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

Project No.: **10-HORT9-Shackel**

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Objectives:

1) To determine whether varietal differences in stem water potential (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.

Interpretive Summary:

Across four locations and multiple dates, blocks, and conditions, the midday stem water potential (SWP) of Almond varieties Nonpareil, Carmel, Fritz, Butte, and Monterey were measured to determine whether there any consistent varietal differences occurred which might be related to the relative drought resistance of these varieties, or indicate the need to establish different “baseline” values for each variety. Nonpareil was present at each location, and at two locations there were statistically significant varietal differences, but the differences in SWP between varieties was always very small (typically less than 0.5 bar). These data indicate that the same baseline may be adequate for all varieties, and that over the range of conditions tested (SWP values to -3 MPa) there appear to be no clear varietal differences in SWP. Two automated methods, the “Phytogram” sensor and dendrometers, were tested for their sensitivity to changes in SWP. The phytogram sensor 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. Dendrometers were able to reliably track short term changes in scaffold size, and many of these changes were

clearly influenced by irrigation events, but not reliably enough to be used as a substitute for SWP. Neither method appears suitable as a substitute for SWP.

Materials and Methods:

The pressure chamber method was used to measure midday stem water potential (SWP) in the following 4 sites (varieties tested): Livingston (Nonpareil, Fritz), LeGrand (Nonpareil, Monterey, Carmel), Merced (Nonpareil, Carmel), and Parlier (Nonpareil, Butte, Carmel). At the Merced site, 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 addition to monitoring the normal irrigation cycles and irrigation cutoff for harvest, two 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. On one of the cutoff trees with a Phytogram sensor, lab-made dendrometers were also attached to 4 main scaffolds (**Figure 2**) and 10-minute average readings were recorded for the duration of the experiment.

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

Results and Discussion:

Varietal tests. Over a wide range of sites and conditions, there was surprising similarity in the SWP of different almond varieties (**Table 1**). As expected, the seasonal maximum (wettest) SWP did not vary from site to site, because weather conditions are similar and hence this value would be largely determined by the maximum baseline value. However, the minimum (driest) SWP did vary from site to site (**Table 1**), presumably reflecting differences in irrigation management. In

Figure 2. (Micro) dendrometer attached to a primary scaffold.

most cases the differences between varieties were very small (0.5 bar), and even in the case of the largest difference (Livingston), the value of the difference was not large: 1.18 bar (**Table 1**). In three of the four locations, the block effect (ANOVA portion of **Table 1**) was highly to very highly significant, indicating that there is a significant spatial variation of tree stress in these orchards. Whereas variety differences were typically on the order of 0.5 bar (**Table 1**), block differences were typically greater than 2 bars, with one site (LeGrand) showing differences between blocks of 6 bars (data not shown).

Table 1. Summary of variety comparison SWP measurements conducted at 4 sites in 2010. For Average SWP values, means followed by different letters are different at the level of probability shown in the last column for the variety (VAR) source.

site	Seasonal SWP range (bar)	variety	Average SWP (bar)		ANOVA				
					source	DF	MS	F	Probability
Livingston	-4 to -26	Nonpareil	-9.77 a		VAR	1	12.4	306	0.0033
		Fritz	-10.95 b		Block	2	18.7	461	0.0022
					VXB (err)	2	0.04		
LeGrand	-7 to -34	Monterey	-13.6		VAR	2	1.56	0.26	0.78
		Nonpareil	-13.8		Block	2	180	30.55	0.004
		Carmel	-14.1		VXB (err)	4	5.9		
Merced	-5 to -20	Nonpareil	-11.1		VAR	1	0.06	0.05	0.85
		Carmel	-11.2		Block	2	2.91	2.2	0.31
					VXB (err)	2	1.32		
Parlier	-7 to -15	Carmel	-10.5 a		VAR	2	1.38	8.85	0.0061
		Butte	-10.9 b		Block	5	7.64	49.05	>0.001
		Nonpareil	-11.0 b		VXB (err)	10	0.16		

Phytogram sensors. 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 3**). 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 4**). 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 5**). 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 5**). 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 6 and 7**).

