Fertigation: Interaction of Water and Nutrient Management in Almonds

Project No.: **09-HORT11-Shackel/Sanden**

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Objectives:

The primary objective of this study is to document the amount of water applied to the experimental plots of the Patrick Brown fertigation study (including the collection of data related to ETc), and to monitor the effects of the grower's irrigation management on tree Stem Water Potential (SWP) at these sites. At one site (Belridge), more detailed measurements of soil moisture and evapotranspiration (ET) are made and will be reported separately by Blake Sanden. We anticipate that the SWP data will serve as an important covariate in statistical analyses of the Brown study data, particularly any recommendations based on the relation of applied N to tree N status. A broad objective of this combined research effort is to determine whether there is an optimal combination of tree water and nutrient status to achieve high and sustainable almond yields and quality.

Interpretive Summary:

Methods: The basic experimental approach for this project was established by P. Brown and cooperators in a proposal entitled "Development of a Nutrient Budget Approach to Fertilizer Management in Almond" (see Project No: 09-PREC2-Brown). Brown proposed to take detailed nut/leaf samples 5 times over the season from 10 trees in each of 5 experimental sites, distributed around the almond growing regions of the state, three of which are the subject of this report (**Table 1**). All of these sites are micro-sprinkler or drip irrigated. Individual tree yields were also collected from approximately 100 trees at each site, but yield values are not yet available. At each site, we installed water meters on two (2) representative lateral irrigation lines, and also a pressure sensor instrument in one line with a datalogger which recorded system on and off times. This information was used to document the amounts and timings of irrigation water applied, which was compared to nearby CIMIS estimates of Etc. At approximately monthly intervals from May to September, the trees sampled in the Brown study were sampled for midday SWP by us, using the pressure chamber technique. Water meters were read and data from the dataloggers collected periodically during the season, at least as often as SWP measurements are made.

Results: The 3 sites of this study showed contrasting patterns for both applied water (**Figure 1**) and SWP (**Figure 2**). In **Figure 1**, the upper dashed line represents an upper limit estimate for ETc (based on a full cover crop orchard), and the lower dashed line a lower limit estimate (clean tilled orchard). These lines indicate the degree of uncertainly based on the presence or absence of a cover crop; but it must also be recognized that there is currently some uncertainty regarding the appropriate crop coefficients for almond, and so these reference lines must be regarded as tentative. All of the orchards studied were within these reference limits during 2009, but at the Madera site, irrigation was discontinued for an extended time at the start of harvest (mid-August), and there was a clear decrease in SWP as a result (**Figure 2**).

Table 1. Information for the 3 study sites covered in this report.

Site Name	Irrigation System	Tree Spacing (ft)	Row Spacing (ft)	2009 Full Bloom Date
Arbuckle	drip	18	22	Feb. 25
Salida	micro-sprinkler	20	22	Feb. 26
Madera	micro-sprinkler	15	22	Mar. 8

