Establishing Reference Values of Trunk Diameter Fluctuations and Stem Water Potential for Irrigation Scheduling of Olive Trees

A. Moriana  
Servicio de Investigación y Tecnología Agraria  
Junta de Comunidades de Castilla-La Mancha  
Ciudad Real  
Spain

E. Fereres  
Departamento de Agronomía  
Universidad de Córdoba-IAS (CSIC)  
Córdoba  
Spain

Keywords: LVDT, maximum daily shrinkage, Olea europaea, trunk growth rate, water relations.

Abstract

Trunk diameter fluctuations (TDF) and stem water potential (SWP) were recorded in well-irrigated olive trees with the aim of establishing reference values of both indicators for irrigation scheduling. The measurements were performed in a mature (18 years) and a young olive orchard (3 years) during 4 years. Two different indicators derived from TDF: maximum daily shrinkage (MDS) and trunk growth rate (TGR) were evaluated. The annual relationship between MDS and vapour pressure deficit (VPD) was hysteretic, probably caused by the presence of fruit as no hysteresis was detected in ‘off’ trees. All data pooled gave an equation of MDS=0.09+0.19VPD (R²=0.60). When only data until mid-August in mature “on” trees was used, the fit was improved (R²=0.71; MDS=0.05+0.22VPD). Young trees had a slightly different relationship with a steeper slope; MDS=-0.18+0.27VPD (R²=0.80). The relationships between the SWP values and VPD were not as good as with MDS (R² around 0.3), and the regression slope was steeper in ‘on’ than in ‘off’ trees. TGR in the young orchard had two maxima in the year; the first at mid-Spring (0.2 mm day⁻¹) and the second at the end of the summer (0.15 mm day⁻¹). In the mature orchard, TGR had a single maximum value, at the end of summer for ‘off’ trees, and in spring for ‘on’ trees.

INTRODUCTION

The interest in using plant-based measurements for irrigation scheduling is increasing, particularly in fruit trees where regulated deficit irrigation (RDI) is applied. The established procedure is the measurement of stem water potential at midday, relative to a reference value (Shackel et al., 1997).

In the last years, several works proposed the measurement of trunk diameter fluctuations (TDF) as the most sensitive indicators of water stress in fruit trees (peaches, Goldhamer et al., 1999; olives, Moriana and Fereres, 2002). Although there have been several publications since the 1960’s on TDF, its use for scheduling irrigation has been hampered by the lack of practical approaches to use such measurements. Recently, Goldhamer and Fereres (2001) proposed a protocol for irrigation scheduling of almond trees based on using solely TDF measurements relative to reference values. The research reported here was conducted to establish references values of TDF and of stem water potential for irrigations scheduling in olive trees.

MATERIALS AND METHODS

The measurements were performed in a mature (18 years old, cv Picual) and a young (3 years old cv Arbequina) well-irrigated olive orchards. In the mature orchard, trunk diameter fluctuations (TDF) were recorded during 2 years in trees with a heavy crop load (“on”) and during 1 year in trees without a fruit crop (“off”), while in the young orchard, TDF were recorded for 3 years in trees with similar crop load. Trunk diameter fluctuations (TDF) were measured with Linear Variable Differential Transducer (LVDT; Model DF 2.5; Solartron Metrology, West Sussex, U.K.) mounted in a holder built of
aluminum and “INVAR”, an alloy composed of 64% Fe and 35% Ni that has minimal thermal expansion. The sensors were attached to the south main branch of 4 trees in the mature trees, and in the main trunk of the young trees along the irrigation season. Measurements were taken on each experimental tree every 30 seconds and the datalogger (Model CR21X, Campbell Sci., Logan, U.S.A.) was programmed to calculate 15 min means. The daily TDF cycle provides three different indices; Maximum Daily Diameter (MXTD), Minimum Daily Diameter (MNTD) and Maximum Daily Shrinkage (MDS), the latter taken as the difference between MXTD and MNTD (Goldhamer and Fereres, 2001). Trunk growth rate (TGR) is calculated as the difference between two consecutive MXTD.

Stem water potential was measured periodically on fully expanded leaves located in branches near the main trunk that were covered with aluminum foil at least 20 min before excision. The water potential was measured with a pressure chamber at midday (Soil Moisture Equip., Santa Barbara, Calif., U.S.A.). Vapour pressure deficit (VPD) was calculated from data of a meteorological station 300 m away from the experimental orchards.

RESULTS AND DISCUSSION

Maximum daily shrinkage (MDS) increased with vapour pressure deficit (VPD) in well-irrigated olive trees, though significant scattering was detected when all data were pooled (Fig. 1). The regression coefficients improved when the some of the data were grouped in three sets (Fig. 2). “On” mature trees presented a hysteretic relation, having higher MDS for the same VPD during fall, when the fruit is growing rapidly and stomatal conductance is very high (Moriana et al., 2002). When only the two years data until mid-august of “on” trees were used, a best fit was obtained (Fig. 2a). In addition, in off mature trees no hysteretic loops were observed (Fig. 2b). Therefore, the presence of the fruit in the tree may be related with these changes in the relationship. Similar evolution of MDS along the season has been reported in peach trees and was related with the presence of the fruit (Marsal et al., 2002). In olive trees, the fruit is the most important sink of carbohydrates and, during the “on” year, reduces the partitioning to the vegetative organs (Rallo and Suarez, 1989). DeJong (1986) reported that in fruiting peach trees leaf conductance was increased during the stage III, the rapid growth phase. Thus, the hysteretic loops in “on” trees may be related with increase in the transpiration rate probably associated with the beginning of stage III in the fruit development. The relationship for “off” trees had a slope that was significantly less than that of “on” trees (Fig. 2b). Young trees of a different cultivar had a slightly different relationship with a steeper slope than “on” mature trees (Fig. 2c). In both cases, correlation coefficients were greater than in “on” mature trees. The slopes of young trees were significantly different between years 2000 and 2001 (data not shown) at the beginning of the season but were not with data after mid-august (data not shown).

