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Usefulness of stem dendrometers as continuous indicator of loquat trees water status

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ABSTRACT

Postharvest regulated deficit irrigation (RDI) is an effective strategy to hasten flowering and harvest in loquat (*Eriobotrya japonica* Lindl.) trees, which in the Mediterranean countries has been related to an increase in the economic return. The success of an RDI strategy, however, depends on the duration and severity of the water stress reached by the trees. When RDI is applied, then, it is important to regularly monitor the plant water status. The measurement of the trunk diameter variations by means of stem dendrometers, which can be automated to remotely determine the plant water status, is a proven method for many fruit trees. In loquat, however, its use has not been yet assessed. In this experiment performed in a loquat orchard planted with the cv. 'Cardona' during the summer of 2009, the suitability of using stem dendrometers to detect plant water stress was assessed by taking measurements in fully irrigated and trees subjected to a drought cycle of 47 days. Results showed that at the beginning of the drought cycle period there was an increase in the maximum daily trunk shrinkage (MDS) in non-irrigated trees even before that clear differences in stem water potential (Ψ_s) could be detected between treatments. However, when plant water stress became more severe (Ψ_s lower than −1.4 MPa), MDS did not increase further. The maximum trunk diameter (MXTD) evolution in control trees showed a steadily increase in trunk growth during the whole experimental period. In non-irrigated trees, however, MXTD remained stable until the end of the treatment when irrigation was resumed. The Ψ_s was the most sensitive indicator to water stress due to its very low tree-to-tree variability in comparison with the other indicators. Overall results show that trunk diameter variations have some limitations to monitor plant water status in loquat RDI orchards and therefore new alternatives should be explored.

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1. Introduction

Loquat is an evergreen tree crop native of the Southeast of China. Although this is considered as a minority crop and there are no data available in the FAO statistics regarding its production, China and Spain have been reported by some authors (Lin et al., 1999; Soler et al., 2007) as the first and second loquat producers in the world, respectively, with Spain having a sound presence in the international market. The main producing areas of loquat in Spain are located in the semiarid areas of the Southeast, where the annual precipitation is erratic and water scarcity often becomes a major problem. In this context, the RDI technique has been shown as an effective strategy to save water and increase the water productivity in loquat trees in the short (Hueso and Cuevas, 2008) and long term (10 consecutive seasons, Hueso and Cuevas, 2010).

RDI is based on irrigating plants below their water requirements during the less sensitive phenological periods to water stress (Chalmers et al., 1981; Behboudian and Mills, 1997), ensuring that plants are irrigated at full water requirements during the rest of the season. Postharvest RDI in loquat trees (coinciding with the summer months) has been related with an advance in bloom and harvest (Rodríguez et al., 2007), which in the Mediterranean countries usually leads to boost the loquat fruit commercial value (Hueso and Cuevas, 2008) due to the lack of competition with other stone fruit trees that are still not available in the market at that moment. Nevertheless, in order to advance flowering and increase the crop profitability, the accumulated water stress (S_Ψ) should be around the optimal value of 47 MPa days reported by Fernández et al. (2010). Low S_Ψ values do not modify flowering date while high S_Ψ values negatively affect flower development. This is one of the issues that all the studies dealing with water saving techniques

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remark: the duration and severity of the water stress imposed to the plants is a key factor in the success of the RDI strategies (Ruiz-Sánchez et al., 2010). It is crucial therefore to monitor the plant water status during the period of water restrictions to avoid trees to be overstressed, which eventually may compromise the final production.

The stem water potential (Ψ_s) is a reliable and suitable index of irrigation needs in fruit trees (Naor, 2000). However, Ψ_s presents some inconvenience that difficult its regular use in commercial orchards (it is labor and time-consuming, presents some time and space variability, etc.), what has led to the study of alternative methods that could be remotely used. The evaluation of trunk diameter measurements as a plant water status indicator has lately been widely studied due to the fact that can be easily automated at a field scale and it has a great potential for irrigating scheduling (Fernández and Cuevas, 2010; Ortuño et al., 2010). Particularly, the magnitude of daily stem contraction, known as maximum daily trunk shrinkage (MDS), has been shown to be a very sensitive indicator of plant water status in some stone fruit trees (Fernández and Cuevas, 2010). The MDS measurements have been successfully used for irrigation scheduling in crops such as almond, citrus and apple trees (Ortuño et al., 2010) although it has also been reported as a not reliable indicator for other crops such as grapevine (Intrigliolo and Castel, 2007) or olive (Moriana and Fereres, 2002). The daily maximum trunk diameter (MXTD) can also provide information about the tree water status. Since a reduction in trunk growth, particularly in young trees has been reported as one of the earliest signals of plant water stress development (Moriana and Fereres, 2002; Nortes et al., 2005), the difference in MXTD between two consecutive days, which represents the trunk growth rate (TGR), has also been proposed as a water stress indicator.

