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Regulated deficit irrigation in pomegranate (*Punica granatum*) trees. Yield and its components

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Abstract. An experiment has been carried out during two seasons with the objective of identifying pomegranate yield responses to water restrictions applied during different phenological periods. In mature trees, five irrigation treatments where applied including trees watered at 100% and 50% of tree water needs (ETc) during the entire season, and other three regulated deficit irrigated (RDI) treatments with severe restrictions applied only during certain phenological periods. Results showed that all the deficit irrigated treatments allowed increasing water use efficiency (i.e. yield/water applied). An early season water stress, increased the number of fruit collected at harvest, with the drawaback of reducing fruit weight if restrictions were prolonged during all the season. On the other hand, temporal water restrictions applied in the mid summer lead to a very small effect on final fruit weight. Results indicate the potential that RDI has in Pomegranate trees as a tool to cope with water scarcity in this crop.

Keywords. Fruit disorders – Stem water potential – Water stress.

I – Introduction

Pomegranate trees are considered as a culture crop tolerant to soil water deficit (Holland *et al.* 2009). Because of this, in Spain, its culture is concentrated in the south east, where fresh water available for agriculture is very scarce.

Regulated deficit irrigation (RDI) was developed in the 1980s as a strategy to save water and improve the productivity of fruit trees (Behboudian and Mills, 1997). RDI is based on reducing water applications only in those phenological periods when yield is less sensitive to soil water limitations. The effectiveness of RDI depends upon the identification of critical periods for tree performance. In this sense, to the best of our knowledge, there have not been field trials that have explored pomegranate tree responses to different irrigation regimes applied during the season. The objectives of the present research was then to study the effects of time of RDI imposition on tree performance.

II – Material and methods

1. Experimental orchards

The experiment was performed during the 2009 and 2010 seasons in a commercial mature pomegranate tree orchard (*Punica granatum*, L cv. 'Mollar de Elche') at Elche, Alicante, Spain, (38ºN, elevation 97 m). The soil was sandy-loam with an effective depth over 120 cm. Trees were planted in 2000 at a spacing of 5 x 4 m and average tree shaded area was 48% of the soil allotted per tree. Average trunk diameter was 18.2 cm.

Trees received 100, 40 and 80 kg ha^{-1} $year^{-1}$ of N, P_2O_5 and K_2O, respectively. Agricultural practices followed were those common for the area. Weather was recorded at an automated weather station near the orchard. Meteorological variables measured included solar radiation, air temperature, air humidity, wind speed and direction and rainfall. Precipitation and reference evapotranspiration (ETo) during the growing season (April to October) were 111 and 141, and 811 and 940 mm in 2009 and 2010, respectively

2. Irrigation treatments

Drip irrigation was applied with eight emitters per tree delivering 4.0 l h^{-1} each and were located in a single line parallel to the tree row. Irrigation treatments as depicted in Fig. 1 were:

(i) *Control*, where irrigation was scheduled in order to replace 100% of the estimated crop evapotranspiration (ETc). Crop evapotranspiration was estimated as product of reference evapotranspiration (ETo) and crop coefficient (Kc). ETo was calculated with hourly values by the Penman-Monteith formula as in Allen *et al.* (1998). The Kc values increased from an initial value of 0.32 used in March to a maximum value of 0.74 used in July, August and September according to previous recent findings obtained in the same plot (Intrigliolo *et al.* 2011).

(ii) *Sustained deficit irrigation (SDI)*, where water was constantly applied at 50% of control regime.

(iii) *Regulated deficit irrigation (RDI)* RDI_{spring}, where irrigation was applied at 25% of the control irrigation from the beginning of May 9 to end of June coincident with the flowering, fruit set and first exponential phase of fruit growth. During the rest of the season irrigation was applied at 100% ETc.

(iv) RDI_{summer} where irrigation was applied at 25% of the control irrigation from beginninf of July to end of August coincident with a linear fruit growth phase. During the rest of the season irrigation was applied at 100% ETc.