One possibility for irrigation scheduling of olive trees using MDS, would be to use as threshold the relationship found early in “on” trees (Fig. 2a) for the whole season. For instance, in a day or period of days the value of VPD would be introduced in the equation of Fig. 2a and calculated MDS (MDS_c) would be compared with measured MDS (MDS_m) increasing or decreasing the amount of irrigation if MDS_c is higher or lower, respectively, than MDS_m. This assumption for the latter part of the season, would lead to greater sensitivity than needed to changes in MDS if the line in Fig. 2a is used as threshold, but that could be beneficial to avoid water deficits in the critical fruit growth period in the fall. The alternative would be to use both relationships because, if and when irrigation management using TDF sensors would be fully automated, thresholds could be varied at will by the operator. In young trees, the MDS-VPD relationship is less confident because of the change with age and because less sensitivity has been reported for this indicator in water stress conditions (Moriana and Fereres, 2002).

The relationship between stem water potential (SWP) and VPD had lower regression coefficients than those of MDS vs. VPD. However, differences slopes between the three sets were also obtained (Fig 3). “On” and young trees showed higher slope (Fig.
3a and c) than “off” trees which presented almost a horizontal line (not significant) (Fig. 3b). The range of variation in the SWP, even in “on” trees, was lower than the MDS as several authors reported (Goldhamer et al., 1999).

Daily trunk growth rate (TGR) also showed significant scatter in the data (Fig. 4). Moriana and Fereres (2002) suggested that the data were grouped in period of 5 days in order to decrease the variation. This average showed a clearer tendency of the growth along the season. Mature trees growth rates were less than those of young trees, even in “off” trees. The differences measured point between young and mature trees, in the trunk and in a main branch, may affect the TGR values, though no significant different between branch and main trunk in mature trees occurred in preliminary experiments (Morian and Fereres, unpublished data). “On” trees showed a similar tendency until the end of the spring when TGR started to decrease slightly (Fig 4a) with a maximum value around 0.1 mm/day. However, in “off” trees there was a tendency for an increase of TGR until the beginning of fall (maximum value around 0.1 mm/day) when a sharp decrease occurred (Fig 4b). In young trees, TGR presented a similar pattern during the three years of measurements (Fig. 4c). TGR increased from winter to spring reached values of about 0.2 mm/day, it remained between 0.1 and 0.2 until the beginning of fall and then decreased sharply to negligible values.

CONCLUSIONS

Although general relationships were found among the parameters and VPD when all data was pooled, it appears that TGR, MDS and SWP reference values in olive are influenced by seasonal changes, fruit load, tree age, and possibly cultivar. Nevertheless, it is possible to derive reference values for MDS and TGR that are conservative enough, particularly in the case of young trees, to avoid both, overirrigation and water deficits that will be detrimental to the fast growth rates required for canopy development. It appears that the reference values needed for irrigation scheduling in olive trees using plant parameters, will have to be modulated seasonally to account for the variations found in this study.

Literature Cited

Figures

Fig. 1. Relationship between MDS and VPD with all data pooled. Each symbol represents the average of 4 trees. MDS=0.09+0.19VPD ($R^2=0.6^{***}$; RMSE=0.13; n=668).

Fig. 2. Relationship between MDS and VPD. Each symbol represents the average of 4 trees. Some of the data of Fig. 1 were divided in mature on trees (two years data, until mid-august) MDS=0.22VPD+0.05 (a; $R^2=0.71^{***}$; RMSE=0.10; n=160), mature off trees (one year data, all the season) MDS=0.16VPD+0.03 (b; $R^2=0.84^{***}$; RMSE=0.06; n=136) and young trees (one year data, until mid-august) MDS=0.27VPD-0.18 (c; $R^2=0.8^{***}$; RMSE=0.11; n=75).
Fig. 3. Relationship between stem water potential (SWP) and VPD in mature “on” trees
SWP=-0.16VPD-0.86 (a; R²=0.33***; n=83; RMSE=0.20), mature “off” trees
SWP=-0.08VPD-0.96 (b; R²=0.15ns; n=35; RMSE=0.16) and young trees SWP=-
0.13VPD-0.65 (c; R²=0.26***; n=60; RMSE=0.14).
Fig. 4. Trunk growth rate (TGR) evolution along the season in mature “on” trees (a), mature “off” trees (b) and young trees (c). Each square represents the average of 4 trees and each triangle is the average of 5 days. Data of Figure a and b correspond a one year of measurements (year 1999). Vertical lines in Figure c delimit the data in seasons (1999, 2000, 2001, 2002).