Fertigation: Interaction of Water and Nutrient Management in Almonds

Project No.: **08-HORT11-Shackel/Sanden**

Project Leaders:
Ken Shackel
Department of Plant Sciences
UC Davis
One Shields Ave
Davis, CA 95616-8683
(530) 752-0927
kashackel@ucdavis.edu

Blake Sanden
UCCE Kern County
1031 S. Mt Vernon Ave.
Bakersfield, CA 93307
(661) 868-6218
blsanden@ucdavis.edu

Project Cooperators and Personnel:
Patrick Brown, Bruce Lampinen, William Stewart, and Jeremy Nunes, UC Davis
Brent Holtz, UCCE – Madera County
John Edstrom, UCCE – Colusa County
Roger Duncan, UCCE – Stanislaus
Richard C. Rosecrance, CSU Chico
Bob Beede, UCCE – Kings County
Franz Neiderholzer, UCCE - Sutter/Yuba Counties

Objectives:

The primary objective of this study is to document the amount of water applied to the experimental plots of the P. Brown fertigation study (including the collection of data related to ETc), and to monitor the effects of the grower's irrigation management on tree SWP at these sites. At one site (Belridge), more detailed measurements of soil moisture were made in the contrasting fertilizer treatments being applied in order to document whether fertilizer management can also influence tree water demand. 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:

For the sites used in this study, substantial differences in the seasonal pattern and amounts of water application were observed, and in 4 of the 5 sites, we found significant differences in the level of water stress being experienced by individual trees. Seasonal amounts of applied water were roughly correlated with the level of stress, with the orchard that received the least amount of water (47% ETc) showing the most stressed stem water potential (SWP) values (average -17.4 bars), although in this case, equipment breakdown was the main reason for the low applied water. Despite the differences in SWP that were exhibited between sites and between trees within a site, there was no clear correlation of SWP to yield or mid-summer leaf nutrient levels, however, carry-over effects may be observed in subsequent years. This is the first year of a multi-year study, and hence these conclusions must be considered preliminary.

Materials and Methods:

The basic experimental approach for this project has been established by Brown and cooperators in a proposal entitled "Development of a Nutrient Budget Approach to Fertilizer Management in Almond." Brown has 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 (**Table 1**).

All of these sites are micro-sprinkler or drip irrigated, and two are a side-to-side comparison (southern SJ valley) of micro-sprinkler and drip, combined with multiple levels of N and K application rates. Individual tree yields were also collected from approximately 100 trees at each site. 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 HOBO datalogger which recorded system on and off times. Water meters were installed at the Arbuckle, Salida, and Madera sites in late April and early May. Meter M909 installed at Madera was damaged by a tree limb and re-installed following repairs. This information was used to document the amounts and timings of irrigation water applied, and to estimate the degree of spatial variation within the irrigation system, at least to the level of the irrigation lateral. A description of the layout for each study plot is displayed in **Table 2**. 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 developed by Shackel (http://fruitsandnuts.ucdavis.edu/crops/pressure-chamber.shtml). In order to describe the typical range of stress experienced by the trees, measurements were made just prior to an irrigation and just following an irrigation event when possible. Water meters were read and data from the dataloggers collected periodically during the season, at least as often as SWP measurements are made. Data from nearby CIMIS stations was obtained and the seasonal pattern of water applied was related to calculated values of almond ETc. At one site (Southern SJ valley), neutron access tubes were installed and calibrated in selected treatments so that soil moisture can be accurately monitored and a tree water budget estimated.

