

Preliminary observations on the use of microtensiometers to continuously measure water potential in a mature olive orchard

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Abstract— The modern cultivation of olive needs to be performant and sustainable. Stem water potential (SWP) is a key indicator to implement precise irrigation and increase system productivity, but it is a manual and labor-intensive measurement. New trunk-embedded microtensiometers allow to measure trunk water potential (TWP) continuously, and in this study we report for the first time their performance in olive. TWP values were generally higher than SWP values measured with the pressure chamber. The values of both indicators showed a very clear trend in response to irrigation and similar relative changes. Overall, this new technology looks promising but further studies are needed.

Keywords — *precise irrigation, proximate sensing, *Olea europaea*, tree water status.*

I. INTRODUCTION

The modern cultivation of olives needs to be performant and sustainable. Irrigation should be provided in all cultivation areas to maximize yield and water use efficiency. Climate change has increased the frequency of drought events, thus reducing available water for agriculture. In parallel, the global temperature is rising, potentially increasing trees' transpiration rates [1]. Farmers urgently need to increase irrigation efficiency by using plant-based indicators associated with desired physiological responses to stress.

Stem water potential (SWP) is among the most used tree water status indicators. SWP is assessed by measuring the balancing pressure of non-transpiring, equilibrated leaves. Importantly, SWP is a direct measure of the water status of the tree, in particular, of most of the canopy, as opposed to the indirect soil or remote methods, and the localized leaf water potential. The SWP method has been largely used in research, so there are several references on how to efficiently use it for water management; however, it presents some limitations. The time requested for the measurements can limit the number of observations achievable during the day. This can be a constrain both for research trials and large farm operations. Furthermore, the measurement is destructive, limiting its use in young trees with reduced foliage. Finally, it is labour-intensive, the measurements are generally performed in a

small time frame in the hottest period of the day (to obtain the 'midday' SWP), and specialized personnel is needed, because of the use of pressurized gas.

Continuous measuring technologies have been widely tested for water management in woody species [2]. They are non-destructive and automatic measurements that allow for remote real-time access. Despite these advantages, there is still a gap between the amount of information developed by researchers and private companies, and the adoption by growers and irrigation managers. The main reasons for this discrepancy have been carefully discussed in Fernández [3] and can be summarized as: difficulty to use and maintain, high price, and complex data interpretation. In addition, most of these technologies do not directly measure tree water status, but some other physiological parameters, such as shrinkage and swelling of organs, or canopy temperatures, that are influenced by tree water status. Environmental parameters and the genotype specific response to drought can affect these processes, having a strong effect on data interpretation [4,5].

Microtensiometers are a new technology that allows continuous information of tree water status. It measures directly the pressure on the trunk (or primary branches) using a mechanical pressure sensor installed directly in the wood. In almond, values obtained using microtensiometers and the pressure chamber were similar [6,7], while some differences, especially during evening, were seen in pear [8,9]. In nectarine, the difference between trunk and stem water potential was around 0.1 MPa in a well wet soil, and about 0.3 MPa in deficit irrigation trials [10] with $\Psi_{\text{trunk}} < \Psi_{\text{stem}}$. All the works that used the microtensiometers demonstrated a circadian trend (daily) of trunk water potential (TWP) with a decrease during daylight and an increase during the night.

To our knowledge, there are no official reports on the performance of microtensiometers in olive (*Olea europaea* L.). Considering the key role of SWP as an irrigation tool for this drought-tolerant species [11], we decided to characterize the changes in TWP in response to irrigation with the microtensiometers in a mature commercial olive orchard. We aim to give insights into the pros and cons of this methodology

and on its potential to be used to improve water use efficiency in olive.

II. MATERIALS AND METHODS

The experiment was conducted from June to October 2022, in a 17-year-old olive orchard cv Manzanillo planted in a 6.4 x 3.2m spacing and located in Orland (CA, USA). The orchard was drip irrigated with a double drip line and 1.89 l/h emitters spaced 0.91 m, delivering a total of 5.11 l/h per tree. The soil was a sandy loam.

