Agricultural Water Management 98 (2011) 691–696

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Water relations of field grown Pomegranate trees (*Punica granatum*) under different drip irrigation regimes

D.S. Intrigliolo[a,*], E. Nicolas[b], L. Bonet[c], P. Ferrer[c], J.J. Alarcón[b], J. Bartual[d]

[a] Instituto Valenciano Investigaciones Agrarias (IVIA), Centro Desarrollo Agricultura Sostenible, P.O. Box 46113, Moncada, Valencia, Spain
[b] Centro de Edafología y Biología Aplicada del Segura (CSIC), Dept Riego P.O. Box 164, E-30100 Espinardo, Murcia, Spain
[c] Instituto Valenciano Investigaciones Agrarias (IVIA), Servicio de Tecnología del Riego, P.O. Box 46113, Moncada, Valencia, Spain
[d] Instituto Valenciano Investigaciones Agrarias (IVIA), Estación Experimental Agraria de Elche, Ctra. Dolores, Km. 1, 03290 Elche, Alicante, Spain

ARTICLE INFO

Article history:
Received 20 June 2010
Accepted 13 November 2010
Available online 14 December 2010

Keywords:
Deficit irrigation
Photosynthesis
Stem water potential
Stomatal conductance

ABSTRACT

Pomegranate (*Punica granatum* L.) is a deciduous fruit tree native of central Asia included in the so-called group of minor fruit tree species, not widely grown but of some importance in the south east of Spain. Fruit consumption interest is due to the organoleptic characteristics and to the beneficial effects on health. Pomegranate tree are considered as a culture tolerant to soil water deficit. However, very little is known about pomegranate orchard water management. The objective of this work was to characterize, for the first time in *P. granatum*, water relations aspects of applied significance for irrigation scheduling. Trees under different irrigation regimes were used and midday stem water potential (Ψ_{stem}) and mid-day leaf gas exchange were periodically measured over the course of an entire season. During spring and autumn, Ψ_{stem} did not show significant differences between irrigation treatments while there were considerable differences in leaf photosynthesis and stomatal conductance, suggesting a near-isohydric behaviour of pomegranate trees. This might explain why the signal intensity of Ψ_{stem} was lower than those of gas exchange indicators during the experimental period. Thus, leaf photosynthesis rates and stomatal conductance might have a greater potential for irrigation scheduling of pomegranate trees than Ψ_{stem} measured at solar noon.

1. Introduction

Pomegranate tree (*Punica granatum* L.) is a deciduous fruit tree native of central Asia included in the so-called group of minor fruit tree species, not widely grown but of some importance in the South east of Spain. At present, the cultivated surface in Spain is more than 3000 ha and there are other producing countries in the Mediterranean area (Turkey and Tunisia) with extensive crops (Holland et al., 2009). Nowadays, in Spain, pomegranate culture is steadily increasing because of high fruit commercial value.

Fruit consumption interest is due to the organoleptic characteristics of the arils (i.e. the seeds) and to the beneficial effects on health. According to Lansky and Newman (2007) pomegranate fruit consumption might have some important pharmacological actions on a wide range of applications for the treatment and prevention of cancer and other diseases.

Pomegranate trees are considered as a 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. However, very little is known about *P. granatum* orchard water management. Water use for this crop is for instance not listed in FAO water use book by Allen et al. (1998). However, it can be speculated that the crop water requirements can be high based on information provided in an horticultural pomegranate review by Holland et al. (2009). For instance, in Israel water application for pomegranate tree culture is around 5000–6000 $m^3\ ha^{-1}$ (Holland et al., 2009). More recently, Bhantana and Lazarovitch (2010) reported water use values of young trees grown in lysimeters in Israel under different soil water electrical conductivity values. Water use of control trees under no soil water limitations changed during the growing season from 0.23 to 5 $mm\ day^{-1}$ under class 'A' pan evaporation values of 3.06–9.19 $mm\ day^{-1}$. In another report, Sulochanamma et al. (2005) did not find any significant increase in fruit yield when water was applied at 0.6, 0.8 or 1.0 of pan evaporation. These reports are, to the best of our knowledge, the only scientific information available for irrigation management of this culture. In this sense, it should be noted that there are not studies that have reported the seasonal variation of leaf water potentials for well watered and deficit irrigated pomegranate trees.

Scheduling irrigation can be calculated as suggested by Allen et al. (1998). Complementarily to this approach plant water

* Corresponding author. Tel.: +34 96342400; fax: +34 963424001.
E-mail address: intrigliolo_die@ivia.gva.es (D.S. Intrigliolo).

0378-3774/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.agwat.2010.11.006

status information can be used to determine when to irrigate. This is because measurements of plant water status integrate both soil water available to the plants and the weather conditions.

