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Water Relations in the Irrigation Scheduling of Olive Orchards

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ABSTRACTS

Olive trees (*Olea europea* L) are traditional Mediterranean specie. The agricultural management of olive orchards has been changed from 90's of the last century. The most important change is the great increase of the irrigation surface. This new water demand has been produced in water scarcity areas. Such conditions and the traditional rainfed management of the orchards have produced very restrictive water used. The traditional irrigation scheduling based on water budget is a useful tool in conditions of full irrigation, but most of the olive orchards are deficit irrigated. In the last decades, plant water status measurements have been suggested in different fruits trees in order to improve the management of deficit irrigation. In this work, results of several experiments in different olive orchards using midday stem water potential and trunk daily diameter are presented. The water stress sensitivity and the real commercial utility are discussed.

INTRODUCTION

Olive tree is traditional rainfed fruit specie in the Mediterranean basin. Olive tree is drought resistant specie that could allow severe level of dehydration and midday water potential around -4.0 MPa are common in scientific papers. Such capacity of drought resistant and the rainfed management have produced that, in the traditional growing zones, deficit irrigation is the most common practise. Water relations have been considered until the end of the XX century as a tool for evaluated the irrigation scheduling strategies in scientific works, but not as real parameter for water management. Plant water status measurements have the advantage of characterised the whole tree and provide a "global point of view" of the irrigation management. However, they have the big disadvantage of the strong relationship with the environment and the plant physiology. The aim of this work is to present the results obtained in several studies of irrigation scheduling in olive trees based on plant water status measurements and discuss and suggest strategies for commercial use.

First steps in the use of plant water status measurements in irrigation scheduling

Water budget is the traditional irrigation scheduling in the field. Deficit irrigation is difficult to control with this information, mainly if the water available is small, such as in olive orchards.

The great capacity of olive trees for dehydrating suggests that water potential is likely one of the most easy and early water stress indicators. Moriana and Fereres (2004) reported that the influence of evaporative demand in the values of midday stem water potential (Ψ) is low in no water stress conditions (Figure 1). Then, it would be possible to use the same value of Ψ along the summer. Moriana et al (2012) reported several experiments in difference conditions (locations and olive cultivars) with the same irrigation scheduling based on stem water potential. This work suggested that -1.2 MPa before pit hardening and -1.4 MPa after pit hardening could be threshold values for full irrigated conditions (Figure 2). These threshold values have been used in other experiments in different conditions and cultivars when a good agreement with the Orgaz et al (2006) model (data not shown). This suggests that though a mild water stress could be assumed, the seasonal physiological response of the orchard would be near to full irrigated conditions.

The determination of the water stress level in deficit irrigation is also affected for the moment and the length of the drought period. From Goldhamer (1999), there is a general agreement about that pit hardening is the most drought resistant phenological stage. The water stress level reported in this period in the literature is very variable with minimum values very low which corresponded with not too high decrease in yield. During the pit hardening period, the fruit is a very important source of carbohydrate and controls the water relations of the whole tree (Martín-Vertedor et al., 2011). Dell'Amico et al (2012) suggested that in low water stress conditions tree water relations delayed the decrease in fruit turgor in table olive. These authors suggested that until values of midday stem water potential around -2.0 MPa fruit growth could be not affected. Unpublished data obtained in a mature hedgerow, showed no significant differences between treatments at -2.0 MPa and -3.5 MPa though a clear trend to reduce yield around 10% (data not shown). Then two levels of water stress could be considered around -2 MPa (a low water stress) and -3.5 MPa (a moderate water stress).

High sensitive irrigation scheduling. Water relations for increasing the accuracy.

Water potential is likely the easiest and cheapest methodology now for commercial purpose but it is not the most accurate. Moriana and Fereres (2002) reported that trunk growth rate (TGR) measured with dendrometers was earlier sensitive to drought conditions than midday stem water potential. Trunk diameter fluctuations are, also, a continuous and automatic measurement which could permit a daily irrigation scheduling. However, this increase in the precision is likely related with an increase in the error. Pérez-López et al (2013) estimated in olive a very high number of sensors (34) to obtain a standard error which were the 10% of the average in the Maximum daily shrinkage (MDS) indicator.

There have been a lot of works with trunk diameter fluctuations parameter from 90´s but with different results between species. In olive trees, the relationship between MDS and stem water potential shows that this indicator is very confusing (Moriana et al 2010). There are no clear differences in MDS in moderate water stress conditions. Full irrigated trees in summer are around maximum values of MDS and water stress trees from -1.5 to probably -2.5 MPa are also in the same range of values. Only with very severe water stress, MDS in stress trees is lower than control.