At the beginning of June, a tree was equipped with microtensiometers (FloraPulse, Davis, CA, USA, Fig 1). Two sensors were installed at the base of two primary branches, following the procedure suggested by [6]. Despite sensors being placed in the branches, microtensiometer measurements are referred to as Trunk Water Potential-microtensiometer (TWP-mt) throughout the text for consistency with literature.

The tree was irrigated following the farmers' practices all the season except for the pit hardening stage (from July 1st until August 20th) when water application was reduced by 50%. Grower irrigation was based on ETC, calculated using historical ETo values and the Kc of 0.7 [12]. A flowmeter (Sensus iPEARL, Raleigh, NC, USA) was installed in the irrigation line to continuously monitor grower's water applications, which resulted in 508 mm in the experimental period, 762 mm over the entire season. It was distributed in irrigation cycles of 72-96 hours at 5 days intervals until mid-July, and 2-3 days intervals in the second half of July, August and September.

Stem water potential was measured at midday every 1 or 2 weeks throughout the growing season using a pressure chamber (PMS Instrument Co., Corvallis, OR) on shaded shoots with 2-3 pairs of leaves bagged with myler bags at least 15 minutes prior to the reading. On August 31st and September 21st a daily survey was conducted, with 8 and 6 measurement points, respectively. Pressure chamber measurements are referred to as Stem Water Potential-pc (SWP-pc) throughout the text. The SWP baseline (corresponding to non-stressed values for those specific days of measurements) was calculated using the values of VPD collected by the closest CIMIS (California Irrigation Management Information System) meteorological station # 222 (Gerber), located 30 km from the experimental site and the equation reported by [13].

Data analysis was performed using Sigmaplot 14 (Systat Software, Inc., San Jose, CA, USA).

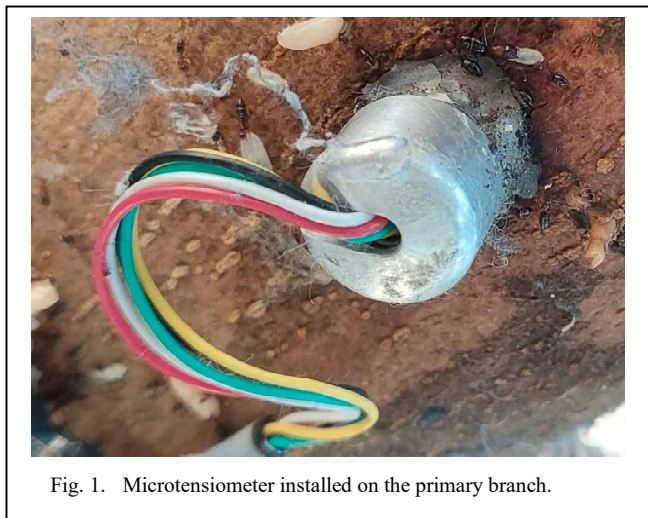


Fig. 1. Microtensiometer installed on the primary branch.