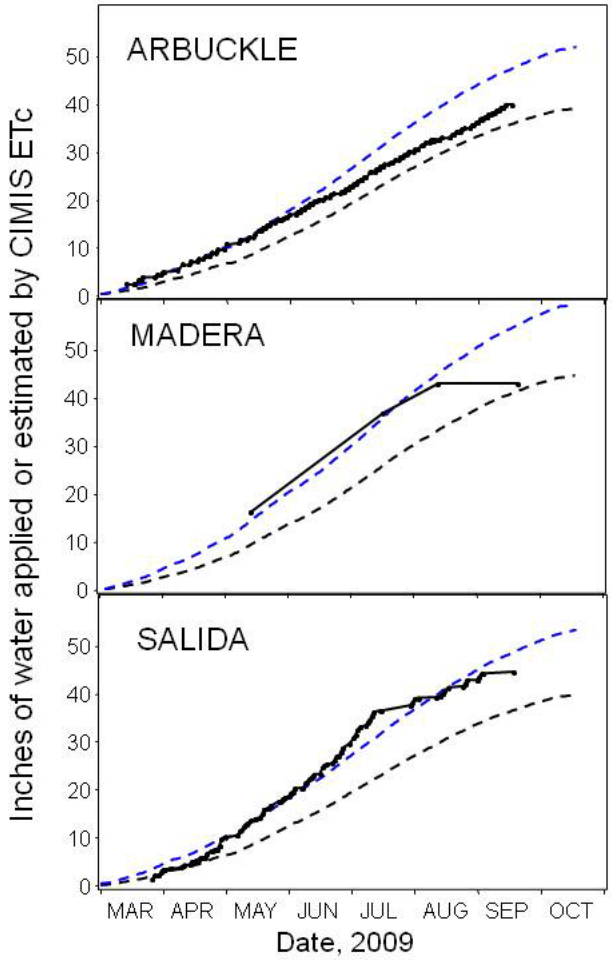

Figure 1. Cumulative inches of water applied by the grower or by rain in 2009, and upper (full cover) and lower (clean tilled) CIMIS estimates of irrigation requirements (ETc, dashed lines) for each site. Points connected by solid lines represent irrigation events, and the solid line shown for Madera is based on periodic water meter readings (irrigation event data was not available).

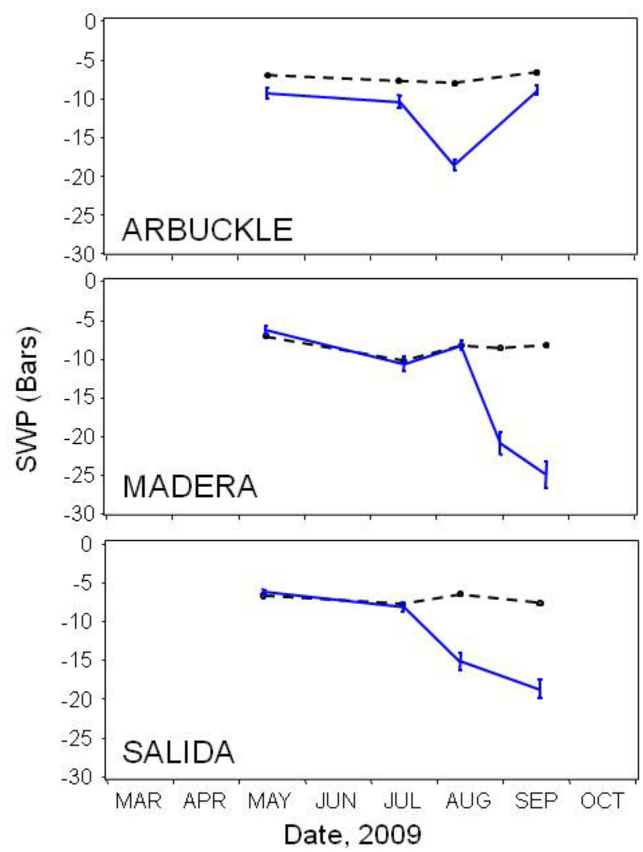

Figure 2. Seasonal pattern of observed stem water potential (SWP), and for reference, the SWP expected for fully irrigated almond trees (non-stressed baseline). Error bars are ±2 SE and indicate variation among trees (N = 24).

It is also interesting to note that the mid-August and mid-September SWP readings in Salida showed significant tree stress, and this was associated with the end of a period of 9 and 14 days, respectively, since the last irrigation. In both of these orchards the trees had exhibited a SWP similar to the baseline (non-stressed) value earlier in the season, and the cumulative irrigation applied to both, particularly Salida, were close to the upper estimate of ETc at the time when the trees were exhibiting this stress (Figure 1). Hence, after only 9-14 days without water, trees in Salida were exhibiting the same level of stress as found in Arbuckle mid-August (around -20 bars), even though the Arbuckle trees were substantially more "behind" in the cumulative seasonal irrigation applied up to that point (**Figure 1**). This may indicate that a gradual withholding of water during the season, as occurred in Arbuckle, may be an effective acclimation strategy to avoid the rapid drops in SWP that were experienced at Salida when irrigation was withheld.

