Fertigation: Interaction of Water and Nutrient Management in Almonds – Kern County

Project No.: **09-HORT11A-Sanden/Shackel**

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Objectives:

The broad objective of this combined research effort is to: 1) Better understand the variability of almond tree response to water and fertility inputs, and 2) determine the optimal combination of tree water and nutrient status to achieve high and sustainable almond yield and quality.

(Statewide-Shackel) Document the variability of yield in four production orchards from Arbuckle to Kern County as a function of tree stress (as measured by midday bagged leaf/stem water potential (SWP)) throughout the season, applied water and nitrogen fertility.

(Kern County-Sanden) For this intensively monitored site, determine:

1) The maximum crop water use (ET) potential of almonds.

2) If N fertilizer rates and crop yield differentially impact tree ET.
3) If these factors behave differently under drip vs. microsprinkler irrigation.

Interpretive Summary: (Kern only. See 09-HORT11-Shackel for other locations)

Many almond irrigation trials have been conducted over the last 30 years in California where the Control treatment has been assumed to represent "non-stressed" or "100% evapotranspiration (ET)" conditions. The maximum applied water for these trials rarely exceeded 45 inches even in the southern San Joaquin Valley, and maximum yields were low by today's standard. (The 2002-2008 Spur Dynamics Trial by Bruce Lampinen was the exception both in higher levels of applied water and achieved yield. However, precise tree ET was not calculated.) Personal conversations with some of the involved researchers and cooperators have confirmed that visual signs of stress were often seen in the "100% ET" treatments. This project provides for very detailed monitoring of soil moisture levels and actual tree stress to schedule irrigations so that stress is truly avoided. Weekly ET is calculated using applied water and soil moisture depletion. Daily field ET is calculated by an energy balance using very precise meteorological equipment (eddy covariance, EC). All of this is laid over the multi-rate fertility trial of Brown, et. al. to see if varying levels of N fertility (125 to 350 lb/ac) impact tree water use in mature, full cover trees. As of this writing (July 2010), we are in the third season of this trial.

Using the energy balance (EC) method, the average January through December measured almond ET for microsprinklers with no cover crop for the southern San Joaquin Valley was 60.3 inches. This is 43% higher than the old standard of 42.2 inches for April 1 to November 15 published by the University of California more than 20 years ago (Snyder, et al., 1989. See **Figure 3** following.) The average crop coefficient value (Kc) for 4/1 to 11/15 from this earlier work was 0.72 (basically 72% of what a well-watered pasture grass would use over the same period). The average Kc for this same period calculated by our study is 1.06. **(NOTE: This is not a recommendation that almonds should be irrigated with 60 inches of water, but rather the fact that this is indeed the true potential ET of these trees. As long as salt is not a problem, our best current estimate would be around 50 to 54 inches of in-season irrigation would be sufficient.)**

Yearly ET measured by applied irrigation and soil moisture depletion for individual N fertilizer rates and locations varied from 53.9 to 59.7 inches. These totals were not significantly different and showed that N fertility status did not affect tree ET. If this were an immature orchard (say 2^{nd} to 6^{th} leaf) this would not be the case as the higher N rates would cause trees to grow more quickly thereby increasing ET over the smaller low N trees. But effective cover in this established orchard has been 85 to 100% from the start of the trial, and, therefore was already at maximum potential energy interception (via light and wind) for maximum ET. Hull rot was a significant problem in 2009 even though soil moisture was kept around 65% available and we will attempt some deficit irrigation during hull split in 2010 for reducing this problem.

The double-line drip irrigation set has maintained trees at a lower stress level (less negative stem water potential levels) and with a higher average stored soil water content compared to the microsprinkler set. This has NOT translated into a consistent yield advantage. Average Nonpareil kernel yields for intensively monitored irrigation sites have ranged from 3,164 to 3,997 lb/ac for the two higher rates of N fertilizer (275 and 350 lb/ac, see **Table 1**) over 2008 and 2009.