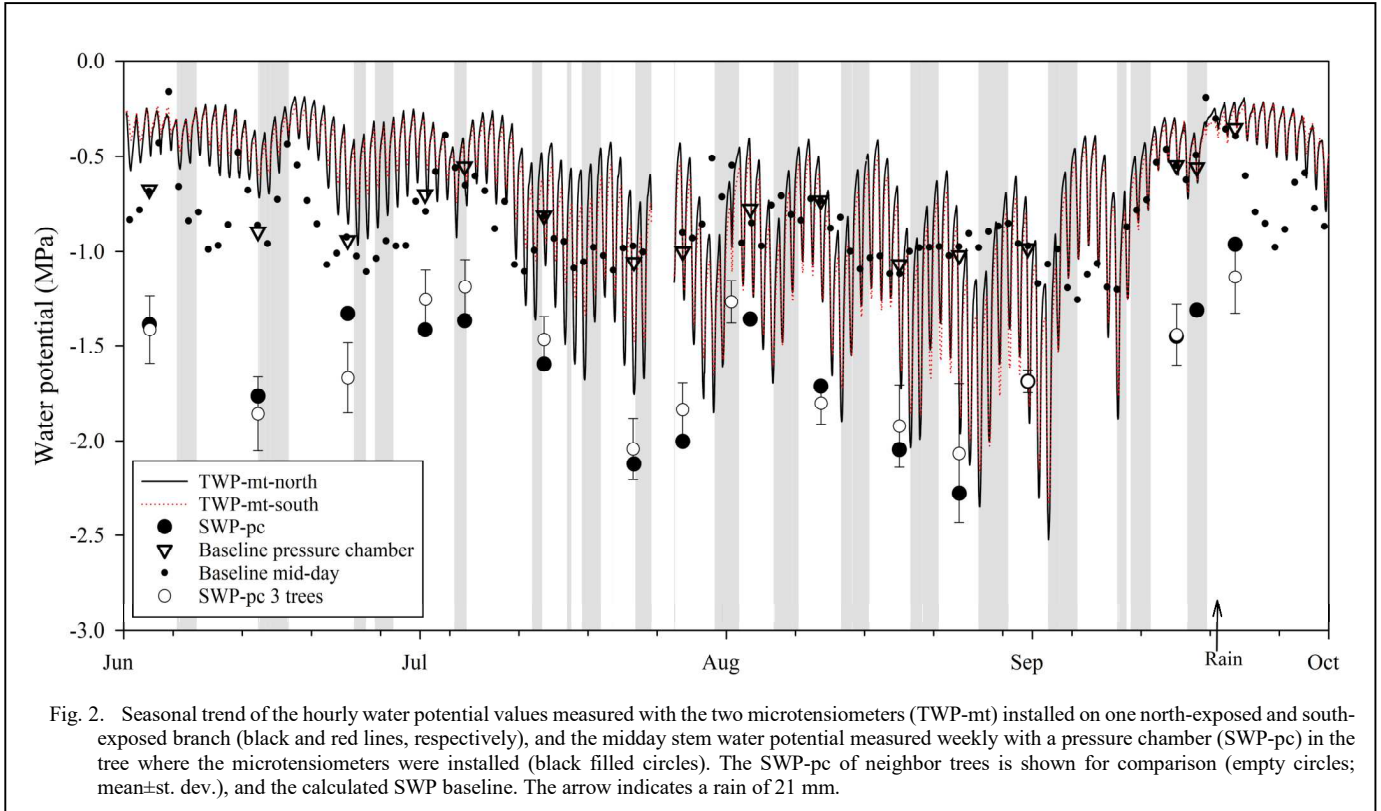
III. RESULTS AND DISCUSSION

The continuous TWP-mt showed a very clear trend in response to irrigation cycles, with an increase of the TWP-mt in response to irrigation (an average of 79 % increase in the daily minimum TWP after watering and 85 % in the maximum daily TWP during each irrigation cycle in the study period) and a decrease when irrigation was withheld (an average of 32 % decrease in the daily minimum TWP in the day before watering and 26 % in the maximum daily TWP during each irrigation cycle in the study period, Fig. 2 and 4). After the reducing irrigation at the beginning of July, WP-mt slightly decreased in one month, showing a response of the tree water status to the deficit irrigation. The midday SWP baseline was close to the daily TWP-mt minimum in June and September, when trees were fully irrigated, and to the daily TWP-mt maximum in July and August, during the deficit irrigation.

The data of SWP-pc taken with the pressure chamber were lower than the TWP-mt in 32 out of 33 measurements, with a maximum difference of 1.15 MPa on the 14th of June.

