Fertigation: Interaction of Water Management and Nutrient Management in Almond

Project No.: **11-HORT11-Shackel/Sanden**

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Objectives:

- As part of the larger fertilizer study by Patrick Brown, document the amount and timing of water applied to each study site
- Monitor plant water potential at each of the fertilizer/nutrient study sites to determine whether irrigation and fertilization levels independently influence tree nutrient status.
- In the Kern Co. (southern San Joaquin Valley) site, use soil moisture, meteorological, and satellite-based remote sensing methods to monitor non-stressed almond evapotranspiration (ET) under both drip and microsprinkler irrigation. Assess the impact, if any, of fertility on almond ET through replicated sites in this one orchard.

Interpretive Summary:

Water and nutrient management are both important factors for maximizing almond yield and minimizing environmental impact. A key objective of this research is to determine whether nutrient levels themselves can influence the level tree water status (measured by stem water potential, SWP). For instance, it is possible that increased fertility might increase tree water demand and hence cause more water stress (lower SWP) for the same level of irrigation, or that increased fertility might improve tree water use efficiency and/or root health and hence

cause less water stress for the same level of irrigation. However, to date we have not found evidence of a strong link between fertility and SWP. Drought is known to lower SWP and reduce yields, but there are many other environmental factors that can determine site-specific almond yields. For the four orchard sites (Colusa Co. to Kern Co.) and three years (2008 – 2010) of this study, there was no clear relation between current year SWP (ranging from -9 to -18 bars June-October average) and current year yield (ranging from 2,600 to 3,400 lbs. nutmeats/acre). However, consistent with the results of previous drought studies, there was clear evidence of a 1-year SWP carryover effect on yield, with a decline in yield of about 25% for a 5 bar decline in seasonal average SWP from -10 to -15 bars. These results indicate that changes in water management may have a delayed effect on almond yield. A detailed analysis of leaf responses to water stress at the Kern Co. site showed that stomatal opening and leaf transpiration are primarily influenced by SWP and secondarily influenced by leaf exposure, whereas for leaf photosynthesis, the opposite was the case. Combined with the fact that we have not seen a clear reduction in orchard ET with stress, these results indicate that even though water use efficiency (WUE) at the leaf level may improve with mild to moderate water stress, WUE at the canopy level may actually decrease.

Materials and Methods:

This study is being conducted in four orchard locations distributed across the almond growing regions of the state (from north to south: Arbuckle, Salida, Madera, and Belridge) in which irrigation practices, stem water potential (SWP), yield and other parameters are being monitored. At the Belridge site, a meteorological tower is also using an eddy co-variance approach to measure orchard evapo-transpiration (ET) directly. All of these sites are microsprinkler or drip irrigated. Periodic (typically weekly) measurements of SWP have been obtained from 2008 – 2011, and end of season individual tree yields for 2008 – 2010. Previous research has shown that a very substantial closure of stomata (50%) occurs for sunlit leaves when SWP drops to below about -15 bars (mild to moderate stress), but at the Belridge site, canopy ET has not been observed to decline under these conditions. Hence, in 2012 a detailed study of leaf level responses (stomatal conductance and photosynthesis) to SWP levels was conducted at the Belridge and Madera sites, as well as two additional sites (M&T ranch in Butte Co. and Nickels experiment station in Colusa Co.), which together represented a wide range of SWP values. These measurements were conducted to test whether the contribution of shaded leaves to canopy ET could explain the reason why canopy ET was unaffected with mild to moderate stress.

Results and Discussion:

As observed in previous years, early season (May) SWP values were similar at all sites (**Figure 1**), and close to the fully irrigated baseline (not shown). As the season progressed, lower values of SWP (more water stress) were observed at most sites (**Figure 1**). As also found in previous years, the Madera site showed substantial levels of stress late in the season when irrigation was discontinued (data not shown), which was apparently the normal practice for this grower. All sites exhibited moderate levels of stress (-15 to -19 bars) associated with harvest (July/August), but by the end of the season, the levels of stress at the Madera site (approaching -30 bars) were also sufficient to cause substantial orchard defoliation. Yields at these sites have been recorded on an individual tree basis, and the average for all trees (54 at each site) is shown in **Table 1** (no yields were measured in 2011).

