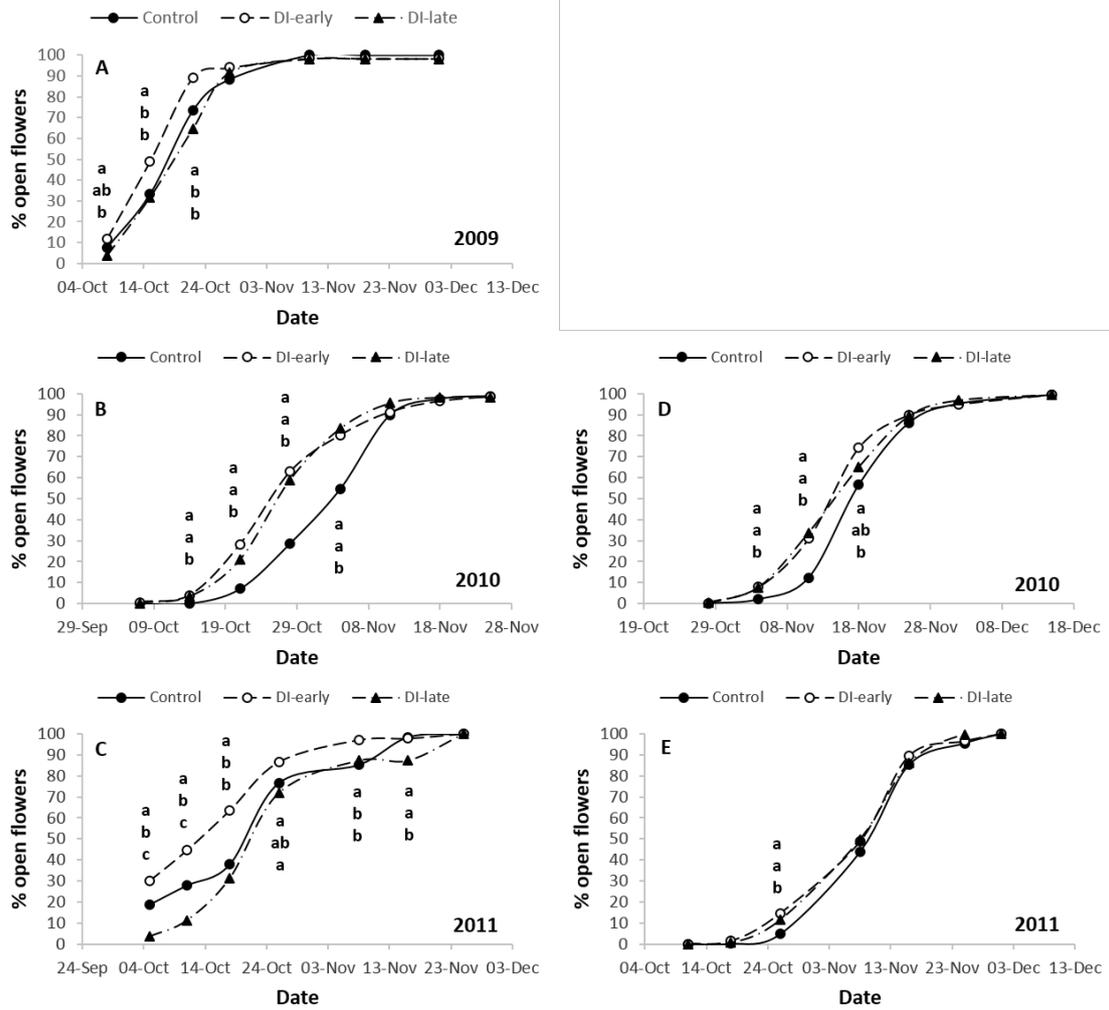


Figure 2 Mean percentage of open flowers monitored in the control, early deficit irrigation (DI-early) and late deficit irrigation (DI-late) treatments applied to ‘Cardona’ trees during the 2009/10 (A), 2010/11 (B) and 2011/12 (C) seasons, and to ‘Algerie’ trees during the 2010/11 (D) and 2011/12 (E) seasons. Within each specific date, different letters denote statistically significant differences at $p < 0.05$ among treatments, indicating the letter ‘a’ the highest value.

