Plant-based measures of water stress for irrigation management in multiple almond varieties

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Objectives:

1) **To determine whether varietal differences in SWP occur across a range of soil and orchard conditions**
2) **To determine whether varietal differences in water stress responses occur, and to what extent any of the observed differences are related to inherent physiological differences between varieties.**
3) **To determine whether there is a reliable and consistent relation between SWP and other candidate plant-and soil-based measures of stress, particularly those that can be automated.**

Introduction (objective #3)

Over the last 5-10 years, the pressure chamber measurement of midday stem water potential (SWP) has become the standard for measurement of water stress in almonds, but this method requires special equipment, technically trained labor, and is currently not possible to automate. A number of alternative plant- and soil-based methods have been developed for measuring water stress, some of which are automated and being sold commercially for the purpose of automated or semi-automated irrigation scheduling. This study was developed to test a number of alternative methods in almond, and the focus of this poster will be on the Phytogram sensor and the technique of (micro) dendrometry.

Figure 1. Phytogram sensor for automated and continuous measurement of sapwood water content, installed in the tree trunk.

Results (Phytogram)

Phytogram sensors were installed by the manufacturer into the trunks of 15 Nonpareil trees in a single row of the test orchard in early February (Figure 1). Sapwood water content and irrigation on/off status was measured every 30 minutes from that time until the equipment was damaged in mid-September. In late February, prior to bloom, there was a marked increase in sapwood water content, and marked increases and decreases in water content until early May, when SWP measurements began (Figure 2). From May through September there was a gradual decline in both water content and SWP, and there was an overall positive correlation between SWP and moisture content (Figure 3).

Even though there was a correlation between SWP and moisture content over the long term (Figure 3), there was no clear relation between these values for a number of short-term experiments. For instance, following an irrigation in early July, SWP had not recovered to baseline values, and the grower substantially increased irrigation during July (irrigations shown at the base of Figure 4). This resulted in a gradual increase in SWP and an approach to baseline SWP values over this period, but a gradual decline or no clear change in sapwood water content at this time (Figure 4).

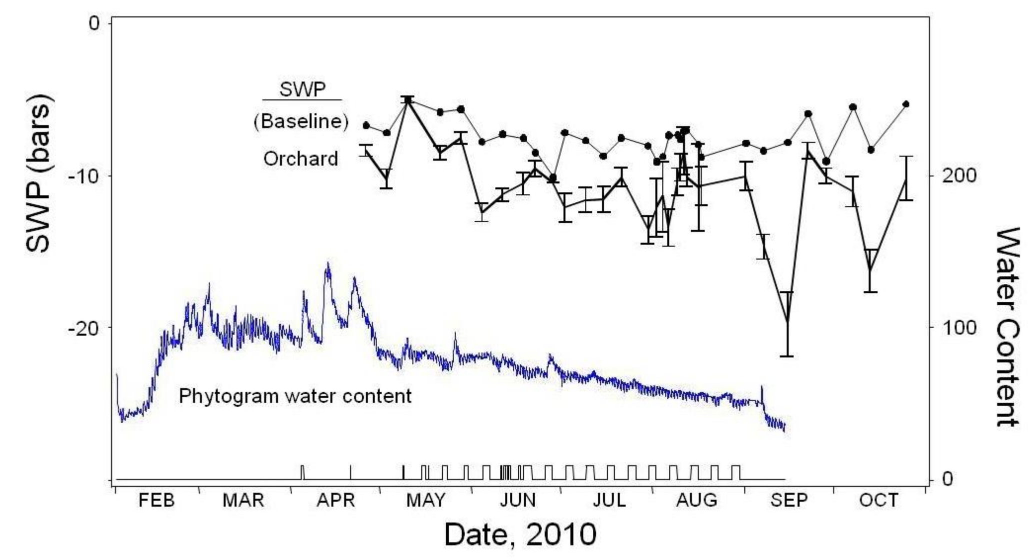

Figure 2. Water content (purple line, right axis), and baseline and orchard SWP values (upper lines, left axis) over the season in 2010. Also shown are irrigation events, logged by the phytogram system (lowest line).

