Plant-Based Measures of Water Stress for Irrigation Management in Multiple Almond Varieties

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Background:
Accurate and timely irrigation management is a key to both successful almond production and appropriate environmental stewardship, especially in times of protracted water shortages. In recent years, in deciding when and how best to irrigate, growers have relied increasingly on gauging the trees' level of water stress by using a pressure chamber (the "bomb") to measure midday stem water potential (SWP). Although this method is reliable, one drawback is that it requires time and labor, and is not amenable to automation. It is also important to determine whether there are varietal differences in SWP under the same orchard environment conditions, and whether the SWP corresponding to tree stress is the same or different in all varieties.

Objectives:
- Determine whether different almond varieties exhibit differences in midday stem water potential (SWP) across a range of soil and orchard conditions.
- Determine whether there are differences in response to water stress among selected almond varieties, and whether any observed differences are related to inherent physiological differences among the varieties.
- Determine whether there is a reliable and consistent relationship between SWP and other candidate plant-based and soil-based measures of water stress, particularly those that can be automated.

Results and discussion:
Similar to previous findings, given the same environmental conditions, differences between almond varieties does not appear to be substantial. Figure 1 shows a comparison between Nonpareil and Monterey varieties in northern and southern counties during 2012, and while there is a trend for a larger difference as SWP declines to relatively low levels (-20 to -30 bars), for most of the range the SWP, values are very similar in the two varieties. The somewhat lower SWP for Monterey under stress conditions may be indicating an interesting difference in drought resistance between Monterey and Nonpareil, and this will be investigated further.

A major effort was undertaken to evaluate the reliability of a commercially available psychrometer for the automated measurement of SWP in almonds. Initial results obtained in 2011 were promising in terms of the apparent reliability of the data (reasonable daily patterns and in some cases close agreement with the pressure chamber), although good agreement with the pressure chamber was not always obtained. Figure 2 shows a description of the process of sealing the psychrometer to the leaf surface, and the steps required to insulate the psychrometer against rapid fluctuations in temperature. The insulation we have developed is rather bulky, but no other method tried to date has given an acceptable level of temperature stability.

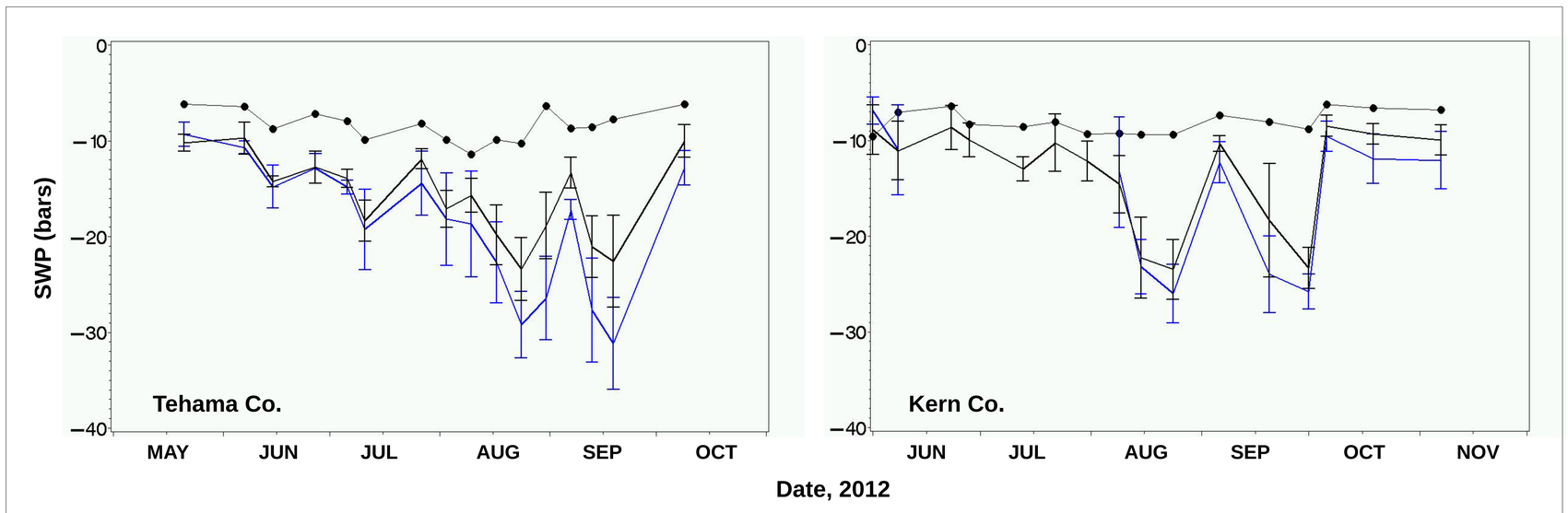


Figure 1. Comparison between Nonpareil (black line) and Monterey (blue line) SWP in commercial orchards at two locations. Also shown are the baseline values for the dates and times of sampling.