Results and Discussion:

The 5 sites of this study showed contrasting patterns for both applied water (**Figure 1**) and SWP (Fig. 2). In **Figure 1**, the two dashed lines represent a high and a low estimate for ETc (full cover orchard and clean tilled orchard, respectively), with one site near the lower limit (Arbuckle), one near the upper limit (Salida), one between the two limits (Belridge) and one site both below the lower limit and exhibiting a substantial degree of variability (Madera). Normal irrigation management at the Madera site involved long sets and infrequent irrigation compared to multiple irrigations per week at the other sites, but the Madera site also experienced irrigation equipment breakdown during this season, resulting in much lower applied water amounts (**Figure 1**) and SWP values (**Figure 2**) than the other sites. Belridge generally showed the highest (least stressed) SWP. Madera the lowest SWP and Arbuckle and Salida intermediate stress levels (**Figure 2** and **Table 2**). At 4 of the 5 sites there were highly significant tree-to-tree differences in SWP (**Table 2**), suggesting that these may be important in explaining tree-to-tree differences in leaf N levels and/or yield.

Tree stress, as measured by SWP, is influenced both by the environment and by soil water availability. The average baseline SWP value shown in **Table 2** takes into account the environmental effects of air temperature and humidity on the sampling dates of this study, and hence the SWP difference is an indication of the relative stress levels at each site. The Madera site was clearly affected by the irrigation system breakdown, but among the other sites, it is interesting that the Salida site, which had the highest amount of applied water, was not the site with the lowest stress level. More frequent measurements will be necessary to confirm this trend, and since soil water availability for a give irrigation level may also depend on soil characteristics.

Based on the close positive relation between SWP and tree growth and yield that has previously been found in controlled experimental studies at a single site, we hypothesized that a similar positive relation between yield and SWP would be found across the sites of this study, but this was not observed (**Figure 3**). Even for the site with the most continuous SWP monitoring (Belridge), there was no clear relation of tree yield to average tree SWP (**Fig. 3**). This was also the case for mid-summer leaf nutrient levels (N, P, K, S, B, Ca, Mg, Zn, Mn, Fe and Cu) at Arbuckle, Madera and Salida (data not shown). Given that the variability in individual tree SWP was substantial (-8 to -19 bars), this is a surprising result, and must be confirmed with further study. If it is confirmed, then it may indicate that mature orchards can tolerate substantially more stress than previously thought. Stress tolerance may also result from a progressive development of stress over the season, as was observed at Salida and Madera, rather than intermittent or variable stress, as was observed in Arbuckle and to some extent Belridge. To date, there have been no studies in almond designed to determine the production effects of water stress which develops at different rates and with contrasting patterns over time. If the current study documents that little or no production effects are associated with a substantial range in SWP, then further studies to determine the basis of stress tolerance in almond will be proposed.

Table 1. Information for the 5 study sites.

Site Name	Irrigation System	Tree Spacing (ft)	Row Spacing (ft)	2008 Full Bloom Date
Arbuckle	drip	18	22	Feb. 29th
Salida	micro-sprinkler	20	22	Mar. 3rd
Madera	micro-sprinkler	15	22	Mar. 4th
Belridge (fanjet)	micro-sprinkler	21	24	Feb. 29th
Belridge (drip)	drip	21	24	Feb. 29th

Table 2. Water applied, CIMIS ETo, and baseline and measured midday stem water potential (SWP). The SWP difference between the measured and baseline values is a relative indicator of average stress experienced at that site (a more negative value means more stress). Also shown is a statistic indicating the significance of tree-to-tree variation at each site.

Site Name	Applied Water (in.)	CIMIS Cumulative ETo (in.)	Applied Water (% ETo)	Baseline SWP (Bars)	Measured SWP (Bars)	SWP difference (bars)	Tree variation statistic
Arbuckle	25.5	30.7	83.00	-8.9	-13.7	-4.8	0.1989
Salida	40.0	33.5	119.58	-7.0	-12.7	-5.7	<0.0001***
Madera	16.9	35.7	47.26	-7.8	-17.4	-9.6	<0.0001***
Belridge (fanjet)	50.7	49.2	103.1	-8.0	-10.0	-2	<0.0001***
Belridge (drip)	51.7	49.2	105.1	-8.0	-8.8	-0.8	<0.0001***