Project design: This trial is designed to document, as close as possible, non-stressed almond ET, and any interaction with N fertilizer rates by using high frequency meteorological monitoring equipment (similar to CIMIS) and detailed weekly measurements of applied water and soil moisture depletion in 30 locations throughout the orchard. Midday tree stem water potential (SWP) is measured for 2 trees/location, weekly using the pressure chamber and shaded bagged leaves to insure uniform measurements. These data are combined into a weekly custom irrigation schedule provided to the cooperator to minimize stress in the trees while not leaching out of the rootzone. Soil salinity and fertility is also monitored at the end of every season. This water/fertigation trial is superimposed over Patrick Brown's extensive fertility trial with 12 different fertilizer treatments, each having 5 to 6 replicated plots in a given irrigation set. All fertility treatments and water monitoring sites are set up in identical fashion in the two eastern 50 acre sets (microsprinkler FANJET and double-line DRIP) of a 150 acre, 3 set block. The flowrate from the drip set is equal to that of the micro-sprinkler set at 22 gph/tree. In all, yield and tissue data are taken from 768 individual trees for the Brown fertility trial. A subset of 60 of these trees is used for plant water status stem water potential (SWP) and soil moisture monitoring. This is the end of the second season for this trial. All data are from the Nonpareil variety. (Monterey is the pollinator.)

Almond crop evapotranspiration (ETc) is determined using two meteorological methods (eddy covariance (EC) and surface renewal (SR)) with instruments placed on a 28 foot tower located in the FANJET block. These instruments collect data several times a second to provide an overall ET measurement every ½ hour for the block. Daily ET is totaled and compared to the nearby Belridge CIMIS station 1.5 miles due West, which calculates the daily potential evapotranspiration (ETo). The almond ETc is divided by the ETo to calculate daily/weekly crop water use coefficients (Kc).

ET is also calculated weekly using tree specific measurements of applied water and soil moisture depletion to a depth of 9 feet for 15 sites in the FANJET set and 15 sites in the DRIP set. Due to the intensive effort of installation and weekly monitoring of these sites only 5 fertilizer treatments with 3 replications are monitored. These treatments are 125, 200, 275 and 350 lb/ac N from UAN32 fertigation with 200 lb/ac K (125 lb/ac from winter broadcast potassium sulfate and 75 lb/ac from fertigated potassium thiosulfate), and a fifth treatment with the same 275 lb/ac N but 300 lb/ac K (125 broadcast, 175 K thiosulfate). These treatments appear in the following figures and table as "125, 200, 275, 300 and 350".

Results and discussion:

Figure 1 shows weekly crop ET over the entire year from the meteorological estimates of latent heat flux (evaporation of water, which is basically ET) and soil moisture depletion by neutron probe (NP) plus applied water estimates of ET. You'll notice the meteorological estimates closely follow the curve of the CIMIS ETo (potential evapotranspiration) while the NP estimates of ET jump up and down from one week to the next. This "saw tooth" pattern is due to the fact that the neutron probe does not adequately measure the moisture change in the top 3 to 5 inches of soil and, therefore, it doesn't record the additional stored water shortly after an irrigation when this zone is very wet, or the depletion of this moisture when it is very dry just before an irrigation. So when you add in the depth of applied water (measured by a small flowmeter in the hose and calculated over the wetted area) this method overestimates ET when soil moisture readings are made just after irrigation and underestimates ET when readings are taken just before the irrigation. However, if these weekly estimates are used as a cumulative sum over time and there is virtually no percolation of water below the rootzone at the measurement site (which is the case in this study area as shown by the lack of leaching of salts) then the cumulative NP estimate of ET should basically equal the applied irrigation plus additional moisture depletion and agree with the meteorological estimates of crop ET, which it does very nicely as shown in **Figure 2.** (During the season there is virtually no leaching past the 5 foot depth in the Fanjet block and none past 7 feet in the Drip block, with the average water content at these depths showing a slow decline over the season.