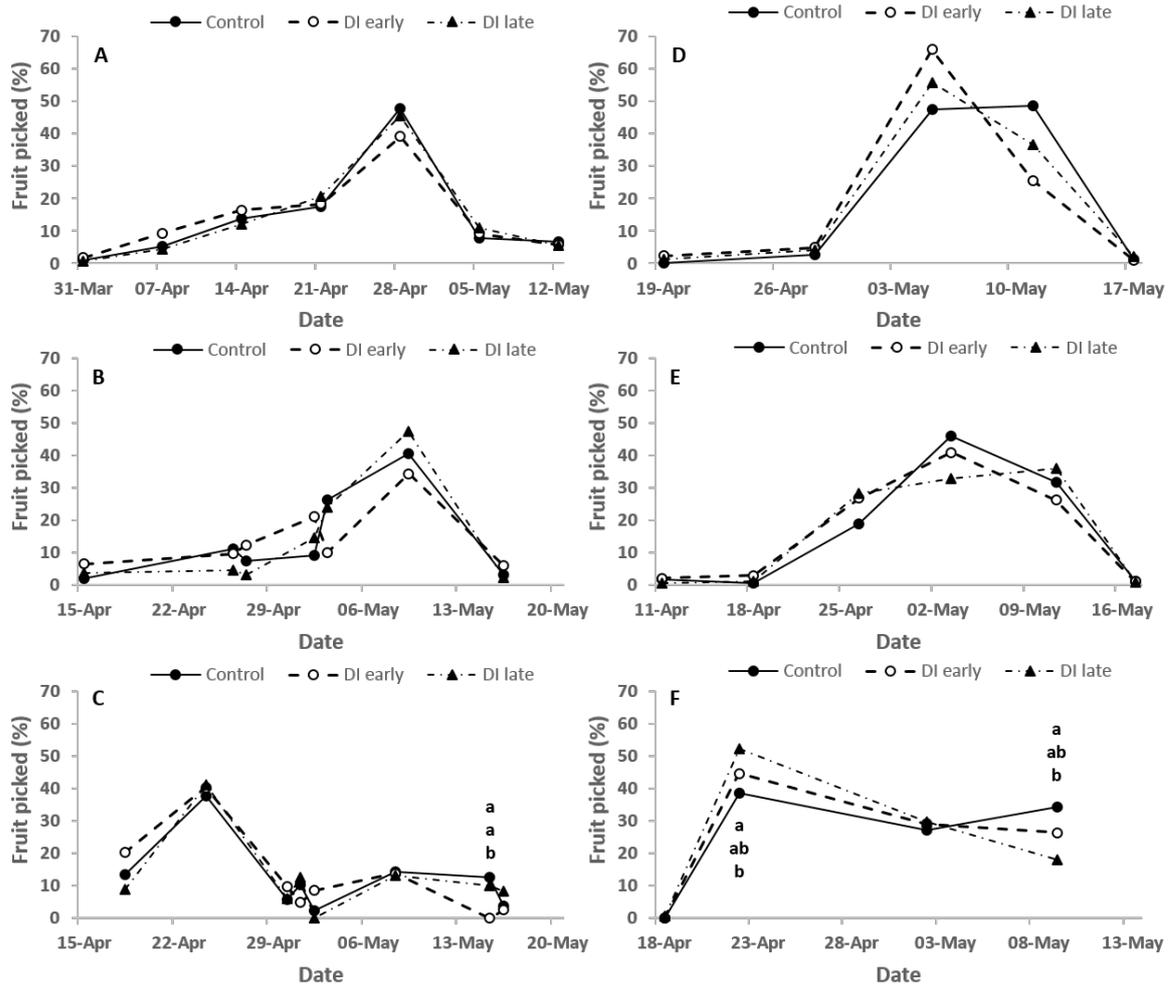


Figure 3 Mean percentage of fruit picked during each picking date at harvest in the control, early deficit irrigation (DI_{early}) and late deficit irrigation (DI_{late}) treatments applied to ‘Cardona’ trees during the 2009/10, 2010/11 and 2011/12 seasons (A, B and C, respectively), and to ‘Algerie’ trees during the 2010/11 (D), 2011/12 (E) and 2012/13 (F) seasons. Within each specific date, different letters denote statistically significant differences at $p < 0.05$ among treatments, indicating the letter ‘a’ the highest value.