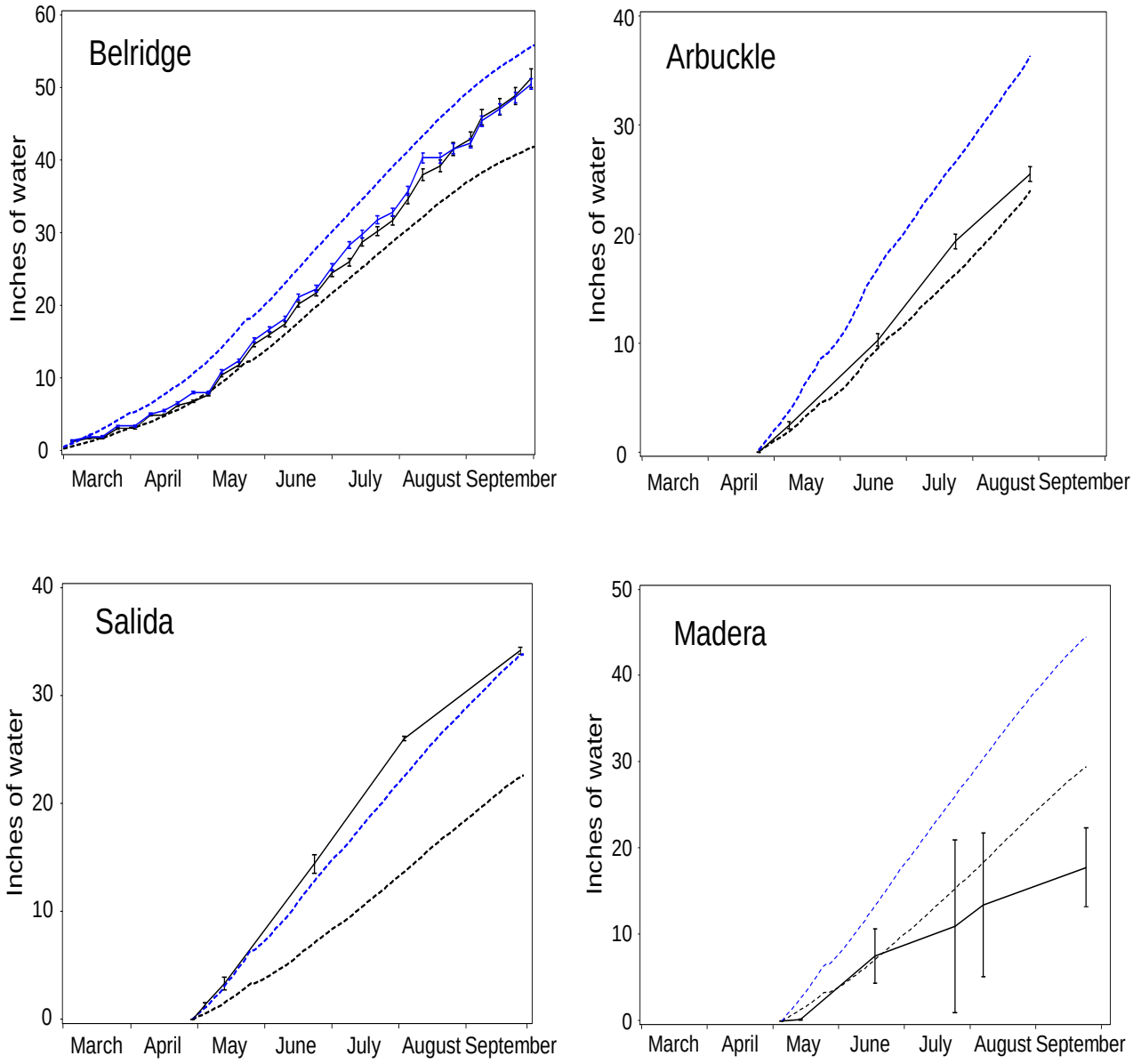

Figure 1. Cumulative inches of water applied during the observation period (starting with water meter installation, solid lines), and upper (full cover) and lower (clean tilled) CIMIS estimates of irrigation requirement (Etc-rain, dashed lines). Error bars are ±2 SE and indicate variation in the water applied through two independent lateral lines.