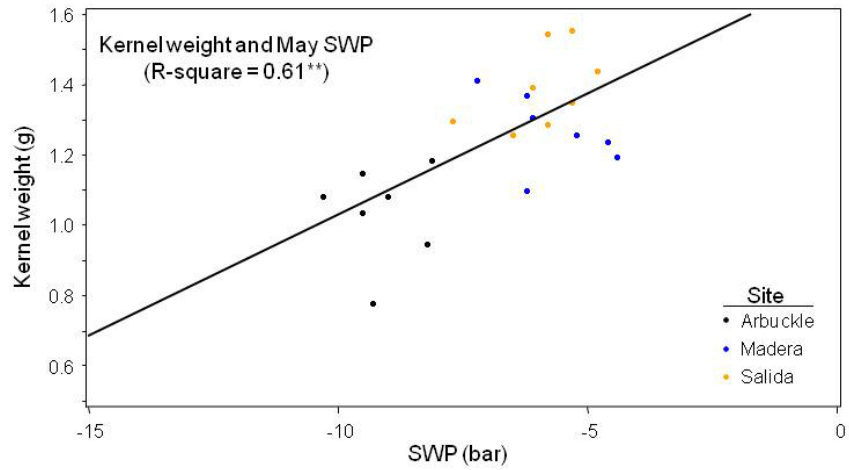

Figure 3. **Relation of kernel weight at harvest to the SWP** measured in May for individual trees at each of the three sites. Note that kernel weight data was not available for all of the trees monitored for SWP.

As found in 2008, there were significant tree-to-tree differences in SWP at all sites (**Table 2**), and a relatively strong correlation was found between the SWP measured on individual trees in May and the average kernel size for each tree (**Figure 3**). The fact that all sites and all monitored trees within each site showed the same relation (**Figure 3**) is important, as it indicates that both site effects and tree effects may be attributed to the same factor, that is, tree water stress. A close relation between kernel size and the level of tree water stress was also reported in the 2009 almond project "Drought Survival Strategies for Established Almond Orchards on Shallow Soil," and this may indicate that kernel growth

Table 2. Range in observed tree stress (Bar) within each site, and the overall average SWP for all trees at each site, compared to that expected for non-stressed almond trees (baseline). Also shown is a statistic indicating the significance of tree-to-tree variation at each site.

Site Name	Lowest stressed tree SWP (season average)	Highest stressed tree SWP (season average)	Overall seasonal average SWP for all trees	Average seasonal baseline (non-stressed) SWP	Tree variation statistic
Arbuckle	-10.0	-16.4	-11.9	-7.4	0.0001***
Salida	-8.8	-15.4	-14.2	-7.1	0.0016**
Madera	-11.0	-19.2	-12.1	-8.5	<0.0001***

is relatively sensitive to tree water stress, contrary to common belief. In 2010, more frequent measurements of SWP will be made at all sites in order to determine whether this sensitivity can be confirmed and whether it is limited to certain periods of kernel growth. Even though kernel size was influenced by tree stress, overall tree yield was not (**Figure 4**), indicating that there were differences in crop load. A few trees in the Madera site showed very high yields (equivalent to over 5,000 lbs/ac), but it should be noted that these yields are from individual trees and are extrapolated to an equivalent orchard yield per acre for the purposes of comparison. Hence, only the average yields from each site should be considered as a reasonable estimate for orchard yields.

A number of leaf nutrient levels have been measured as part of this study, and these data were analyzed to determine whether tree and site effects on nutrients could also be related to SWP. The highest correlation between SWP measured in May and any nutrient was for boron, with drier trees showing lower amounts of B (**Figure 5**). As for **Figure 3**, the same relation between SWP and B was exhibited both between and within sites, indicating the possibility of a close physiological connection between tree water status and tree boron nutrition. Because boron and SWP were positively correlated (**Figure 5**), and SWP and kernel size were positively correlated (**Figure 3**), it was not surprising that boron and kernel size were also positively correlated (**Figure 6**). All of these relations had similar