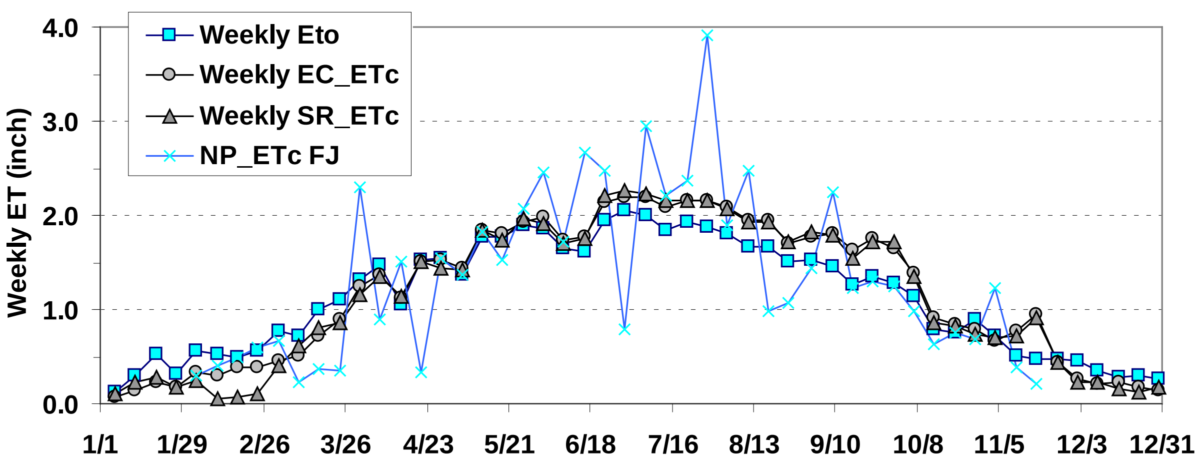

Figure 1. Weekly Fanjet ET from eddy covariance (EC), surface renewal (SR) and neutron probe soil moisture depletion/applied water (NP) compared to the Belridge CIMIS ETo for 2009.

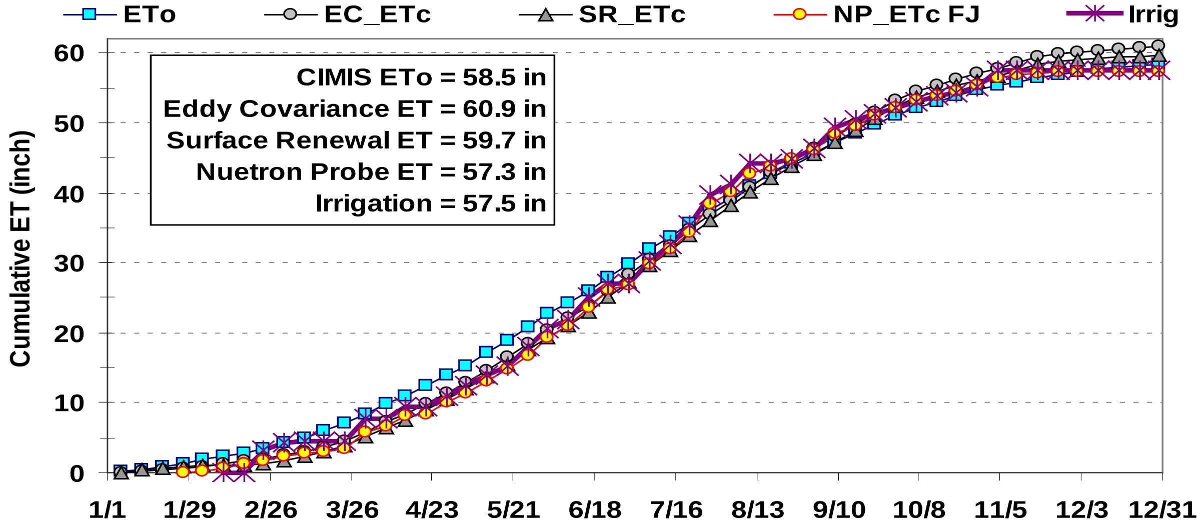

Figure 2. Cumulative CIMIS ETo, crop ET and applied irrigation for the 2009 season.

One of the important goals of crop water use research for arid irrigated climates like the Central and San Joaquin Valley is the determination of “crop coefficients” (Kc) for various crops. The idea is that this coefficient for a given crop is constant for that species for a given growth stage and canopy cover. So if you have appropriate Kc values over the season you can estimate the expected crop ET based on weather data for that particular area. For example: the California Irrigation Management Information System (CIMIS) has divided CA into 18 climate zones with “historic (average) ETo” (basically pasture grass ET) that ranges from a yearly total of 33 inches on the north coast to 72 inches in the Imperial Valley. Just multiply the local historic average ETo, or the real-time CIMIS ETo, by the right Kc for a given week to get a reasonable estimate of the crop ET for a particular zone.

