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Brief Communication

Precision irrigation in Almonds based on plant water status

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Abstract

The irrigation can to increase the yield agricultural crops. The conventional method to determinate the quantity and depth water available uses moisture sensors that considers, basically, the soil features. The objective of this study was evaluate the irrigate in almonds orchard, based on real-time plant water status as estimated by a wireless network of these continuous leaf monitors, comparing with results obtained by grower practice, using soil moisture sensors. The irrigation system that used management in real-time resulted in reduction around 70% of the water applied compared to ET, and 85% of water applied compared to grower practice which used soil moisture sensors.

Keywords: Precision Irrigation, Plant Transpiration, Water Management

Precision irrigation or variable rate irrigation has the potential to conserve water by increasing water use efficiency and water productivity. For orchard and vineyard crops, which have extensive root systems, soil moisture content measured at shallow depths may not adequately represent total water available to the plants.

Plant water status is believed to be a good indicator of irrigation needs of trees and vines (Dhillon et al., 2014). A pressure chamber is often used to measure plant water status. While this device is considered as the standard to measure plant water status, it is time consuming and tedious to use and measurements must be done around solar noon, when California's Central valley temperature can exceed about 38° C. Udompetaikul (2012) and Dhillon et al. (2014) developed a sensor suite to measure plant water status using a suite of sensors that included a thermal IR sensor to measure leaf temperature, and sensors to measure air temperature, relative humidity, incident radiation, and wind speed.

They conducted extensive field tests in almond, walnut and grape crops and showed that this sensor suite can successfully predict plant water status. Dhillon (2015) and Dhillon et al. (2017) further developed this system to continuously monitor plant water status and interfaced it to a wireless mesh network so that data can be uploaded to the web and made available on a personal computer or a handheld device.

This version of the sensor was called a continuous leaf monitor. This system could not only monitor the system, but also could control latching solenoid valves through the same wireless mesh network to implement precision irrigation. The objective of this study was to irrigate orchard crops based on real-time plant water status as estimated by a wireless network of these continuous leaf monitors.

To accomplish this objective, two management zones were created based on spatial variability in soil (texture, electrical conductivity (EC) at two different depths, and digital elevation) and plant (light interception and canopy temperature) characteristics

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in an almond orchard in Arbuckle, CA (Nickels Soil Lab) as shown in Figure 1 (Kizer, 2017; Kizer et al., 2017; Upadhyaya et al., 2017). These management zones are considered stable over the years as they are primarily based on static characteristics of the soil. Within each management zone, both conventional grower treatment and plant water status based precision irrigation management were implemented.

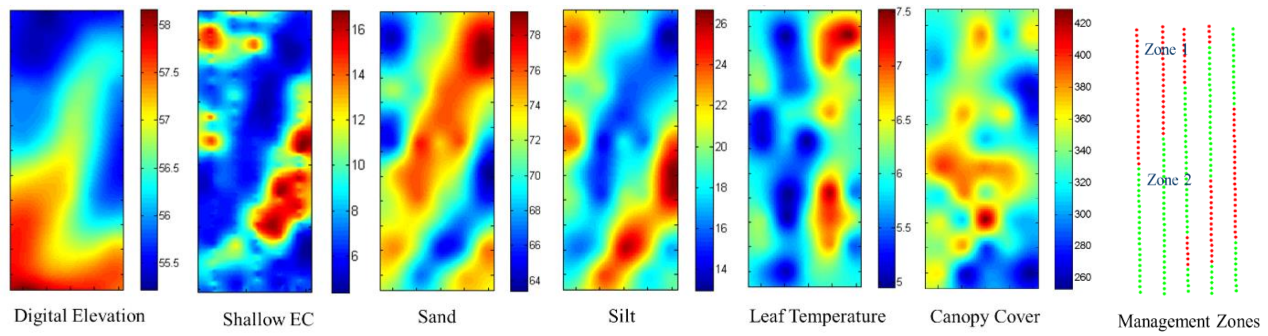

Fig. 1. From left to right: Krigged maps of (a) digital elevation, (b) shallow EC, (c) sand, (d) silt, (e) leaf temperature and (f) canopy cover, and (g) classification result for the almond plot in Nickels Soil Lab, Arbuckle, CA.