Figure 2. Steps in the process of sealing an in-situ psychrometer to an almond leaf. The chrome face of the psychrometer must be lined with a thin strip of non-toxic silicone grease (1 and 2), then placed in an aluminum block, which fixes the psychrometer against the leaf (3 and 4). The leaf surface in the area covered by the psychrometer must be gently abraded in order to have good vapor exchange between the leaf and the psychrometer (not shown). The psychrometer and attached leaf are enclosed in metal cans which dampen thermal fluctuations (5 and 6), which are relatively bulky and must be supported by clamping to a nearby scaffold (7). During the insulation assembly, it is critical that the leaf is not disturbed with sufficient force to disturb the psychrometer/leaf seal or damage the leaf or leaf/stem connection.

Figure 3 shows the basic design of the psychrometer, and figure 4 illustrates the good agreement generally found between the psychrometer measurement of SWP and the pressure chamber measurement of SWP. Since the SWP measured with the pressure chamber on different leaves of the same tree are generally within about 0.2 bar , It was expected that two psychrometers would also agree to this extent, and in some cases this was found (figure 5, top). However, there were occasions in which psychrometers agreed closely over a particular day (figure 5, September 4-5), but diverged over time (figure 5, September 6-10), with no obvious differences that might indicate an artifact, such as differences in psychrometer temperature (figure 5). A change to the surface of the leaf, such as spreading of the silicone grease, could cause artifactually low apparent SWP, but if artifacts of this magnitude (5 bar) do occur, then the psychrometer will not be reliable enough for irrigation scheduling in almonds.

Conclusions:
No firm conclusions about the reliability of the psychrometer can be made at this time. Since the physical principle of measurement in the psychrometer and pressure chamber are entirely different, it is likely that the good agreement found on some occasions indicates that the psychrometer approach is sound, and that such disagreement as shown in figure 5 indicates the presence of an artifact. We are currently performing additional experiments to determine the possible source(s) of this artifact.

Figure 3. Schematic diagram of a thermocouple psychrometer, used to measure SWP automatically. The lower chrome plated surface of the psychrometer is sealed against a leaf or stem, creating a small chamber above the tissue, and a data logger measures the relative humidity of the chamber every 10 - 30 minutes using a thin wire thermocouple junction. Maintaining a clean junction, and a uniform temperature throughout the psychrometer, are critical to obtain accurate data.

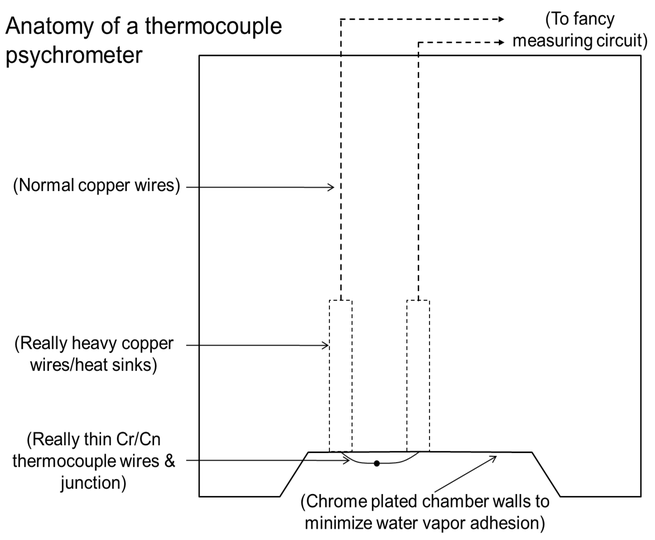
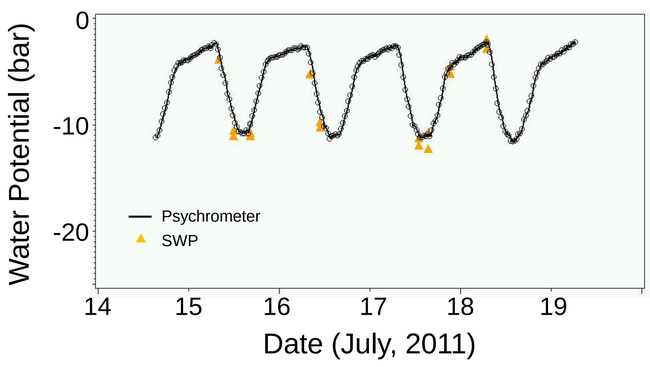