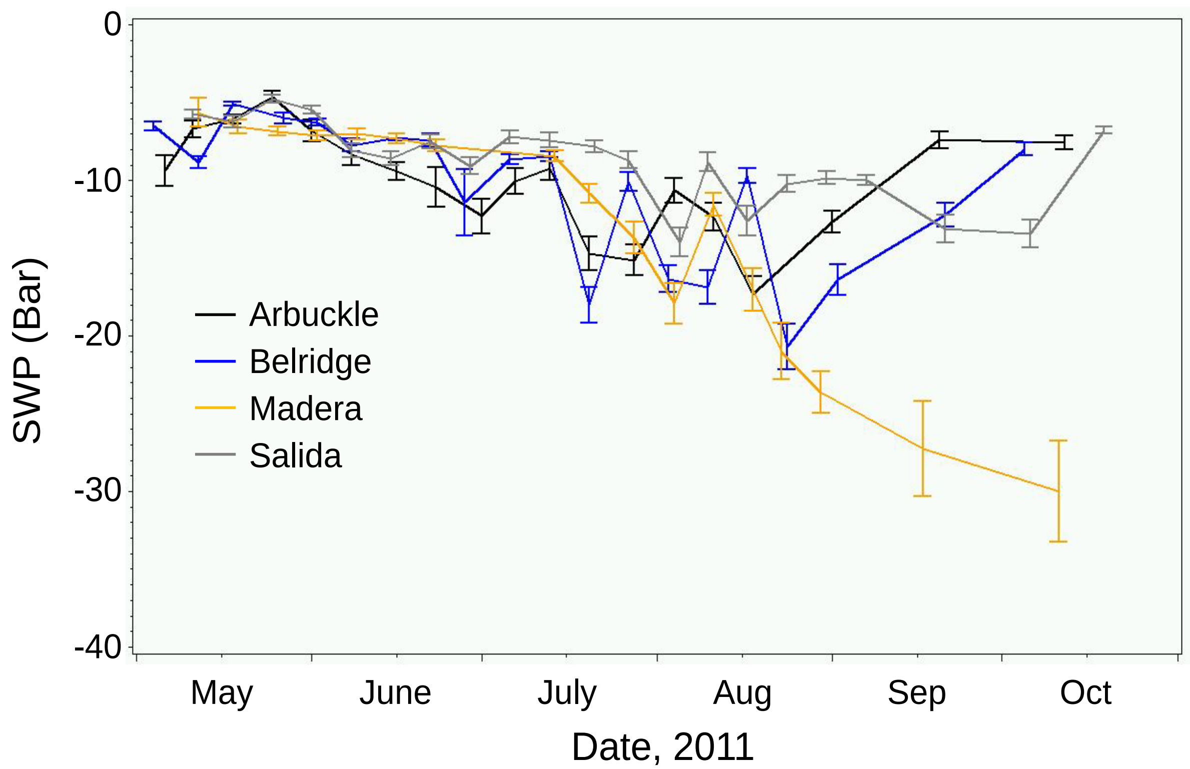

Figure 1. Seasonal pattern of SWP for all sites in 2011.

Generally, all orchards were in the 3000 pounds/acre range, but most notably, yields at the Madera site have been declining over time.

Based on previous results obtained from a drought stress study in the Arbuckle area, we suspected that almond yield may be more determined by carryover (previous year) effects of water stress than by current season water stress, and consistent with this hypothesis, for the data shown in **Table 1**, there was no clear relation of current year yield to current year

Table 1. Site average SWP (June – October) and kernel yield for 2008 – 2010.

Site	2008		2009		2010	
	SWP (bar)	Yield (#/ac)	SWP (bar)	Yield (#/ac)	SWP (bar)	Yield (#/ac)
Arbuckle	-13.8	3400	-12.7	2880	-10.9	2620
Belridge	-10.0	2920	-11.8	3180	-11.6	3310
Madera	-17.6	4590	-16.1	2690	-15.4	1160
Salida	-12.6	3110	-14.0	3310	-9.4	2600

SWP (**Figure 2 top**), but an indication of a positive relation of current year yield to previous year SWP (**Figure 2 bottom**). Overall yield in almonds is determined by many factors, but this indicates that the long term effects of irrigation management may be more important than the short term effects.