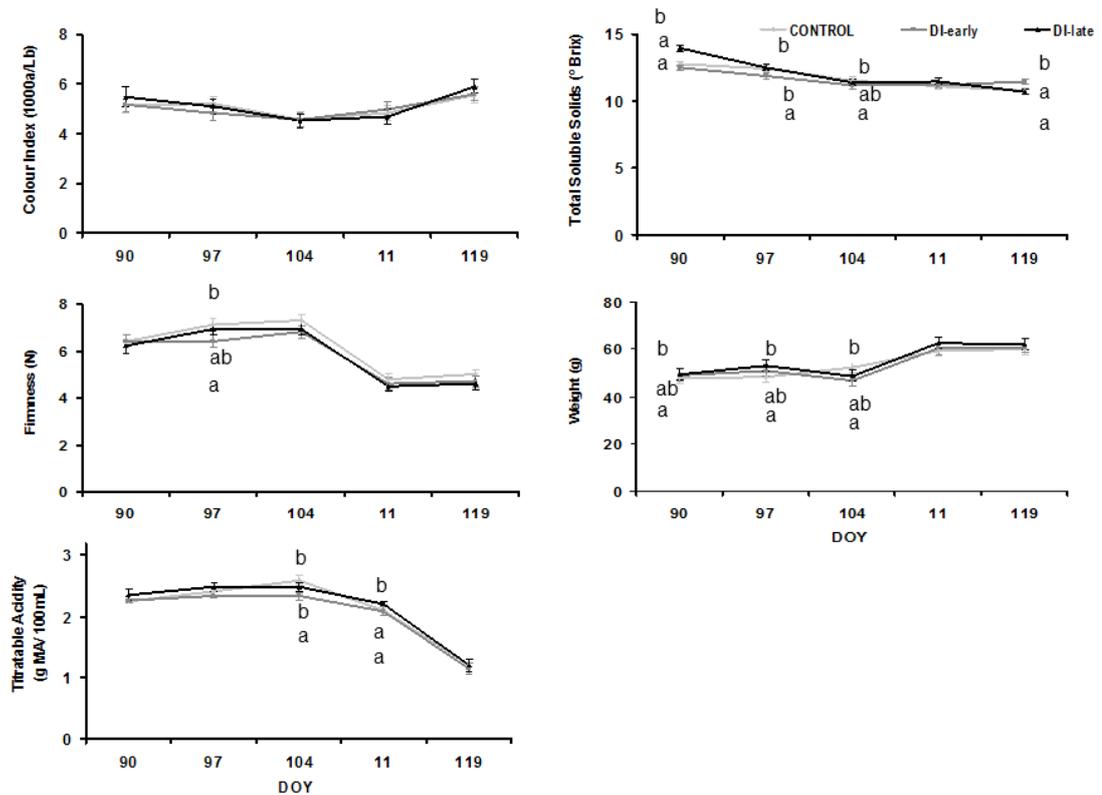


Figure 4. Effect of deficit irrigation strategies applied during the season 2009/2010 on quality parameters of 'Cardona' fruit in the control, early deficit irrigation (DI_{early}) and late deficit irrigation (DI_{late}) treatments. Vertical bars indicate the standard error for each measurement date. In addition, in those harvest dates when there were differences among treatments, different letters indicate statistically significant differences at $p < 0.05$.