Leaf water potential measured with the pressure chamber, either at predawn or at midday, has been long used as a plant water stress indicator. More recently, the use of water potential of bag covered leaves, named stem water potential (Ψ_{stem}) (Shackel et al., 1997) has been adopted because of its value as a water stress indicator (McCutchan and Shackel, 1992) and its predictive potential in relation to yield response to deficit irrigation (Naor, 2000). This is because, at midday, leaf-to-leaf variability in Ψ_{stem} is generally lower than for leaf water potential (McCutchan and Shackel, 1992). In fruit trees Ψ_{stem} has been used to modify the irrigation regime, preventing mild water stress from becoming severe (Lampinen et al., 2001). However, particularly in drought resistant species, midday plant water status might be similar in well watered and stressed plants if there is a clear stomatal and vegetative growth reduction in response to water restrictions (Tardieu and Simonneau, 1998).

A decrease in stomatal conductance can correlate with a declining of Ψ during water deficit periods, but can also occur before any measurable change in Ψ is recorded (Gollan et al., 1985; Trejo and Davies, 1991). Differences in stomatal sensitivity during drought may serve to limit transpiration to compensate for differences in the vulnerability of xylem to cavitation (Jones and Sutherland, 1991).

For this reason the main working hypothesis was to determine if in a species a *priori* moderately tolerant to drought as pomegranate (Holland et al., 2009) the stomata function would prevent a decline in leaf water potential below a minimum critical value under water deficit conditions which would make it an unsuitable plant-based indicator for irrigation scheduling.

2. Materials and methods

2.1. Experimental plot

The experiment was performed in a commercial mature pomegranate tree orchard (*P. granatum*, L cv. 'Mollar de Elche') at Elche, Alicante, Spain (38°N, elevation 97 m). The soil was sandy-loam with an effective depth over 120 cm. The irrigation water had a moderate risk of salinization with an average electrical conductivity at 25 °C of 2.63 dS m^{-1} and an average Cl^- and Na concentration of 43.5 and 326.3 mg L^{-1}, respectively. However, pomegranate trees are considered moderately tolerant to salinity (Holland et al., 2009). Trees were planted in 2000 at a spacing of 5 m × 4 m and average tree shaded area was 56%. 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 experimental period (May to October) were 141 and 849 mm, respectively.

2.2. Treatments

Drip irrigation was applied with eight emitters per tree delivering 4.0 L h^{-1} and was located in a single line parallel to the tree row. Irrigation treatments tested were based on either applying different irrigation regimes throughout the growing seasons, or severe water restrictions limited during certain given phenological periods (regulated deficit irrigation, RDI). This was done in order to explore crop responses to both the timing and the regime of irrigation applications. The six treatments were:

Farm irrigation, where irrigation was scheduled in order to replace 100% of the estimated crop evapotranspiration (ETc). Crop evapotranspiration was estimated as product of 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 employed were based on results reported by Bhantana and Lazarovitch (2010).
Control. Trees were irrigated at 120% of farm irrigation regime. This was done in order to ensure that the potential crop water needs were replaced.
Sustained deficit irrigation (*SDI*), where water was constantly applied at 50% of farm regime.
RDI_{spring} where severe water restrictions (25% of the Farm irrigation) were imposed during May and June, coinciding with flowering and early fruit growth, while during the rest of the season 100% of farm irrigation was applied.
RDI_{summer} where severe water restrictions (25% of the Farm irrigation) were imposed during July to August 21 (linear fruit growth phase), while during the rest of the season 100% of farm irrigation was applied
RDI_{fall}, where severe water restrictions (25% of the Farm irrigation) were imposed from August 23 to the end of October (last part of fruit growth and ripening period) while during the rest of the season 100% of farm irrigation was applied.

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. Water meters measured water application for each experimental unit.

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

2.3. Water relation determinations

Midday stem water potential (Ψ_{stem}) was measured with a pressure chamber (Soil Moisture Equip. Corp. mod. 5100A, Santa Barbara, CA, USA), following procedures described by Turner (1981). Determinations were carried out in 4 trees per treatment, each tree located in a different experimental plot. Two mature leaves per tree, from the north face near the trunk, were enclosed in plastic bags covered with silver foil at least 2 h prior to measurements, which were between 12:30 and 14:00 h GMT. Measurements of Ψ_{stem} were carried out approximately every week from May to October.

Leaf gas exchange measurements were determined monthly at 13:00 GMT and in the same plants as Ψ_{stem}. Net photosynthetic rate (A) and stomatal conductance (g_s) were measured with a portable photosynthesis system (LI-6400, LICOR, Inc., Lincoln, NE, USA) equipped with a LI-6400-40 Leaf Chamber Fluorometer (LI-6400, LICOR, Inc., Lincoln, NE, USA) and a LICOR 6400-01 CO_2 injector. Similar type of sun-exposed leaves as Ψ_{stem} readings were placed in a 2 cm^2 leaf cuvette. The CO_2 concentration in the cuvette was maintained at 380 μmol mol^{-1} CO_2 (ambient CO_2). Measurements were done at saturating light (photosynthetic photon flux; PPF) of 1.800 μmol m^{-2} s^{-1}. This means that *A* measurement represent the maximum *A* value for the stomatal opening at the measurement time. Measurements were carried out at air temperature and relative humidity in 2 mature and sunny leaves per tree, each one located in a different experimental plot. The