An important objective of this research is to quantify the water use (evapotranspiration, or ET) of almond orchards, and the relation of tree stress (as measured by SWP), and orchard ET. In previous reports, we have found that there is little or no reduction in ET at the orchard level as SWP declined from baseline values (around -8 bars) to moderate stress levels (around -18 bars), even though we have found that this change in SWP should be associated with about a 50% reduction in stomatal opening (stomatal conductance) at the leaf level. Such a reduction has also been found in canopy ET for peach trees grown in a lysimeter (Johnson et al, 2005).

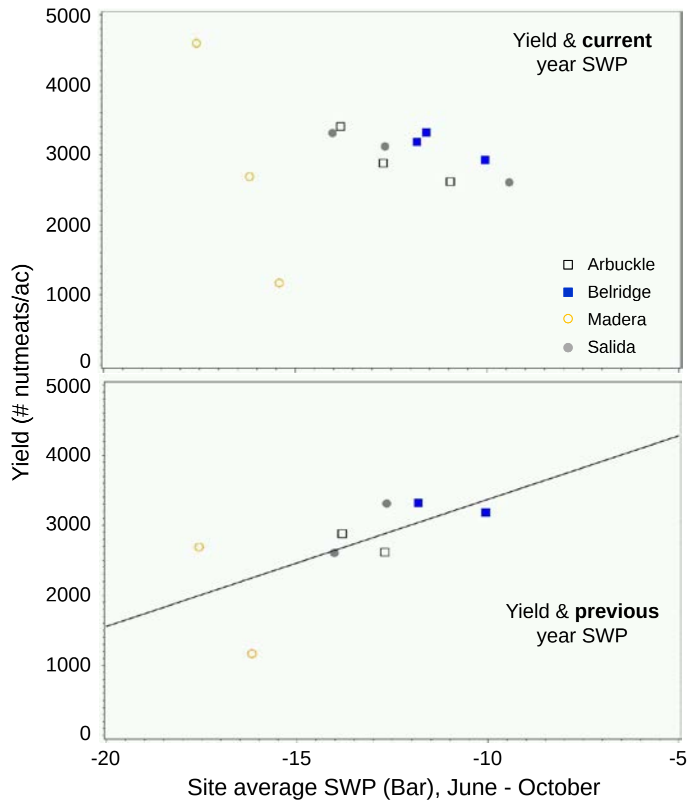

Figure 2. Relation of site average current year yield to either current year SWP (top) or previous year SWP (bottom). Values from **Table 1**.

In 2011 we measured both conductance and photosynthesis in almond leaves at multiple sites, and for both sunlit and shaded leaves. We found that both shaded and sunlit leaves responded to SWP by reducing stomatal conductance, with about -30 bars SWP corresponding to essentially full stomatal closure, as previously reported (**Figure 3, top**). As expected, shaded leaves had low levels of photosynthesis compared to sunlit leaves, but in both types of leaves, photosynthesis (**Figure 3, bottom**) was much less responsive to SWP than was stomatal conductance (**Figure 3, top**). This is an important result because at the leaf level it indicates that almond water use efficiency (photosynthesis per unit of water lost in transpiration) should increase with increasing water stress. This is in contrast to the conclusion which may be reached based on the canopy ET data, which is that water use efficiency may not change, or may actually decrease, with water stress. Because of competition for water resources, it is important to understand the relation of water stress to water use efficiency in almonds, and hence gaining this information will become an important part of future research.