The continuous leaf monitor measured the leaf temperatures (both the leaf of interest and simulated dry leaf), ambient temperature and relative humidity, incident solar radiation, and wind speed to estimate plant water status (Figure 2a).

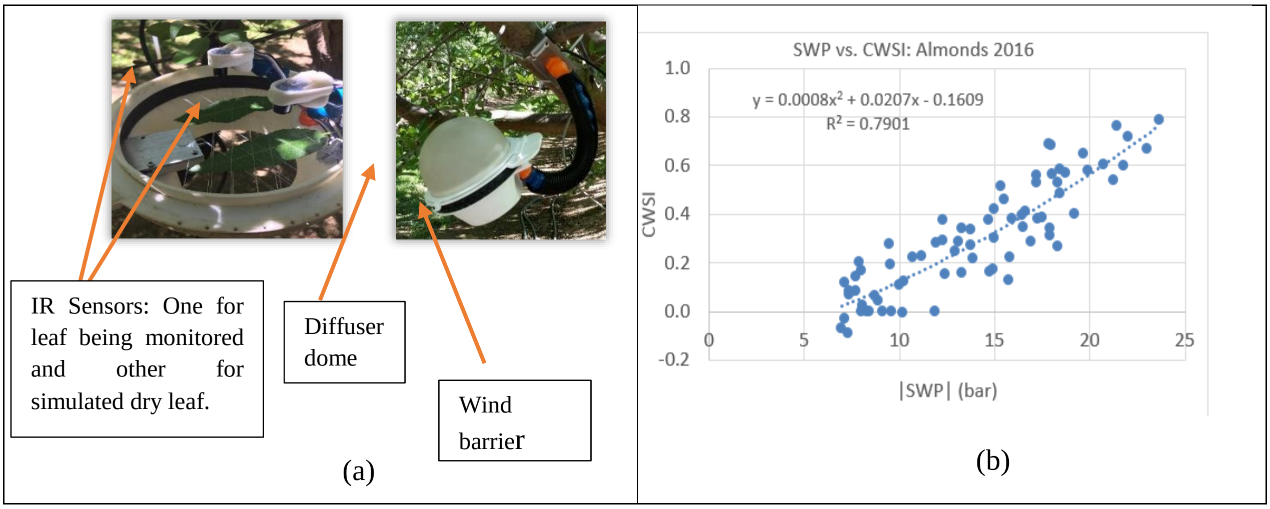

Fig. 2. (a) A leaf monitor mounted on an almond tree and (b) response of the leaf monitor to plant water stress during pre-hull split and hull split period.

The continuous leaf monitors, soil moisture sensors, pressure sensors (to detect the pressure in irrigation lines), and latching solenoid valves (to turn on and off irrigation lines) were all connected to nodes which formed a wireless network.

The sensor information was accessed remotely through PCs or mobile devices. Plant water status of selected trees were estimated by comparing the performance of those trees with respect to a well-watered tree and a simulated dry leaf (i.e., a leaf with a broken stem).

The results were presented as daily crop water stress index (CWSI) values that were then related to the stem water potential measured using a pressure chamber (Figure 2b).

The CWSI values were strongly correlated to the stem water potential with a coefficient of multiple determination value (R2 value) of about 0.79 for the 2016 growing season during the pre- hull split and hull-split period. Figure 3a displays the temperature patterns of a well-watered tree (green curve), simulated dry leaf (red curve) and a tree being monitored (blue curve).

Corresponding CWSI values are shown in Figure 3b. The relationship between CWSI and SWP was not as robust when post-hull split data were included, perhaps due to acclimatization, aging or some other unknown issues.