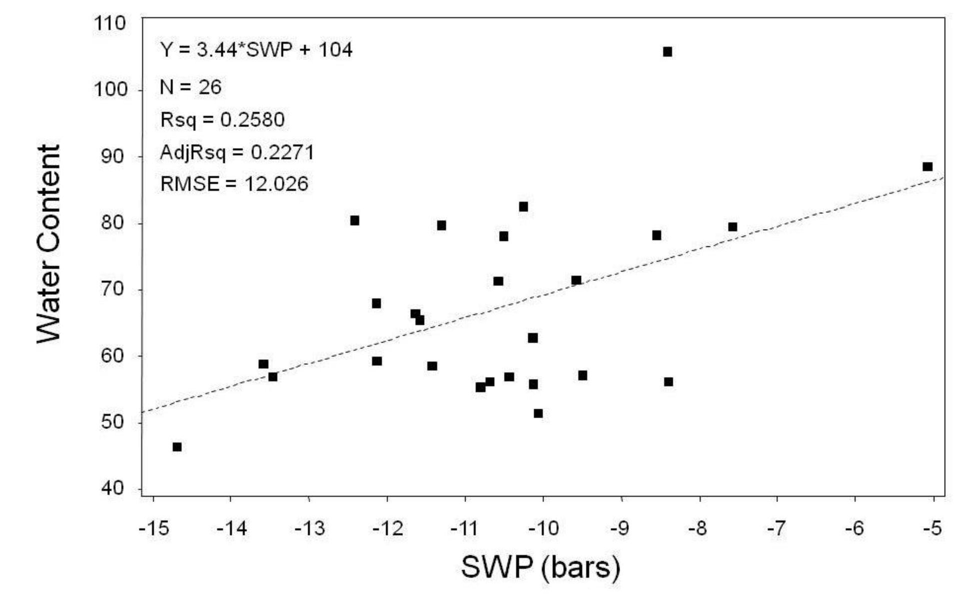

Figure 3. Correlation of all SWP and water content values shown in Figure 2.

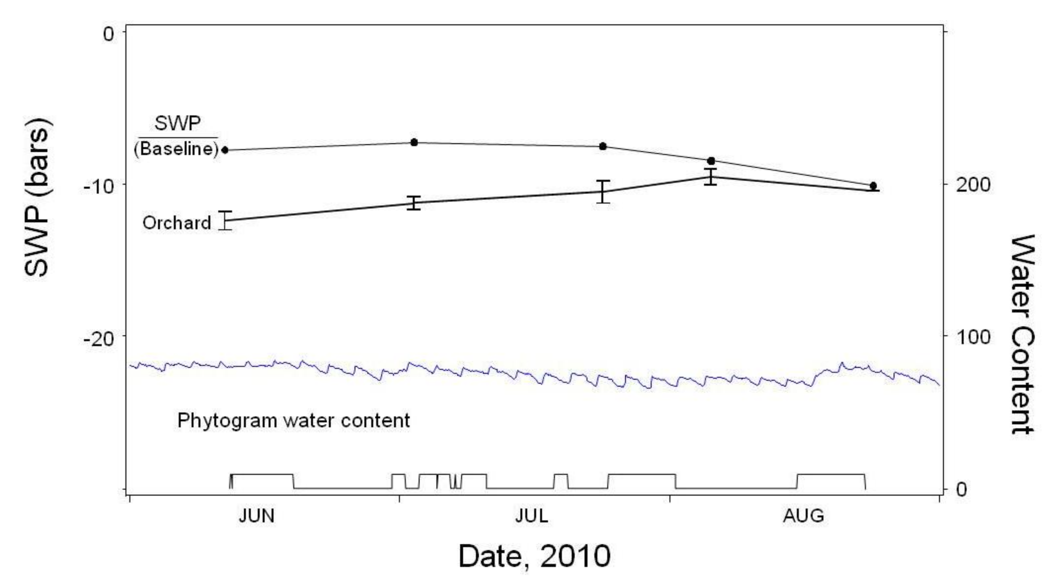

Figure 4. Detail of the data shown in Figure 2, showing the multiple irrigations that were used to successfully increase SWP, but which were not detected by the phytogram