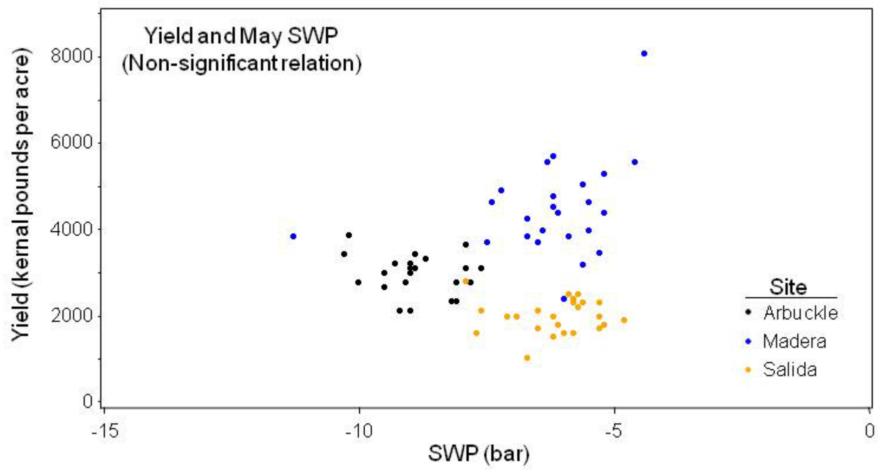

Figure 4. Non-relation of Individual tree yield to the SWP measured in May at each of the three sites.

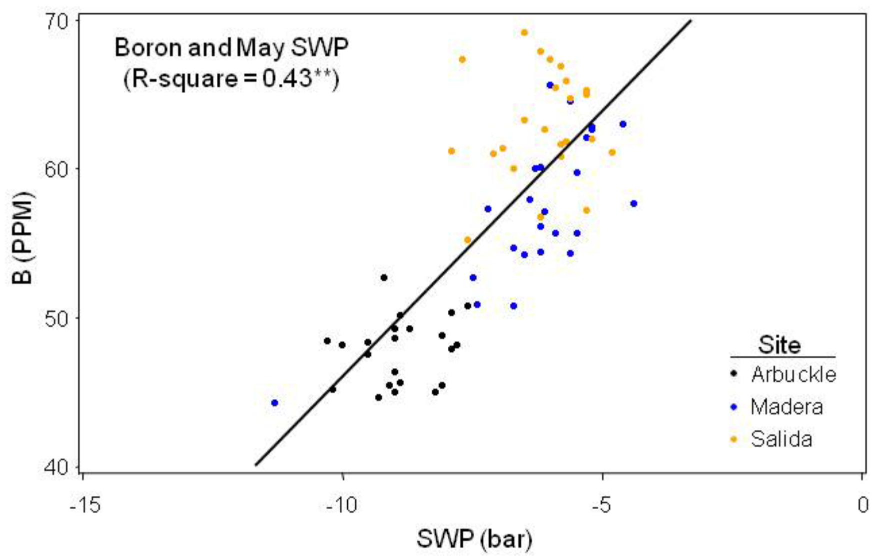

Figure 5. Relation between mid-summer Boron levels of non-fruiting spur leaves to the SWP measured in May at each of the three sites.

statistical significance and goodness-of-fit (R-squared values), and hence specific experiments, in which water and boron status are independently manipulated, will be required to evaluate which factor is more important in determining kernel size.

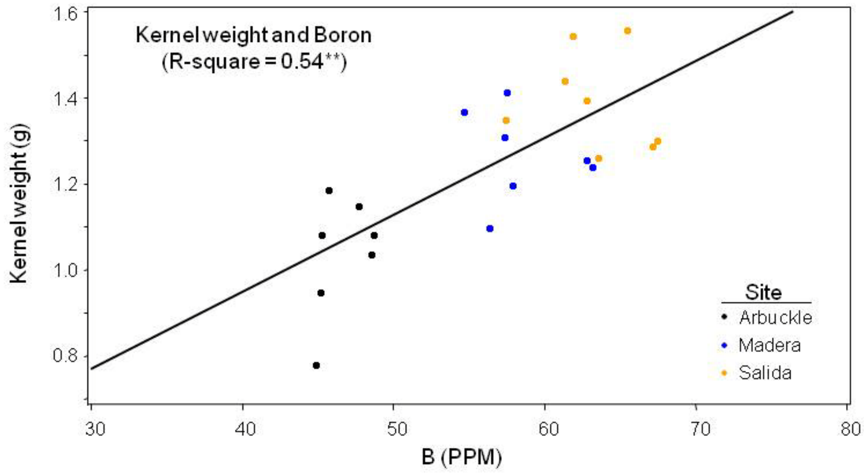

Figure 6. Relation of kernel weight at harvest to the mid-summer B for individual trees at each of the three sites.

Research Effort Recent Publications:

None for this project

References Cited:

None