(v) RDI_{fall}, where irrigation was applied at 25% of the control irrigation by the end of August until leaf fall. Earlier in the season irrigation was applied at 100% ETc.

The reductions in the amount of water applied during the deficits were achieved by reducing irrigation duration, while frequency of irrigation was always the same for all treatments. Irrigation frequency changed over the season with all treatments irrigated once a week in early spring and autumn and five times a week during summer.

The experimental design was a randomized complete block, with four replicates per treatment. Each plot had three rows, with 8 trees per row. In each experimental unit, 1-2 central trees of the middle row were used for data collection.

3. Determinations

Actual irrigation volumes applied were determined using in-line water meters installed on each experimental plot.

Fruit from each tree were harvested in two-three commercial picks carried out by mid October, beginning of november. Yield and fruit number per tree were quantified and average fruit weight was determined by weighting and counting fruit from two harvest bins (approximately 20 kg per bin). Tree water use efficiency (WUE), was computed as (yield: irrigation + effective rainfall). The effects of the different irrigation treatments on two common fruit disorders for pomegranate

trees (fruit sun-burn and cracking) was evaluated by computing the percentage of fruit affected by these disorders over the total number of fruit collected per tree.
Stem water potential was measured in four trees per treatment with a pressure chamber, in two leaves per tree (total of 8 leaves per treatment). Mature leaves from the north face near the trunk, were enclosed in plastic bags covered with silver foil at least two hours prior to the measurements, which were carried out between 12:00 and 13:00 h solar time, approximately every week.

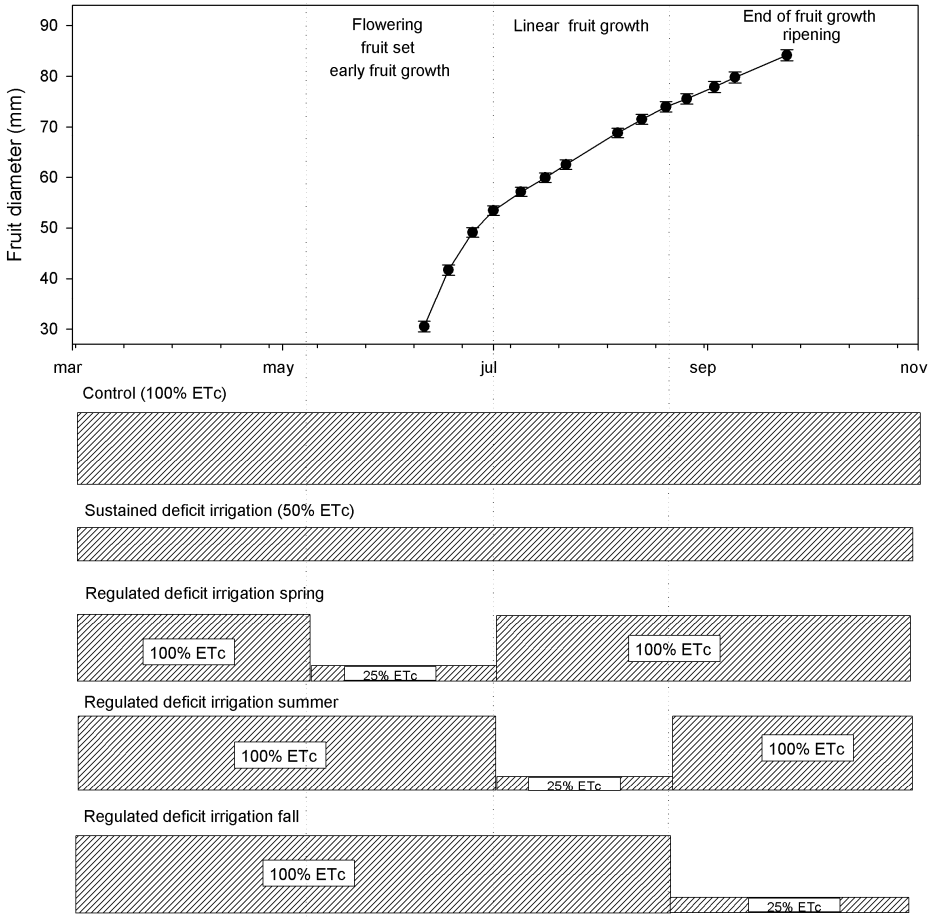

Fig. 1. Irrigation treatments applied during the 2009 and 2010 seasons. Water applications were based on percentage over the estimated crop evapotranspiration (ETc).