Precision irrigation management based on plant water stress was implemented throughout the 2016 growing season. Attempts were made to control PWS level at about -13 bar during the pre- as well as post-hull split period and at about -16 bar during the hull split period as shown in Figure 4a. During the 2016 growing season CWSI values were used as the indicator for stress management. However, when CWSI values indicated high stress levels, actual SWP measurements were taken (just to be sure) before irrigation management decisions were implemented. Figure 4b shows the cumulative amount of water applied to each zone in PWS based treatments and in the grower treatment. This PWS based variable rate irrigation management practice resulted in 70% of the water applied compared to ET and 85% of water applied compared to grower practice which used soil moisture sensors.

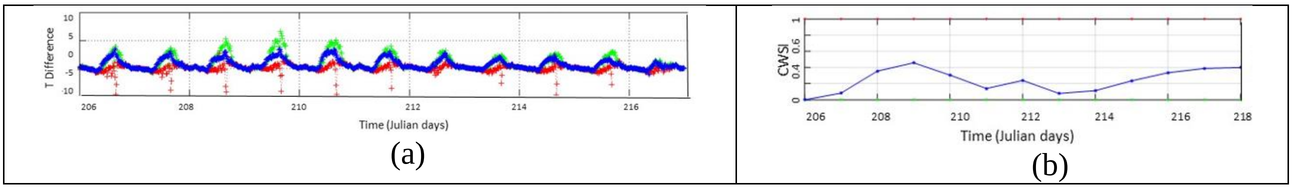

Fig. 3. Continuous leaf monitor data - (a) Display of temperature difference between the ambient and the leaf for a well-watered (green), simulated dry (red), and monitored tree (blue), (b) Computed daily CWSI values.

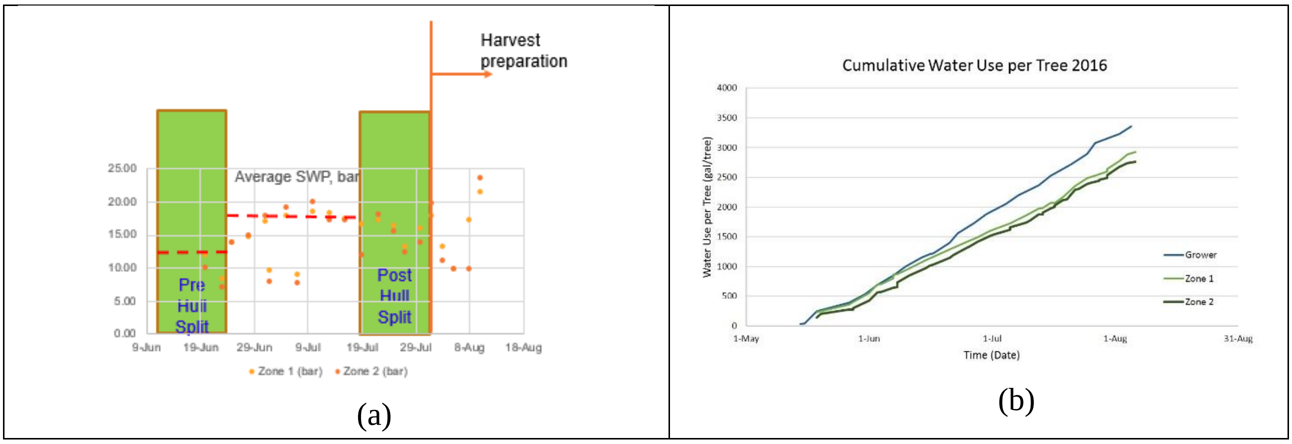

Fig. 4. (a) Management of plant water stress in both zones during the hull split period as well as pre- and post- hull split period but before harvest preparation, and (b) cumulative water application in stress based and grower treatments.

The crop yield and quality attributes such as mass per 50 kernels, size (length, width, and height) and percentage mold were not significantly different between PWS based precision irrigation and grower practice (Kizer et al., 2017; Upadhyaya et al., 2017). The study has been repeated during the 2017 growing season in an effort to obtain additional data to verify the benefits of plant water stress based precision irrigation and develop more robust stress indicators from leaf monitor data that adequately address issues related to acclimatization, age etc. This data is currently being analyzed.

Conflict of interest: All authors declare no conflict of interest.

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