Maximum daily diameter (MXTD) and trunk growth rate (TGR) are in olive trees more sensitive to drought conditions than MDS. MXTD is the sum of the daily TGR. TGR are more suitable for description of water status, mainly in the period of rehydration (Moriana and Fereres, 2002) than MXTD. MXTD in olive trees, as in other fruits, shows a seasonal pattern link to the fruit development (Moriana et al, 2013; Figure 3). In conditions of enough fruit load, the TGR's seasonal pattern has two different phases, trunk growth, with positives TGR, and constant size period, with TGR values around zero. Such pattern provides very interesting information about the phenological stage of the trees because it is strongly related with the period of massive pit hardening (Pérez-López et al. 2008). Recently, Moriana et al (2013) suggested that a TGR around -5 μm day^{-1} from the beginning of this period until harvest is a useful threshold value in Regulated Deficit Irrigation (RDI).

The most important limitation of this parameter is the lack of relationship between TGR and environmental measurements. Our data during pit hardening period show that TGR is even negative in conditions of full irrigation in some days or periods likely related with very high temperatures (Figure 3), though no significant relationship has been found. Then when TGR is used in irrigation scheduling there is not a clear pattern around this value. In other words, when an irrigation scheduling was based on a threshold value of -10 μm day^{-1} the seasonal pattern of MXTD is not a line with a slope of -10 μm day^{-1}, otherwise is a pattern similar to full irrigated control (data not shown). This response and the need of works that provided information with the same irrigation threshold limit the commercial use of these sensors.

All this limitations of the trunk diameter fluctuations indicators show that water relations of this fruit tree are not yet completely solve. Further works than clarify this respond are needed. In addition, it is also very important the experiments in network that provide information of the same threshold value or irrigation scheduling in different conditions.

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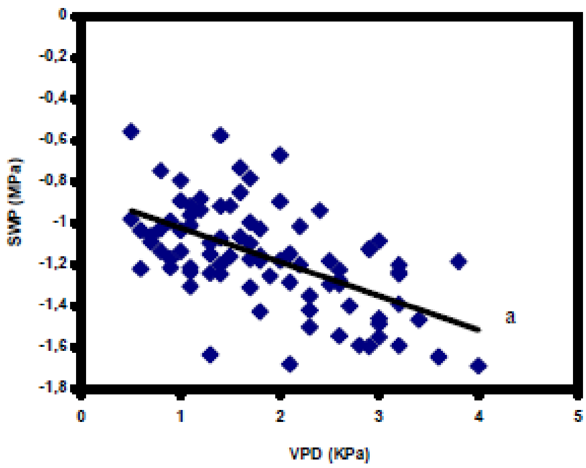

Figure 1. Relationship between midday stem water potential and vapor pressure deficit (VPD) in mature "on" (a), mature "off" (b) and young (c) olive orchards. Source. Moriana and Fereres (2004).

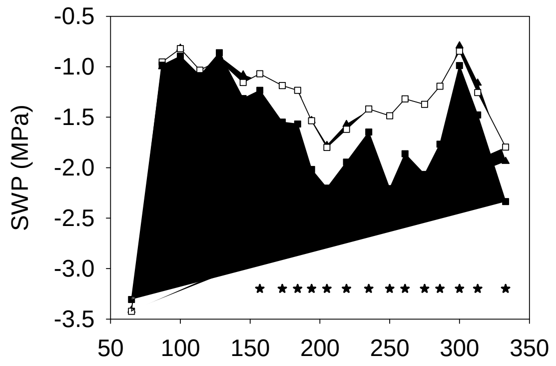

Figure 2. Seasonal pattern of midday stem water potential Badajoz (Spain) cv Morisca. In both experiments the threshold values were the same ▲Control treatment; □ WI treatment (-1.2 and -1.4 MPa); ■ DI treatment (-2 MPa). Source: Moriana et al (2012)

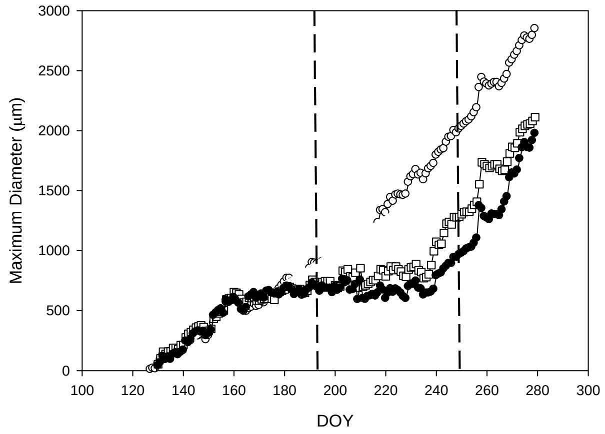

Figure 3. Seasonal pattern of maximum daily diameter during. Solid lines represent Control trees and both dashed lines are regulated deficit treatments. Vertical bars show rain events and vertical lines the periods of pit hardening. Source: Moriana et al 2013