Figure 4. Example of automated measurements of SWP on a cherry tree in the field using the psychrometer, and periodic measurements of SWP on the same tree with the pressure bomb.



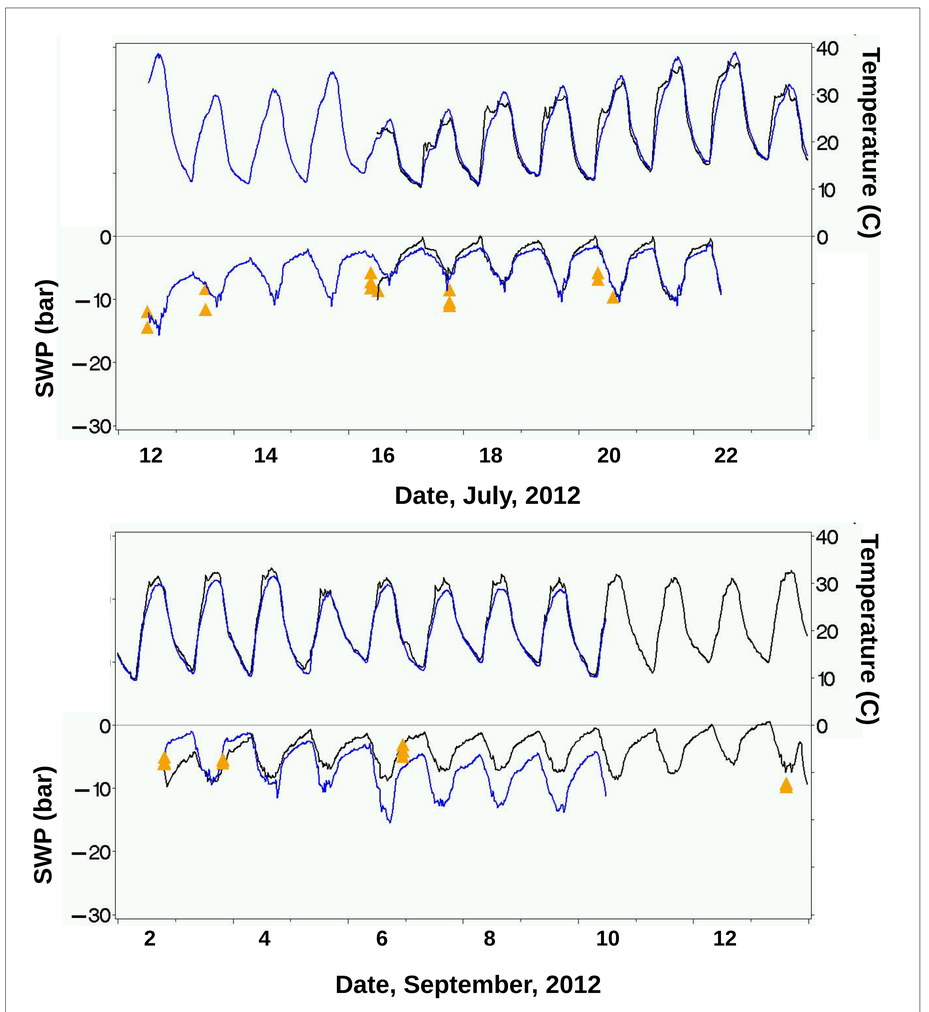


Figure5. Examples of good agreement (top) and poor agreement (bottom) for two psychrometers (blue line and black line) measuring the same almond tree. Also shown are the respective temperatures of the two psychrometers, and periodic SWP measurements (triangles) made with a pressure chamber on the same tree.