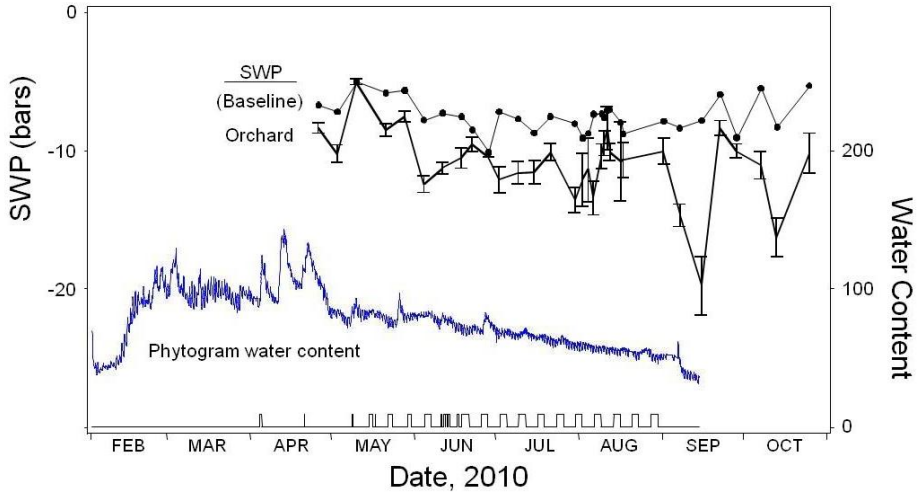

Figure 3. Water content (purple line, right axis), and baseline and orchard SWP values (upper lines, left axis) over the season in 2010. Also shown are irrigation events, logged by the phytogram system (lowest line).

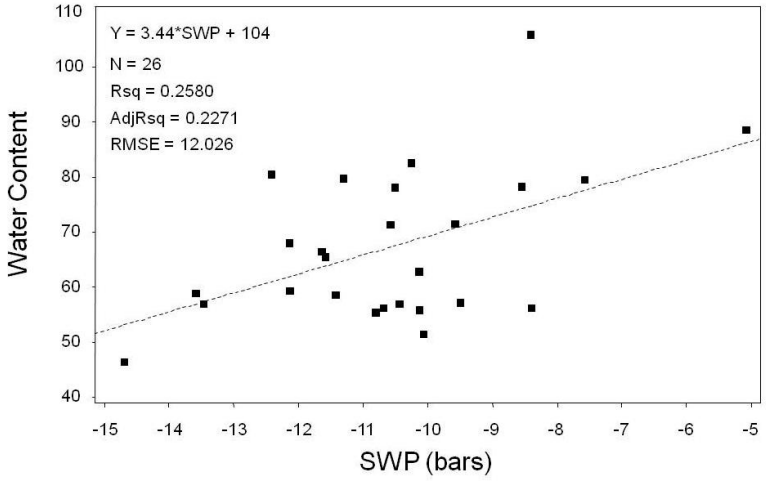

Figure 4. Correlation of all SWP and water content values shown in Figure 3.

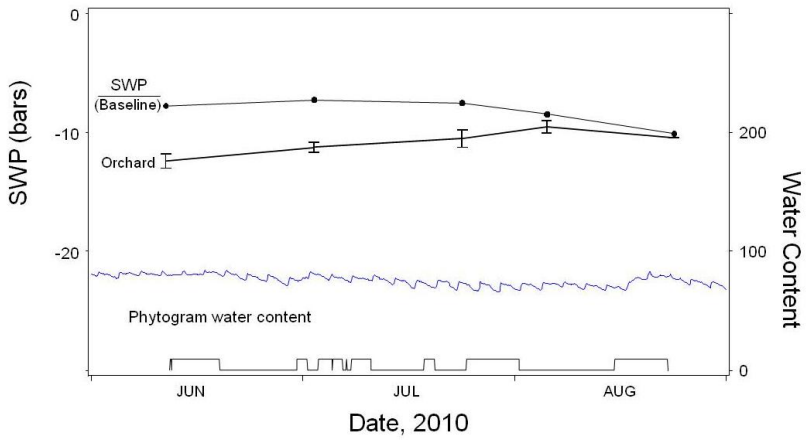

Figure 5. Detail of the data shown in Figure 3, showing the multiple irrigations that were used to successfully increase SWP, but which were not detected by the phytogram