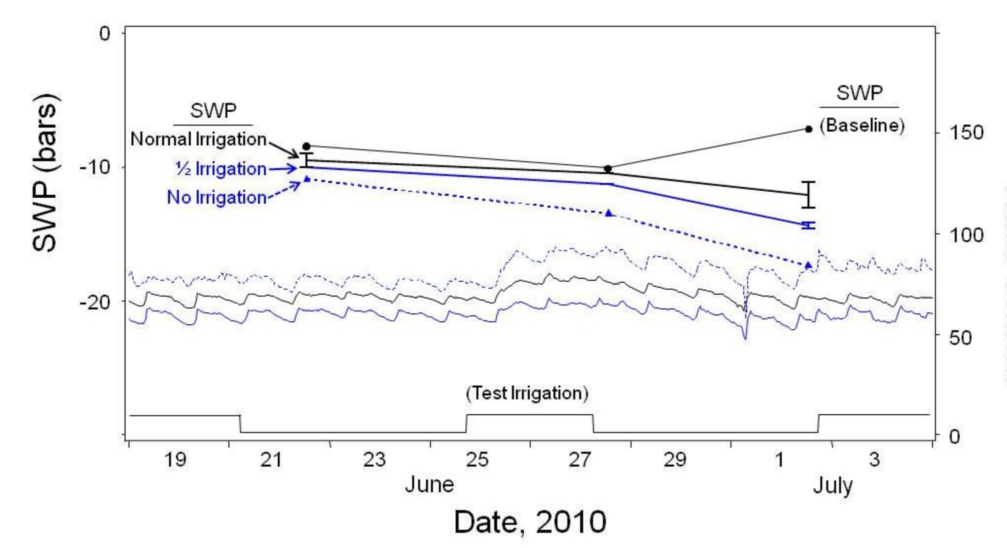

Figure 5. First water cutoff experiment in which no irrigation was applied to a single tree and only ½ irrigation was applied to two adjacent trees in order to test the responsiveness of SWP and the phytogram. The response in SWP was in the order expected, with lower SWP corresponding to less irrigation applied, but the response in the phytogram was not.

Two additional irrigation cutoff experiments were performed on individual trees or groups of trees between mid-June and mid-August. In these experiments, irrigation was discontinued for one cycle for 1-2 target trees, half irrigation was applied to adjacent trees, and normal irrigation applied to the rest of the trees, and all trees were separately monitored for water content and SWP. In both experiments the same results were obtained: full cutoff trees had the lowest SWP, full irrigation trees the highest, and half cutoff were intermediate, but there was no clear pattern in sapwood water content (Figures 5 and 6).

Conclusions (Phytogram): Sapwood water content responded well to the physiological changes that are known to occur in many deciduous trees at the end of dormancy (refilling of xylem by root/stem pressure), and also to the gradual seasonal change in SWP, but did not respond well to irrigation events or irrigation cutoff. This limited response may limit the application of this technology for the purpose of short-term irrigation management, but in view of the overall correlation observed, more research will be needed to make this evaluation.