3. Data analysis

The effects of the irrigation regime on yield and its components was evaluated by analysis of variance using the general linear models "GLM" procedure of the SAS software (version 9.0; SAS Institute, Cary, NC). Since for most of the yield components, the treatment by year interaction was not statistically significant at P<0.05, data presented are averages for both seasons.

III – Results and discussion

During the course of both season, there was a general decrease trend in Ψstem. Thus, even in the control trees, Ψstem decreased from values around –0.8 MPa registered in early spring, to values around –1.5 MPa obtained in the middle of the summer (Fig. 2). This was in part due to the higher evaporative demand as the season advanced. A similar behaviour has been reported in other fruit trees under drip irrigation such as a plum (Intrigliolo and Castel 2004) and it might be also due to a greater proportion of the roots in the dry part of the soil particularly towards the end of the season.

The SDI trees maintained during the course of the experiment the lowest Ψstem values, reaching a minimum values of –2.3 MPa by the end of the 2009 season (Fig. 2). In general, the RDI trees had lower plant water status than the Control during the period of water restrictions. However this effect was more noticeable in the RDI treatments with restrictions in the summer and fall (Fig. 2).

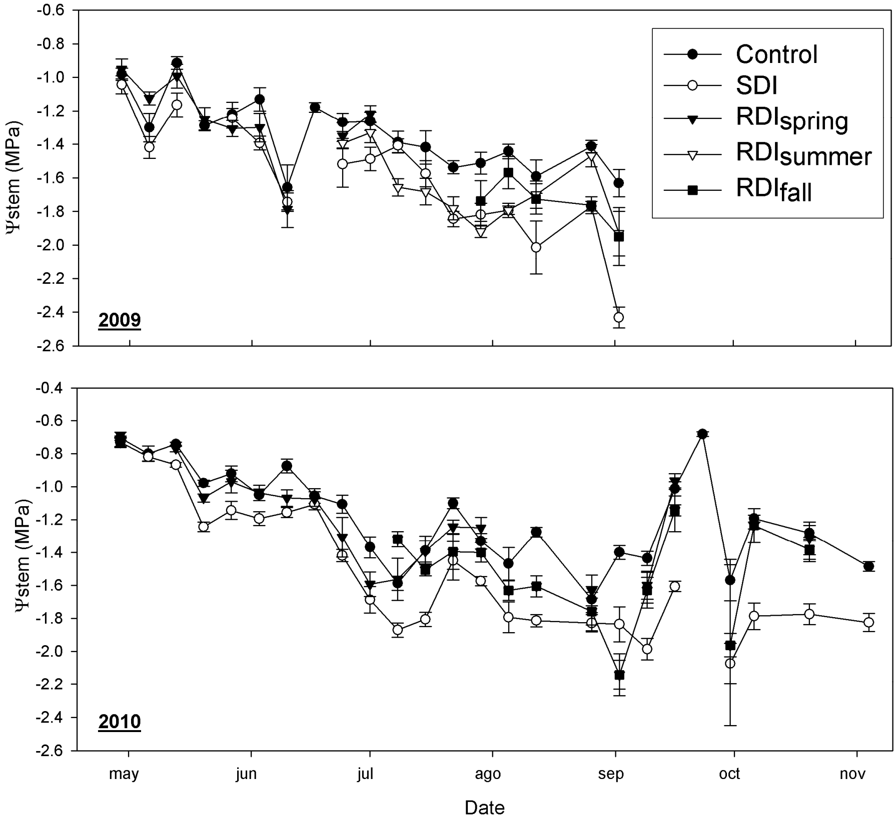

Fig. 2. Seasonal pattern in 2009 and 2010 of midday stem water potential (stem), of the different irrigation treatments. The error bars indicate the standard error.