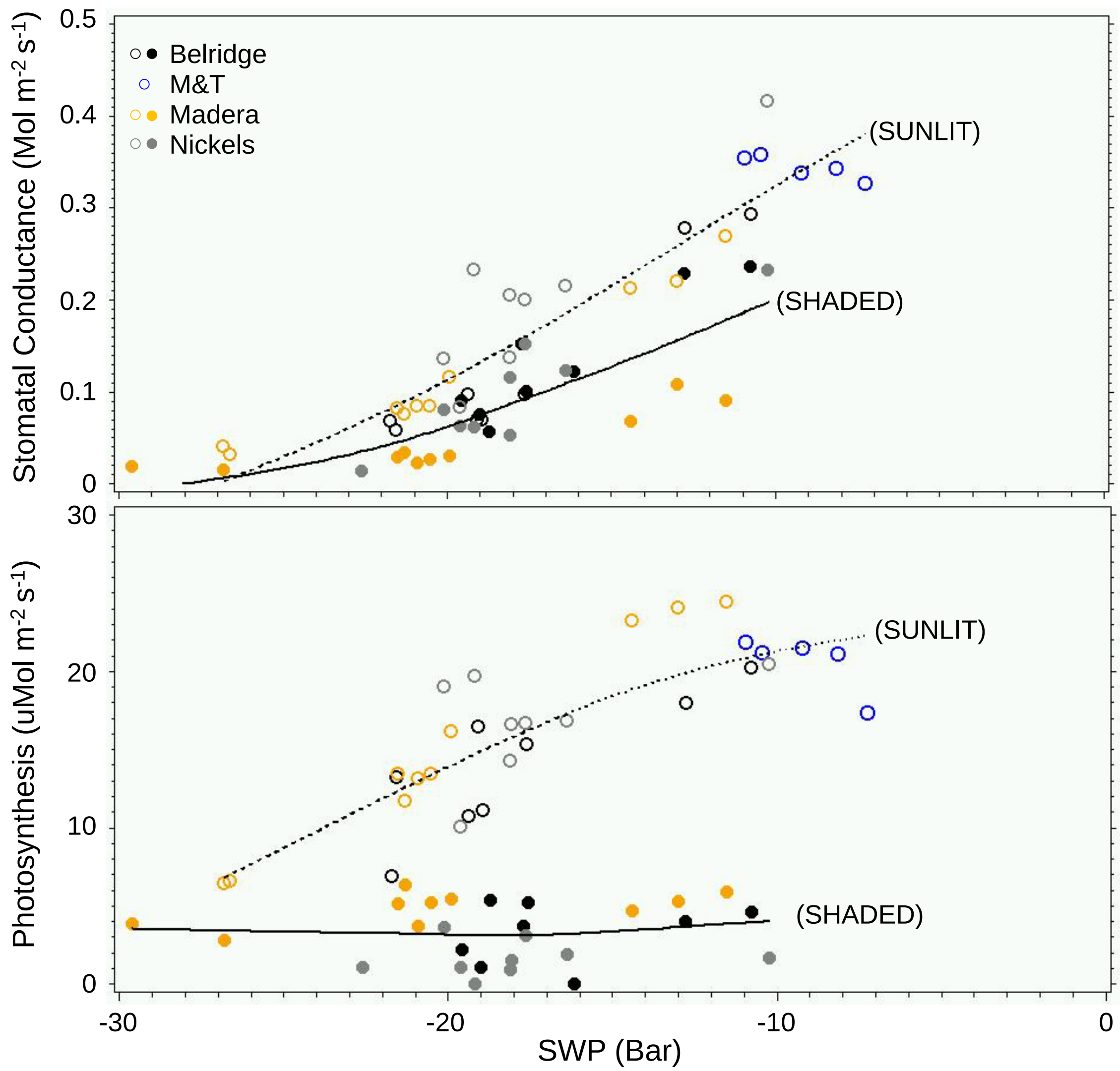

Figure 3. Relation of conductance (top) and photosynthesis (bottom) to SWP for naturally sunlit and shaded leaves.

Research Effort Recent Publications:

Munoz H, 2011, Carry-over effects of water stress in the vegetative development, flowering, fruit set, and yield of almond trees. MS Thesis, UC Davis.

Shackel KA. 2010. A Plant-based Approach to Deficit Irrigation in Trees and Vines. Hort.Sci. 46:173-177.

Stewart WL, Fulton AE, Krueger WH, Lampinen BD, Shackel KA. 2011. Regulated deficit irrigation reduces water use of almonds without affecting yield. Cal Ag. 65: 90-99.

References Cited:

Johnson SJ, Williams LE, Ayars JE, Trout TJ. 2005. Weighing lysimeters aid study of water relations in tree and vine crops. Cal Ag. 59:133-136.