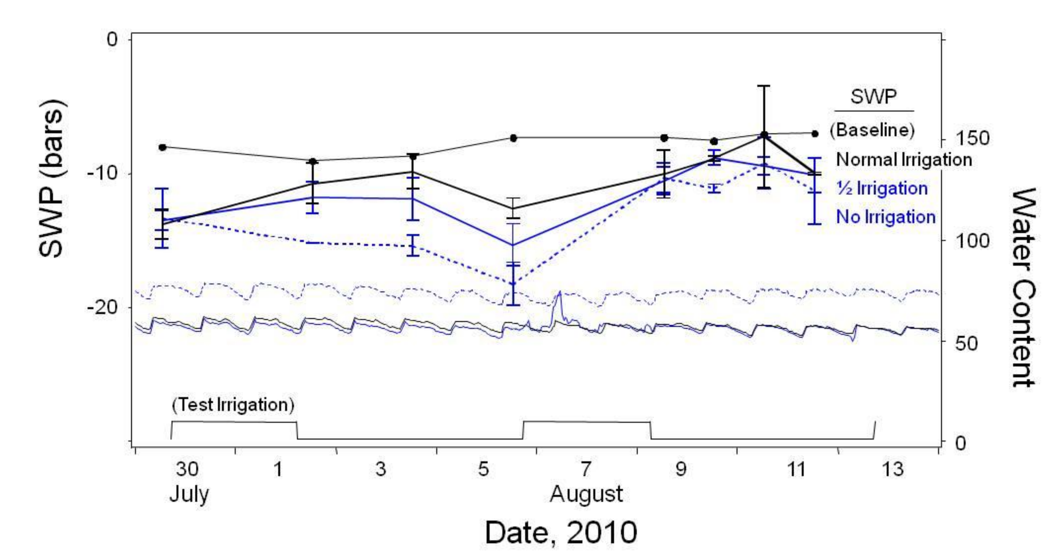

Figure 6. Second water cutoff experiment in which no irrigation was applied to two trees and ½ irrigation was applied to four adjacent trees, as in Figure 5. Similar results to the first cutoff experiment were obtained.

Results (dendrometer)

Figure 7. (Micro) dendrometer attached to a primary scaffold.

Lab-made dendrometers were attached to 4 scaffolds of a single test tree in the irrigation plot (Figure 7). This tree was one of the cutoff test trees that was being monitored by phytogram sensors. Three of the 4 dendrometers functioned properly, and all three showed the same daily pattern, so their readings were averaged. The dendrometer readings showed very clear daily patterns of swelling (growth) at night and shrinkage during the day (Figure 8), as has been found in other studies. Dendrometer readings were also very sensitive to individual irrigation events, showing increased growth and decreased shrinkage after each irrigaiton (Figure 8). The value of midday shrinkage (MDS) has been suggested as an accurate plant-based measure of stress in trees, and this measure was found to have a clear response to irrigation events (Figure 9), but a very poor correlation to SWP (Figure 10). Some of the lack of correlation shown in Figure 10 may be due to the limited set of SWP that was available for this comparison, although the range in SWP observed (-11 to -18 bars) should have been adequate for a reliable comparison. Daily growth has also been suggested as an appropriate plant-based measure of stress, and, as for MDS, there were clear increases in growth following irrigation events (Figure 11), but a poor correlation to SWP (data not shown).

Conclusions (dendrometer): As found in previous studies, relatively low cost dendrometers were able to reliably track short term changes in scaffold size, and many of these changes were clearly influenced by irrigation events. However, neither MDS nor daily growth appeared well enough correlated to SWP to substitute for SWP. In view of the sensitivity to irrigation and relatively low cost of the sensor however, more research into this technology is warranted.