Irrigation water volumed applied in the control treatment were, as an average for the two seasons, 427 mm (Table 1). On the other hand, in the SDI treatment irrigation applied was only 219 mm. Among all the RDI treatments, the one with the lower amount of water applied (- 23%

with respect to the control) was the RDI_{summer}, since this treatment had water restrictions during the time of the year with higher irrigation requirements due to the high evaporative demand.

Despite 46% less irrigation was applied in the SDI treatment than in the control, similar yield values were registered in both treatments (Table 1). As a consequence, the SDI treatment lead to an increase of water use efficiency (WUE) of 41%. The drawback was the reduction observed in average fruit weight that was of 20%. However, it should be noted that this decrease in fruit fresh weight at harvest was most likely due to not only the water stress exprienced by the SDI treatment but also due to the fact that the SDI regime lead to an increse in the number of fruit per tree collected (Table 1). In the SDI trees, there was then a heavier tree crop level and hence an higher fruit sink demand. The SDI strategy can be reccommended in those cases where prices for irrigation (water+energy) are high, or also for those productions focused to delivery pomegranate fruit to the industry.

Table 1. Yield and its components in the different irrigation treatments. Data presented are averages of two seasons (2009 and 2010)

	Irrigation (mm)	Yield (t ha^{-1})	WUE (kg m^{-3})	No. of fruit $tree^{-1}$	Fruit weight (g)	Fruit sun-burn (%)	Fruit cracking (%)
Control	427	22.5a	3.9a	136a	339a	2.4	13.0
SDI	229	22.1ab	5.5c	166b	274c	4.6	16.9
RDI_{spring}	362	24.0a	4.6b	153ab	320b	3.2	9.5
RDI_{summer}	327	21.6ab	4.4ab	137a	321b	4.7	13.0
RDI_{fall}	341	19.4b	3.8a	116c	345a	4.5	14.0

WUE, water use efficiency.
Within each column, different letters indicate statistically significant differences at $P<0.05$.

The fact that in the RDI_{spring}, that had water restrictions early in the season during flowering and fruit set, also had higher crop level than the rest of treatments (Table 1), indicates that a certain degree of water stress suffered by trees during spring might increase the tree bearing capacity. This behaviour observed in pomegranate is very different than what for instance observed in Citrus trees, where water stress during flowering and fruit set decreases tree crop level (González-Altozano and Castel 1999).

In both the RDI_{spring} and RDI_{summer} there was only a small reduction in fruit weight (–6%) with respect to the control trees. This reduction was lower than the amount of water saved in these treatments with respect to the control ones, thus both RDI regimes allowed increasing tree WUE. Particularly, the RDI_{spring} where water stress experienced was milder than in the RDI_{summer} (Fig. 1), seem to be a very convenient strategy for the application of deficit irrigation.

Te RDI_{fall} regime did not affect fruit weight, but it lead to a lower tree crop level. Further investigations are in due course to elucidate the possible reasons for this reduction in tree crop level caused by water restrictions applied late in the growing season.

It is very important to highlight that the different irrigation regimes did not affect the appereance of fruit disorders, since there were not statistically significant differences among treatments for both variables, fruit sun-burn and cracking (Table 1).

IV – Conclusions

Deficit irrigation is a feasible strategy to apply in pomegranate trees in case of water scarcity or high water prices. Contraringly to other fruit tree crops, an early season water stress, increased the number of fruit collected at harvest, with the drawaback of reducing fruit weight if restrictions were prolonged during all the season. On the other hand, temporal water restrictions applied in the mid summer, during the linear phase of fruit growth, lead to a very small effect on final fruit weight, allowing for 23% water savings.

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