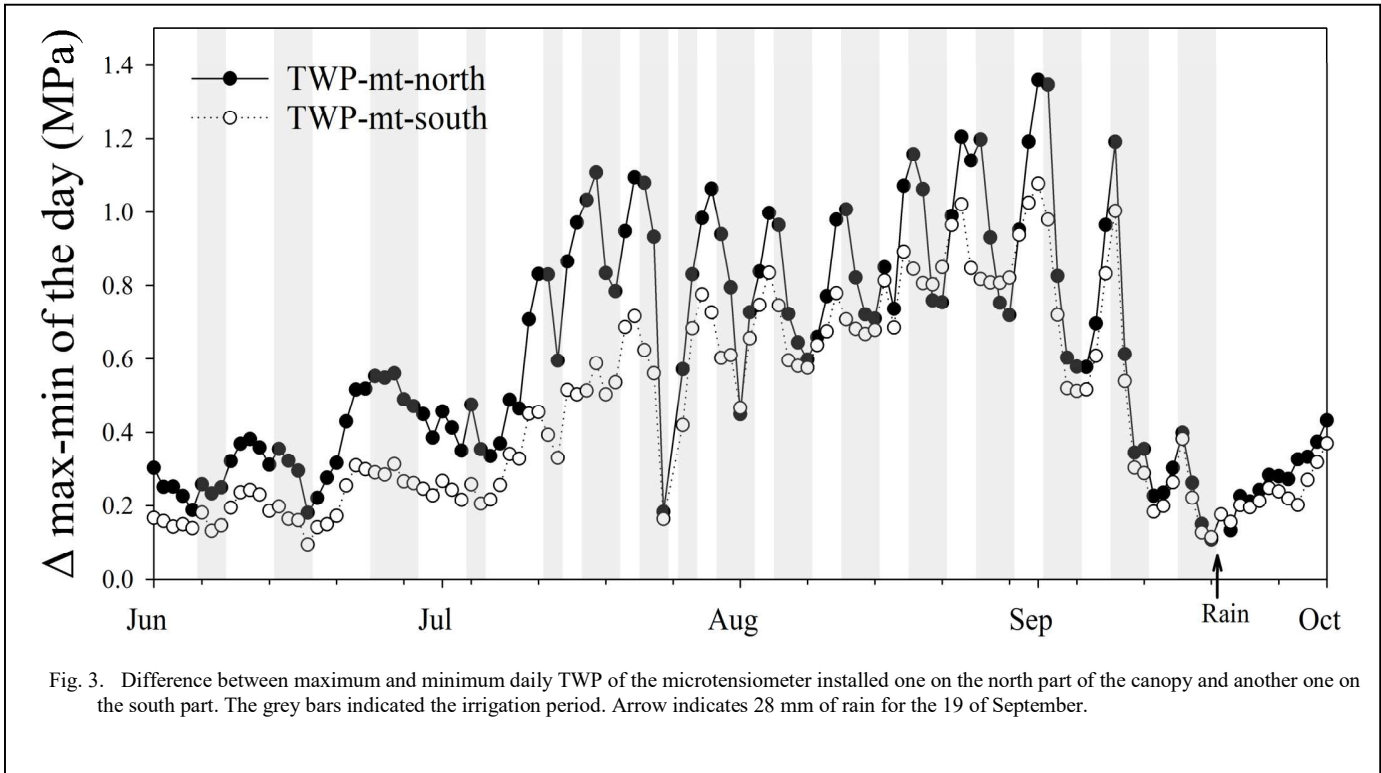
Focusing on a daily trend, the circadian trend is appreciable, with a decrease of the TWP-mt during the light period and, opposite, an increase during the night period of the day. This trend was shown also for the cherry and olive fruit growth with fruit shrinkage during the light period when the VPD was maximum and substantial enlargement during the dark period according to a hysteresis pattern [14, 15,16], while in apple Gonzalez Nieto et al. [17] showed the same trend for the fruit diameter and the TWP-mt. Similar trend was shown also by the pressure chamber measurements. The negative peak of SWP-pc was at the same hours as the positive peak of the VPD, while it was anticipated with respect to the peak of TWP-mt on both days (Fig. 4). This fact needs to be more studied, the delay of the negative peak in TWP-mt with respect to SWP-pc and VPD could suggest also why, in pear, during the afternoon was found lower values of SWP-pc with respect to TWP-mt [9].