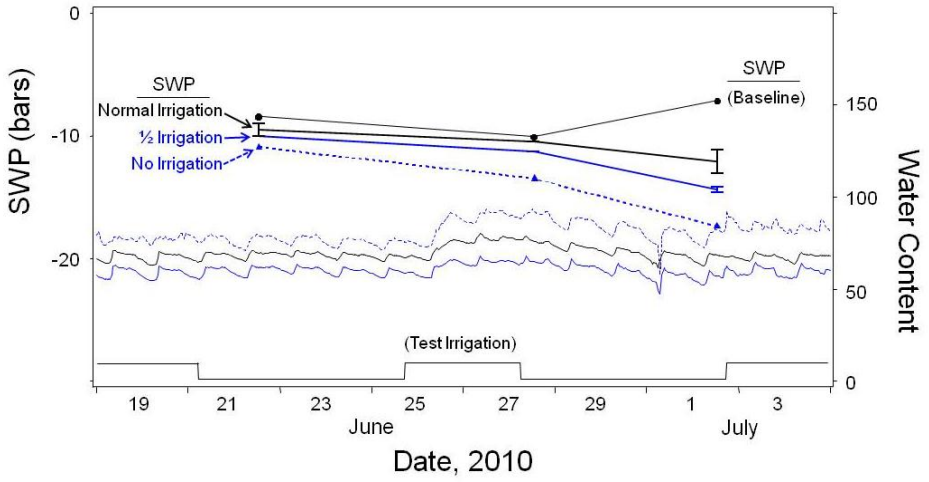

Figure 6. First water cutoff experiment in which no irrigation was applied to a single tree and only ½ irrigation was applied to two adjacent trees in order to test the responsiveness of SWP and the phytogram. The response in SWP was in the order expected, with lower SWP corresponding to less irrigation applied, but the response in the phytogram was not.

Dendrometers. 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 irrigation (**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 values used for the 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).

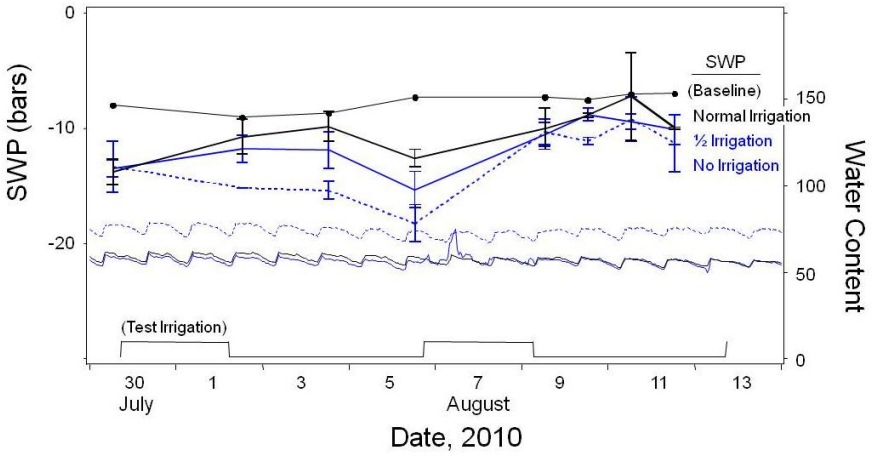

Figure 7. Second water cutoff experiment in which no irrigation was applied to two trees and ½ irrigation was applied to four adjacent trees, as in Figure 5. Similar results to the first cutoff experiment were obtained.

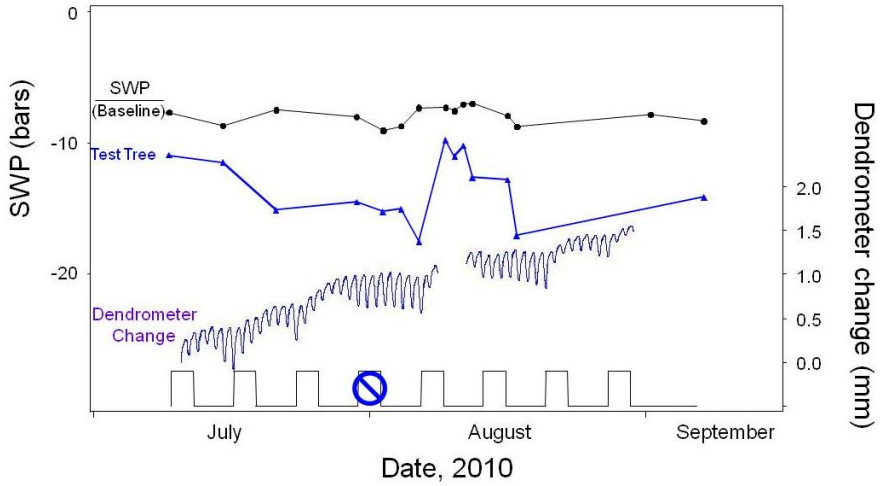

Figure 8. Dendrometer change (purple line, right axis), and baseline and SWP values (upper lines, left axis) for the single test tree that was instrumented in 2010. Also shown are irrigation events, logged by the phytogram system (lowest line). For this tree, the indicated irrigation over August 1, 2010,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