For more than 20 years the published Kc values for almonds on micro irrigation systems with minimum cover have peaked at 0.95 (95% of pasture ET. Snyder et al.,1989). This study has recorded weekly peak season Kc values of 1.15 and higher with no cover crop on the orchard floor using microsprinklers with about a 50% wetted area. Looking again at **Figure 1**, the EC and SR ET are slightly lower than the CIMIS Belridge ETo (Kc <1) until April, about equal (Kc = 1) till June and then exceeding ETo (Kc > 1) for the rest of the season. **Figure 3** compares the older published values with Kc’s developed by me through irrigation demonstrations and observations in high yielding orchards starting in 2002, and finally with average measured Kc’s from the last 3 seasons of this project. These values represent a 43% increase over the old water use numbers. Average almond yields in Kern County, however, have doubled over that same time period, giving a net increase in “crop per drop” water use efficiency.

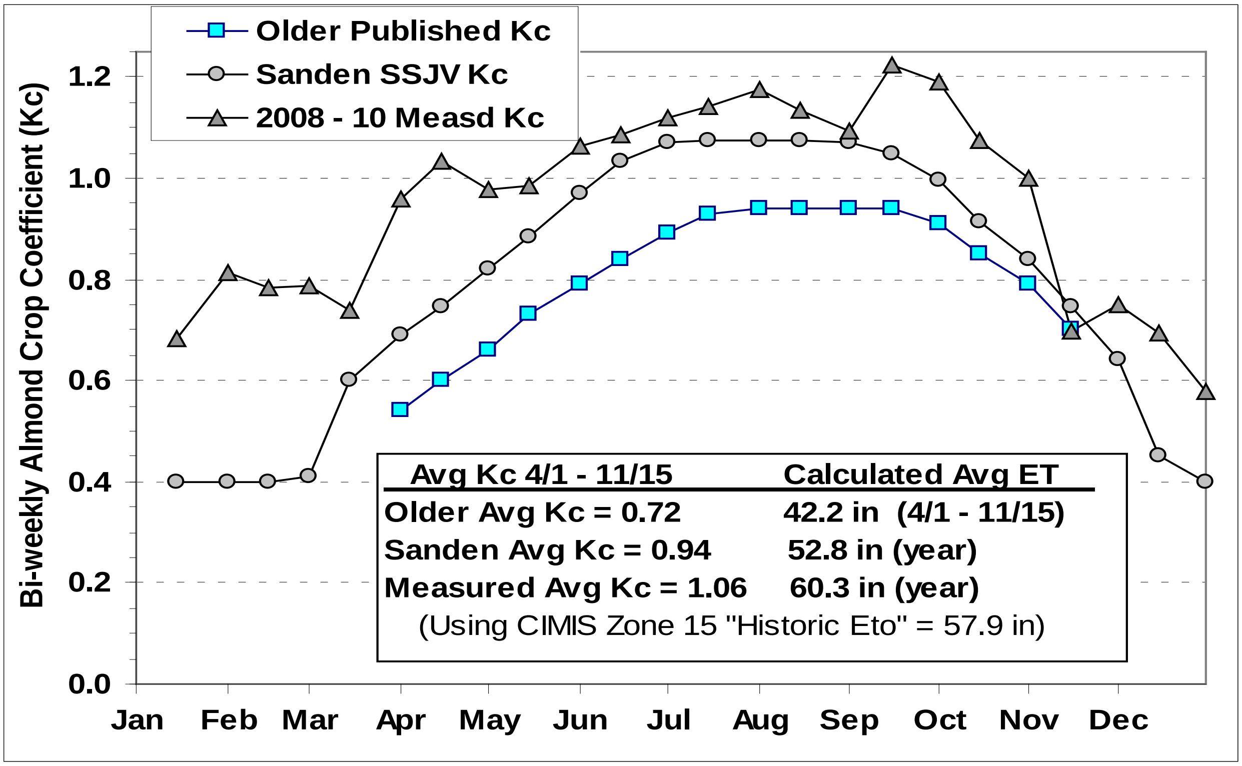

Figure 3. Comparison of Kc values for almonds over the season.

Disclaimer: This is not to say that optimum almond yield requires 60 inches of water. Thus far, this study claims only to document that almonds can use this much water under low to no stress conditions. This figure even includes a couple weeks with SWP < -15 bars (i.e. more negative, more stress). We had no hull rot problems in 2008, but significant strikes in 2009 in both drip and fanjet blocks, which is consistent with high water and N status in production almonds. (The low N rates did have fewer strikes.) 2009 yields were also lower than 2008 (**Table 1**), but this was generally true for the industry. As much as possible we will continue to irrigate with minimal stress.