Differences in the readings of the two sensors installed in two branches of the same tree were assessed by comparing the difference between the maximum and minimum TWP-mt daily values (Δ -mt, Fig. 3). Δ -mt was responsive to the irrigation cycles, decreasing during rewatering and increasing in response to water stress. The north-exposed branch presented the biggest differences Δ -mt, with a gap that increased during the no-irrigation period (Fig. 3). It is possible that the canopy of the branch exposed in this tree to the north part was more sensitive to stress, due to the compartmentalization of the trunk of the olive trees. More studies should explore the effect of installation point on these sensors output.



Values of TWP-mt and SWP-pc show a linear relationship ($R^2:0.7480$). While relative changes in WP measured with the two techniques are similar (slope ~ 1), TWP-mt values tend to be greater (less negative; intercept ~ 8.3) than SWP-pc for the midday SWP range considered, as also shown in Figure 4. In nectarines, this linear relationship showed a slope of ~ 1 , but the intercept was smaller than in olive, indicating less difference between the two measurements [10].

In pear, when using the midday measurements the relationship had a slope of ~ 1 , while, for the same crop, in the afternoon the difference grew, with SWP-pc showing lower values than TWP-mt [9]. Nectarines, pear, and almonds are species with a different capacity to respond to water stress with respect to olive [13,18], for example, olive tree can reach levels of -7 MPa in some environments [19].



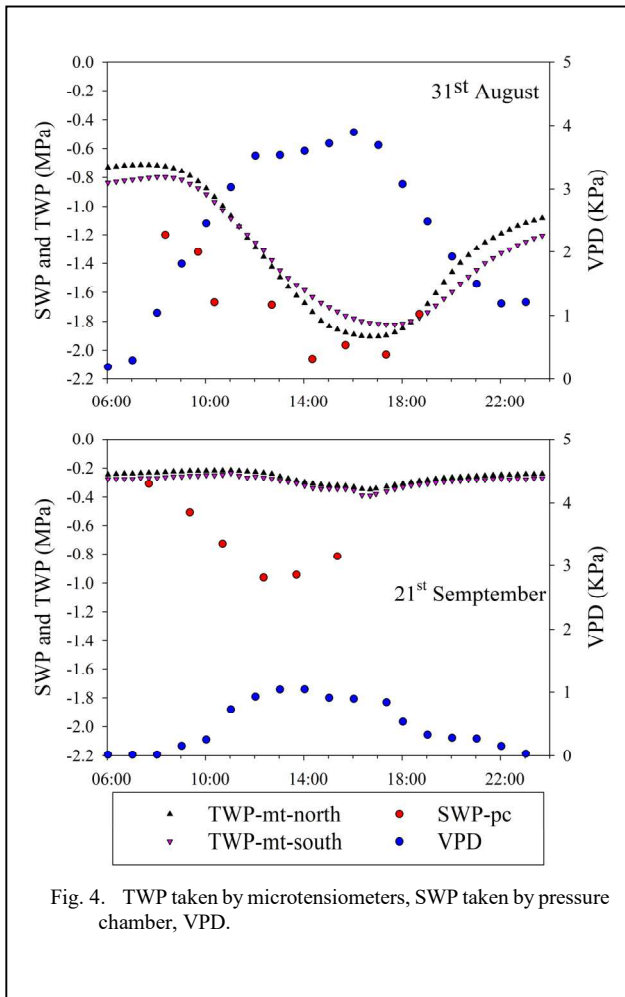


Fig. 4. TWP taken by microtensiometers, SWP taken by pressure chamber, VPD.

IV. CONCLUSION

The microtensiometers were effective in tracking tree water status in olive; nonetheless, they are expensive, and it is not possible for a farmer to set up a fleet of them to have a representative status in heterogeneous fields. These arguments make it important to supplement microtensiometers with mapping tools (ET stations, satellite maps, drones, etc.). In addition, future studies should shed light on the effect of installation point within the tree and on the relation of absolute values of TWP-mt with manual measurements of SWP-pc since we didn't find complete agreements between the two. This study demonstrates that having continuous information of water stress allows to extrapolate multiple parameters that can give larger information on water stress than a single timepoint, which can be key to implement more efficient irrigation in the future.

Further studies are necessary to understand the impact of physiological and environmental factors on microtensiometer readings, and to develop irrigation guidelines based on those readings. .

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