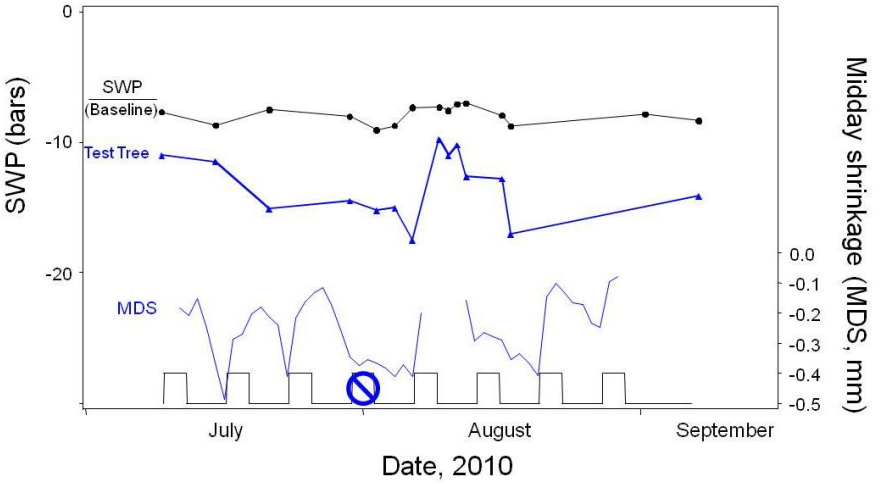

Figure 9. Baseline and tree SWP, and irrigations, as shown in **Figure 8,** with the corresponding daily values of midday shrinkage (MDS, Purple line, right axis) recorded by the dendrometer.

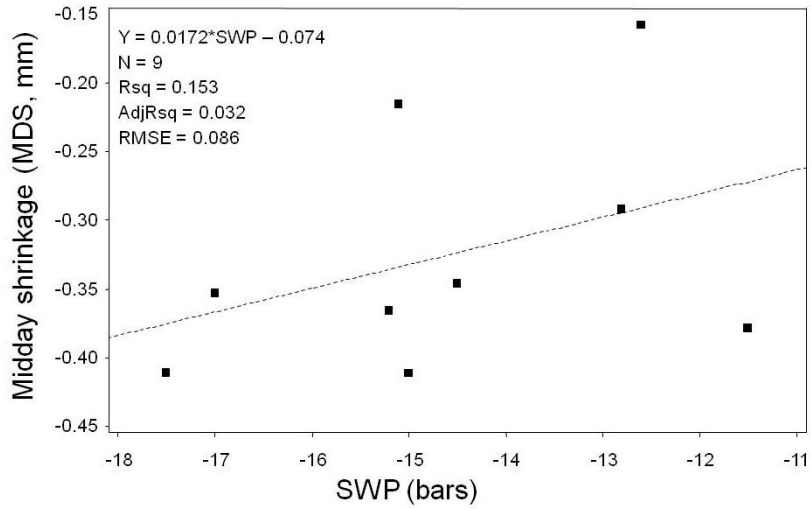

Figure 10. Lack of correlation between SWP and dendrometer midday shrinkage (MDS).

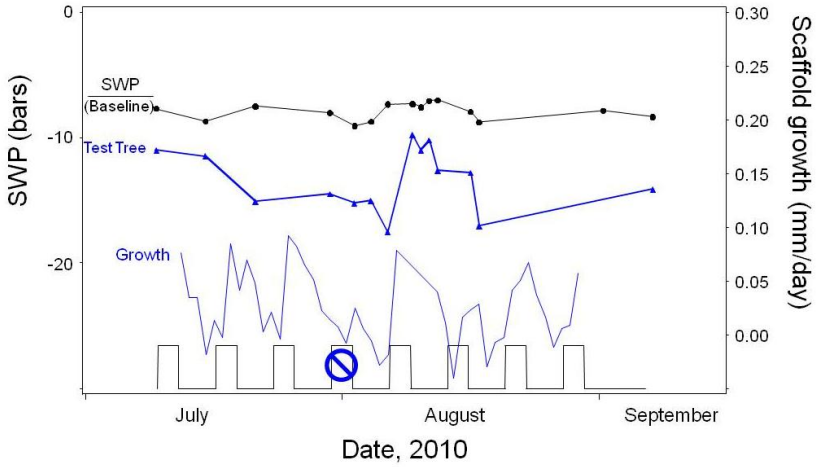

Figure 11. SWP and irrigations as shown in Figure 9, with the corresponding daily values of scaffold growth (right axis) recorded by the dendrometer.

Research Effort Recent Publications:

(None for this project)

References Cited:

(None)