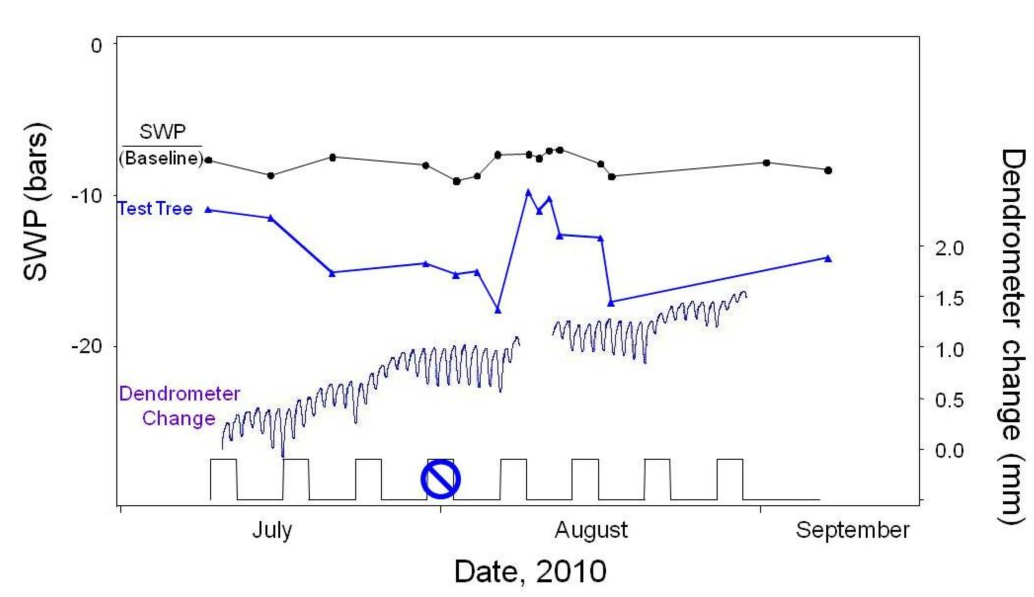

Figure 8. Dendrometer change (purple line, right axis), and baseline and SWP values (upper lines, left axis) for the single test tree that was instrumented in 2010. Also shown are irrigation events, logged by the phytogram system (lowest line). For this tree, the indicated irrigation over August 1, 2010, was skipped.

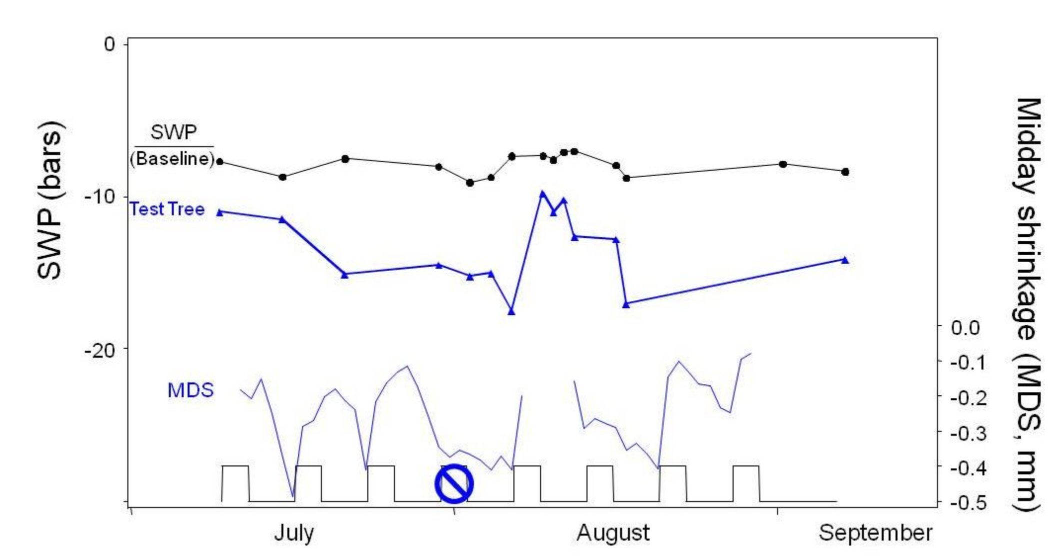

Figure 9. Baseline and tree SWP, and irrigations, as shown in Figure 8, with the corresponding daily values of midday shrinkage (MDS, Purple line, right axis) recorded by the dendrometer.

