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Comparison of the water potential baseline in different locations. Usefulness for irrigation scheduling of olive orchards

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ABSTRACT

Deficit irrigation scheduling needs accurate indicators and in recent decades, continuous plant indicators have been developed. However, threshold values that could be useful in commercial orchards are not commonly reported. The water potential is a discontinuous measurement commonly used as a reference in the description of water stress level. In some fruit trees, such as olive trees, there are several works suggesting threshold values in fully irrigated conditions, but the influence of the evaporative demand is not taken into account. The aim of this work is to compare the values of the fully irrigated water potential in different locations in order to study the estimation of a common baseline. Three mature olive orchards were selected, two in Seville (South Spain) and one in Ciudad Real (Central Spain). There were clear differences between the three orchards during the 2015 season. Orchards in Seville (S-1 and S-2) were close (10 km apart) and had the same cultivar (table olive, cv Manzanilla) but they were different in terms of the fruit load (almost no fruit in S-1, medium fruit load in S-2) and distribution of water (single drip line in S-1, double drip line in S-2). The orchard in Ciudad Real (CR) was very different with regards to the olive cultivar (cv Cornicabra) and the location, as it was in a borderline zone for olives growing with very low temperatures that delay the phenological development. In all the orchards, the best baseline was obtained with different climatic measurements, even in S-1 and S-2. When all the data were considered, the best fit was obtained with the average vapour pressure deficit (VPDav). Influence of the location was significant in the interception term of the equations when Temperature was used but not with VPD. This source of variation was reltade with the level of fruit load. Slope of the equations was not affected for the location. The equation obtained was validated with water potential data from previous seasons of S-1 and CR orchards. Maximum temperature presented the best validation results. The usefulness of this baseline is discussed.

1. Introduction

Water for agricultural uses progressively decreases in arid zones because of the scarcity of natural resources and the increase in water demand for other social uses (Fereres and Soriano, 2007). The climate change models estimate that in these zones rainfall will decrease and temperature will increase, consequently the evaporative demand will rise. (IPCC, 2015). In addition, traditional rainfed fruit crops in these zones, such as olive trees, are converted into more dense, irrigated orchards. These species are usually drought resistant and farmers receive less irrigation water than the real needs of the orchard. Olive trees are a good example, with more than 400,000Ha on irrigated land in Spain (MAGRAMA, 2016) where most of the surface experiences deficit irrigation conditions.

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Nowadays there is a wide variety of soil and plant sensors available, even for commercial orchards, and they could be used to schedule deficit irrigation conditions (i.e., zim probe, dendrometry, canopy temperature). However, to our knowledge, little is known about the water stress threshold level of these tools. Thus, at least in olive orchards, the technology related to the design of new sensors is ahead of the sensor management in the field, understood as the knowledge about the stress threshold values that the plants can be subjected to. Although midday stem water potential is not the earliest indicator of water stress in olive trees (Moriana and Fereres, 2002), it is used as the standard comparison for most of the new sensors. Moriana et al. (2012) suggested using −1.2 and −1.4 MPa of midday stem water potential as the threshold for fully irrigated olive trees. However, according to literature, values below −1.4 MPa are common, mainly in mid-summer or in high fruit load seasons in fully irrigated treatments (i.e. Martín-Vertedor et al., 2011).

Plant measurements have been considered very efficient tools for irrigation scheduling (Turner, 1990) although they were not traditionally used due to their close relationship with evaporative demand (Hsiao, 1990). Shackel et al. (1997) was one of the first works that suggested irrigation scheduling for fruit trees based on the water potential. Nevertheless, the influence of evaporative demand when suggesting water potential threshold values is not commonly considered in the literature (i.e. plum, Lampinen et al., 2001; citrus, Ballester et al., 2013; pecan, Othman et al., 2014; olive, Moriana et al., 2012; Rosecrance et al., 2015; Girón et al., 2015). For continuous indicators, such as dendrometry, it is very common to estimate the baseline (Ortuño et al., 2010). Because these methodologies have a great amount of data, baseline estimations at the beginning of the season are easier to obtain than in water potential measurements. The great sensitivity of plant measurements to the tree physiology also increases the difficulty of obtaining a strong baseline, especially when different cultivars or environments are considered. Thus, few works have been published about the comparison of thresholds or approaches between significantly different locations. The aim of this work is to compare the seasonal baseline of the water potential in different olive orchards in order to verify if a unique estimation would be comparable and useful.