Finally, **Table 1** lists fertilizer treatment and Drip vs. Fanjet averages for a variety of factors for replicated plots with intensively monitored soil moisture and tree SWP. Yields for the various N treatments are, therefore, different from the more complete set reported by Brown. Soil tests have shown nitrate to be very low, but it has taken two years to show a statistically reduced yield for the two lower N rates. (Brown's data for all 768 data trees shows a mixed response.) However, higher N rates have not resulted in significantly different NP estimates of individual tree ET and, therefore, not resulted in any differences in average soil water content in either year. As all plots receive the same amount of water, a higher level of water use by an individual tree should result in lower total average water content over the season. The cumulative NP ET in **Table 1** shows that fertilizer rate had no impact on ET.

The only consistent trend was season-long average soil water content to 9 feet was 17 to 22% greater under drip irrigation compared to fanjet under essentially the same irrigation schedule. This is, of course, due to the larger surface wetting and evaporation under the fanjets compared to the small wetted areas under drip emitters. This higher average soil water content also resulted in tree stem water potential (SWP) being less negative for drip irrigation as opposed to fanjet irrigation. As a ratio, fanjet SWP was 11 to 17% more negative (more potential stress) than the drip.

Table 1. Season long average stem water potential and soil water content and cumulative NP ET as measured by weekly soil water depletion and applied water. (2/7/08 to 11/17/08 and 1/27/09 to 12/2/09). Nonpareil kernel yield using final crackouts for 2008 and 2009 for neutron probe and SWP data trees only.

2008 Treatment (N-K lb/ac)	Stem Water Potential (bars)		Soil Water Content to 9 feet (in)		Cumulative Neutron Probe ET (in)		Final Kernal Yield (lb/ac)	
	Drip	**Fanjet**	**Drip**	**Fanjet**	**Drip**	**Fanjet**	**Drip**	**Fanjet**
125-200	--	-10.2 ab	--	12.6 a	--	55.3 a	--	3301 ab
200-200	-9.6 a	-9.7 b	16.8 a	14.9 b	54.5 a	56.1 a	3260 a	3360 b
275-200	-8.5 ab	-10.1 ab	17.4 ab	14.7 ab	57.3 a	57.7 a	3997 b	3338 ab
275-300	-8.4 b	-10.3 a	16.8 b	12.9 ab	55.9 a	55.3 a	3839 ab	3370 a
350-200	-9.5 ab	-10.0 ab	15.4 ab	13.9 ab	56.2 a	55.6 a	3518 ab	3963 ab
AVERAGE	**-9.0**	**-10.0**	**16.6**	**13.8**	**55.9**	**56.0**	**3653**	**3467**
LSD 0.05	*1.1*	*0.6*	*2.3*	*2.3*	*4.8*	*2.5*	*715*	*517*

2009 Treatment (N-K lb/ac)	Stem Water Potential (bars)		Soil Water Content to 9 feet (in)		Cumulative Neutron Probe ET (in)		Final Kernal Yield (lb/ac)	
	Drip	**Fanjet**	**Drip**	**Fanjet**	**Drip**	**Fanjet**	**Drip**	**Fanjet**
125-200	-9.6 a	-10.5 ab	18.0 a	14.2 a	54.9 a	56.9 a	2722 a	3027 ab
200-200	-9.3 ab	-10.4 b	18.2 a	17.1 b	58.2 a	57.6 a	2642 a	3005 a
275-200	-8.9 b	-11.1 a	18.8 a	15.8 ab	60.5 a	58.3 a	3524 b	3164 abc
275-300	-8.3 c	-11.0 ab	18.6 a	14.2 a	59.2 a	57.0 a	3572 b	3783 c
350-200	-9.7 a	-11.0 ab	15.3 a	14.9 ab	58.3 a	56.5 a	3727 b	3858 bc
AVERAGE	**-9.2**	**-10.8**	**17.8**	**15.2**	**58.2**	**57.3**	**3237**	**3367**
LSD 0.05	*0.6*	*0.7*	*6.2*	*2.7*	*6.9*	*3.5*	*752*	*844*

References Cited:

Snyder, R.L., Lanini, B. J., Shaw, D. A., and Pruitt, W. O. 1989. Using reference evapotranspiration (ETo) and crop coefficients to estimate crop evapotranspiration (ETc) for trees and vines. Leaflet No. 21428, 8 p. UC Cooperative Extension, Department of Land, Air and Water Resources, 113 Veihmeyer Hall, University of California, Davis, CA 95616-8628.