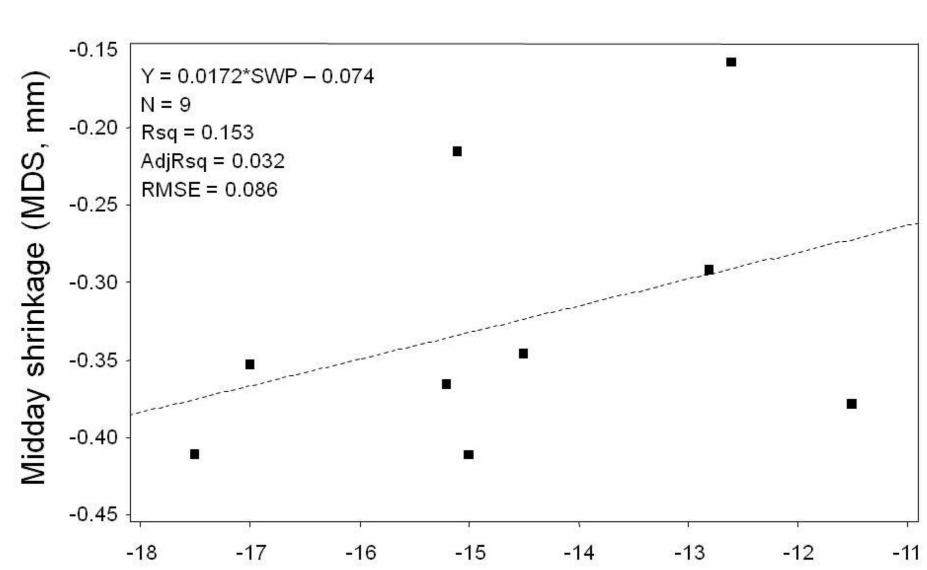

Figure 10. Lack of correlation between SWP and dendrometer midday shrinkage (MDS).

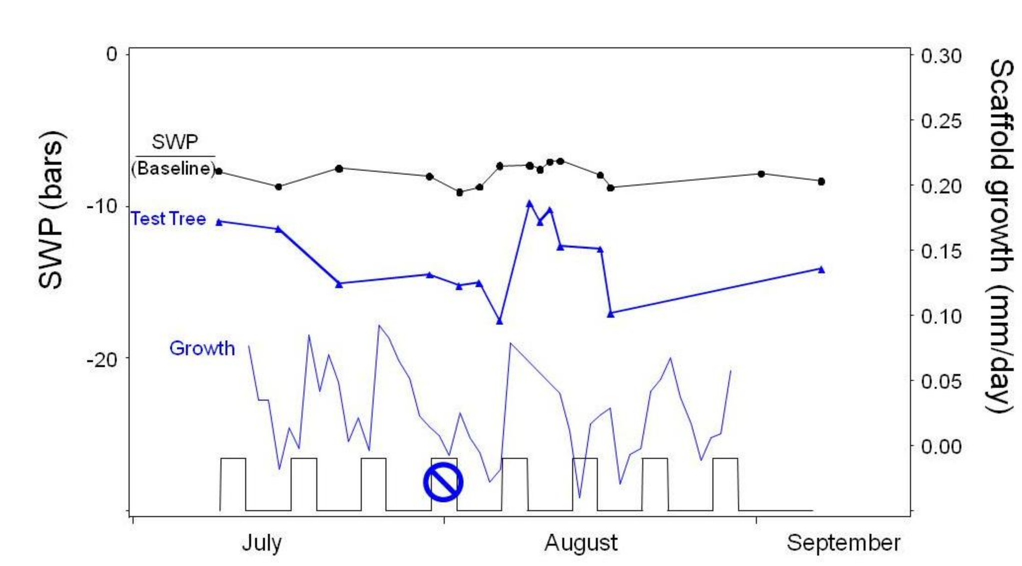

Figure 11. SWP and irrigations as shown in Figure 9, with the corresponding daily values of scaffold growth (right axis) recorded by the dendrometer.