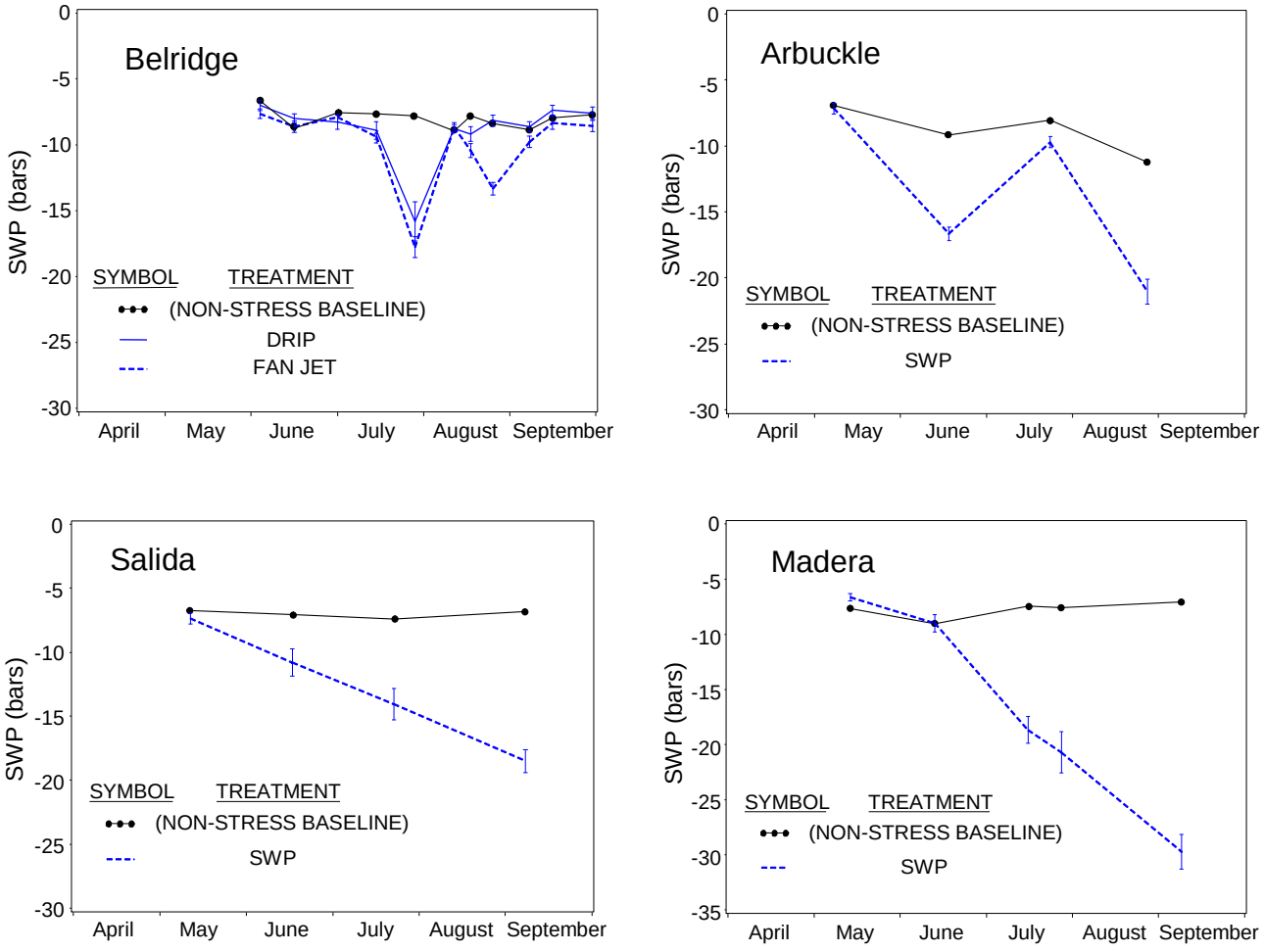

Figure 2. Seasonal pattern of observed stem water potential (SWP), and for reference, the SWP expected for fully irrigated almond trees (non-stressed baseline). Error bars are ±2 SE and indicate variation among trees (N = 30 for Belridge fan jet and N=24 for all others).

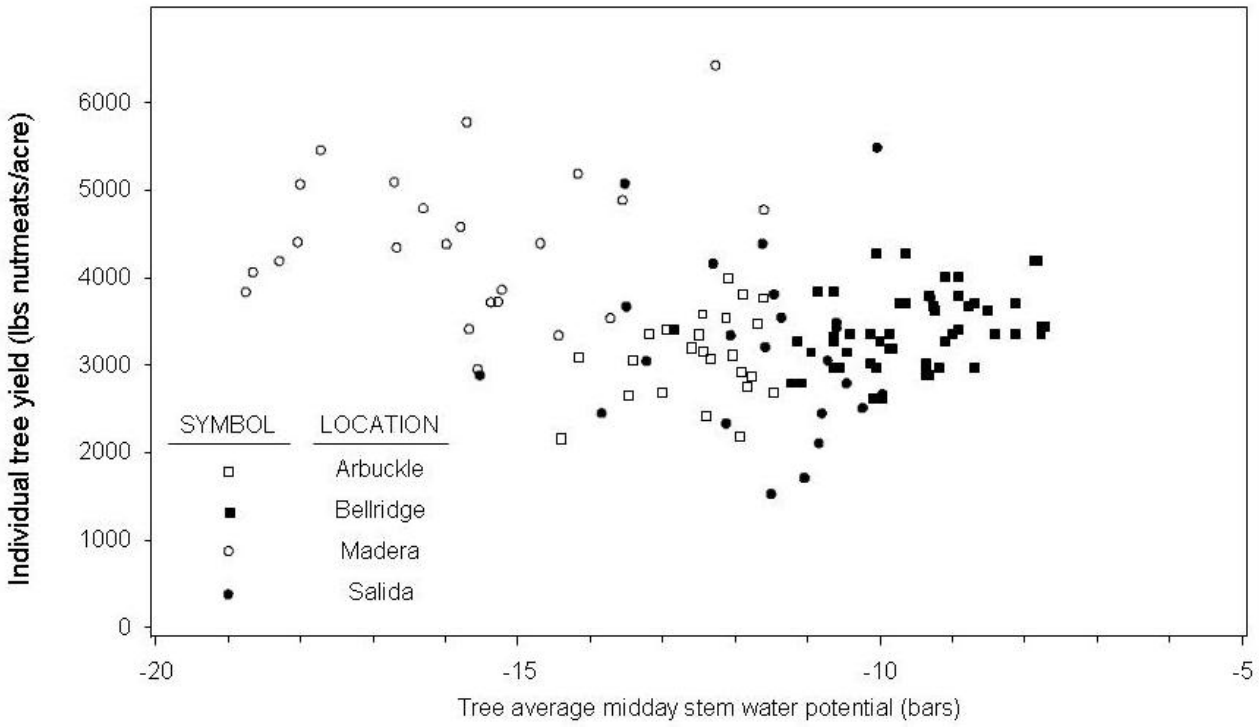

Figure 3. Lack of relation between individual tree yields and the average SWP exhibited by the tree over the season for all sites in the study. At the Belridge and Arbuckle sites, linear regressions showed a positive slope, but were not significant, and for all sites together, the slope was negative, but also not significant.