As far as we know, the use of stem dentrometers to monitor the plant water status has not been tested yet in loquat trees as an automated alternative method to the classical Ψ_s measurements. The objective of this work was to assess the usefulness of stem dendrometers as continuous water stress indicators in mature loquat trees cv. 'Cardona'.

2. Material and methods

2.1. Plot characteristics and irrigation treatments

The experiment was performed during 2009 in a mature 0.6-ha orchard of loquat, cv. 'Cardona', located at Callosa d'En Sarrià (38°45′N, 0°08′W, elevation 247 m), Alicante, Spain. At the moment of the experiment trees were nine years old and were planted in patches with a separation between trees of 3 m. The average canopy and trunk diameter were of 3.16 and 0.14 m, respectively.

The soil was of clay texture with an effective depth of 0.80 cm. As a common practice in the Loquat culture within the area, shading net was installed in the orchard. The solar radiation reaching the tree canopies was of 65% of the incident global solar radiation just above the net.

Irrigation was localized using only one line per row with four emitters of 3.85 L h^{-1} per tree. In-line water flow meters were installed at the beginning of each experimental orchard to measure the volumes of water applied on each treatment. Two irrigation treatments were applied: (1) a control treatment, where irrigation was applied in order to refill the estimated crop evapotranspiration during the entire season, and; (2) a water-stressed treatment, where irrigation was applied as in the control treatment except from mid July [day of the year (DOY) 196] to the end of August (DOY 243), when irrigation was withheld to force a drought cycle. It has to be mentioned, however, that in order to hasten harvest, which was not the objective of this experiment, water withholding during June or July is more convenient than deficit irrigation during August (Cuevas et al., 2007). However, for the purpose of the present experiment, we preferred to impose the drought cycle during the warmest and driest months of the year (i.e. mid-July to the end of August). From DOY 243 and during three consecutive weeks the water-stressed trees received the double amount of water than the control trees. On a seasonal basis (harvest 2008 to harvest 2009) total irrigation applications were of 256 and 215 mm, for the control and water-stressed treatments, respectively.

The experimental design was a randomized complete block, with three replicates per treatment (a total of six experimental plots). Each experimental plot had four sampling trees using perimeter trees as guards. Water relations parameters were only measured in the two central trees of each experimental unit (six trees per treatment). Three soil access tubes per treatment were installed down to a depth of 80 cm. Soil water content was then measured every week using a portable capacitance probe (Diviner 2000, Sentek, Australia). Relative soil water content was calculated considering the maximum absolute value measured in each access tube.

2.2. Determinations

Trunk diameter variations were measured in six trees per treatment using a total of 12 linear variable differential transformers (LVDT, Schlumberger Mod. DF-2.5). Each sampling tree was equipped with a sensor fixed on the north side to the main trunk by a metal frame of Invar (a metal alloy with a minimal thermal expansion), located about 20 cm from the ground. Prior to installation the transformers were individually calibrated by means of a precision micrometer (Verdtech SA, Spain). The typical output coefficient was about 87 mV mm^{-1} V^{-1}. The resolution of trunk diameter measurements, including all sources of variation (calibration, non-linearity, excitation, and output voltage recording and thermal changes), was about 10 μm. The trunk diameter variations were used to calculate the MXDT and MDS by the difference between the maximum diameter, reached early in the morning, and the minimum diameter, reached normally during the afternoon. All sensor data were automatically recorded every 30 s using a data logger (model CR10X) connected to an AM16/32 multiplexer programmed to report mean values every 30 min.

The plant water status of all the sampling trees equipped with the LVDT sensors was determined by measurements of Ψ_s following the procedure described by Turner (1981). Measurements were taken weekly at solar noon in two mature leaves from the north side of the canopy enclosed in plastic bags and covered with aluminum foil at least 2 h prior to the measurements.

2.3. Data analysis

Data were analyzed using the SAS statistical package (SAS Institute, 1994). Differences between treatments were assessed by the analysis of variance (ANOVA) according to the 'GLM' procedure. The sensitivity of a plant-based water status indicator is considered an important factor in determining its usefulness for irrigation scheduling (Fernández and Cuevas, 2010). Sensitivity of the water stress indicators studied was assessed according to Goldhamer and Fereres (2001) as the average ratio between the values of a variable for the water-stressed and control treatments (signal intensity), divided by the average coefficient of variation (noise) during a given period of time.

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