2. Material and methods

2.1. Orchards locations

Three experimental orchards were considered for the comparison of baselines:

1. Seville 1 (S-1). This orchard is located in La Hampa, the experimental farm of the Instituto de Recursos Naturales y Agrobiología (IRNAS-CSIC) in Coria del Río, near Seville (Spain) (37° 17′N, 6° 3′W, 30 m altitude). The sandy loam soil (about 2 m deep) of the experimental site was characterized by a volumetric water content of 0.33m^3 m^{-3} at the saturation point, 0.21 m^3 m^{-3} at field capacity and 0.1 m^3 m^{-3} at the permanent wilting point, and a bulk density of 1.30 (0–10 cm) and 1.50 (10–120 cm) g cm^{-3}. The experiment was performed on 44-year-old table olive trees (*Olea europaea* L cv Manzanillo) during the 2015 season. Tree spacing followed a 7 m x 5 m square pattern. Irrigation was carried out during the night by drip, using one lateral pipe per row of trees and five emitters per plant, delivering 8 L h^{-1} each.
2. Seville 2 (S-2). This orchard is located in Doña Ana, a private farm in Dos Hermanas, near Seville (Spain) (37° 25′N, 5°95′W). The loam soil (deeper than 1m) of the experimental site was characterized by a volumetric water content of 0.31 m^3 m^{-3} at field capacity and 0.14 m^3 m^{-3} at the permanent wilting point, and a bulk density of 1.4 (0–30 cm) and 1.35 (30–90 cm) g cm^{-3}. The experiment was performed on 30-year-old table olive trees (*Olea europaea* L cv Manzanillo) during the 2015 season. Tree spacing followed a 7 m × 4 m square pattern. Irrigation was carried out during the night by drip, using two lateral pipes per row of trees and twenty-six emitters per plant, divided between the two rows, delivering 2 L h^{-1} each.
3. Ciudad Real (CR). This orchard is located in “El Chaparrillo”, the experimental farm of Consejeria de Agricultura (Junta de Castilla La Mancha) in Ciudad Real, Central Spain, (39° 02′N, 3° 94′W, altitude 640 m above sea level). The soil is a shallow clay-loam (Petrocalcic Palexeralfs) 0,75 m deep and a discontinuous petrocalcic horizon between 0.75–0.85 m. The volumetric water content was for was 26.0% after field capacity and 13.1% at wilting point. The experiment was performed on 17-years-old olive trees (*Olea europaea* L cv Cornicabra) during the 2015 season. Tree spacing followed a 7 m × 4.76 m square pattern. Irrigation was carried out during the night by drip, using one lateral pipe per row of trees and four emitters per plant, delivering 8 L h^{-1} each.

2.3.1. Climatic description

The climatic conditions of the orchards located in Seville are almost equal because the distance between them is only around 10Km and both of them are at the same level in the Guadalquivir Valley. The distance between Ciudad Real and Seville is around 330Km and there are a great differences in altitude (640 m vs 30 m above sea level) and in the distribution of rains and temperatures. Fig. 1 presents the seasonal pattern of reference evapotranspiration (ETo), rain and temperature in both locations during the 2015 season. Winter minimum temperatures are clearly different between both locations. While Seville is slightly below 0 °C, some data of Ciudad Real are in the region of −10 °C. These minimum temperatures indicate that Seville is a traditional olive zone while Ciudad Real is in the borderline where this fruit tree can be cultivated. Although summer temperatures are similar in both locations, the delay in the recovery of spring temperatures causes a shorter growing season in Ciudad Real than in Seville and the date of flowering is very different: around mid-April in Seville and early-June in Ciudad Real. During 2015, seasonal rains were slightly lower in Seville than in Ciudad Real (Fig. 1b). In both locations, late-spring and summer are dry periods and evaporative demand is extremely high.

Table 1 summarises the fruit load of the three orchards considered during the 2015 season in comparison with the historical average. The CR orchard has a lower average yield than the S-1 and S-2 orchards due to the important problems with low winter temperatures. The current yield, the one obtained in the 2015 season, was clearly different between locations. The CR orchard presents a record yield in comparison with the historical average (two fold more than the average). On the other hand, S-1 and S-2 were lower than the average with almost no fruit load in the S-1 orchard.

2.3.2. Irrigation regimes and measurements

All the measurements were made on six to eight trees (depending on the orchard) located in a plot with adjacent guard rows. The water status of the trees for each treatment was characterized by the midday stem water potential (Ψ) and maximum leaf conductance. The leaves near the main trunk were covered in aluminium foil at least one hour before measurements were taken. The water potential was measured at midday in one leaf per tree, using the pressure chamber technique (Scholander et al., 1965) every 7-10 days. Leaf conductance was measured with permanent porometer (S1 and S2 orchards, Decagon) and with an IRGA (CR