Fertigation: Interaction of Water Management and Nutrient Management in Almonds

Project No.: **12-HORT11A-Sanden**

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Objectives:

- Determine actual almond ET under truly non-stressed conditions using two independent methods.
- Determine if differential fertilizer regimens, micro irrigation system type (drip vs. microsprinkler), and yield result in differential rootzone soil moisture, tree stress (SWP) and tree ET.

Interpretive Summary:

Based on data of measured orchard evapotranspiration (ET) over four full years, we have confirmed that previously published estimates of almond water use in the southern San Joaquin Valley were substantially below (about 40%) the maximum possible value. There was good agreement between ET estimated from meteorological and soil water balance methods. Almond ET can exceed 52 inches/year, but there is no evidence that an ET above 52 inches will result in higher yields and no evidence that ET increases with increasing levels of soil fertility. A relatively small but consistent reduction in the level of tree water stress, as measured using midday stem water potential (SWP) was associated with double line drip compared to microsprinkler irrigation, but further study will be required to determine if this was due to a higher irrigation efficiency (less soil evaporation with drip) or local variation in soils.

Materials and Methods:

A 9th leaf 150 acre almond orchard in NW Kern County with three 51 acre sets irrigated with microsprinklers (2 Fanjets @ 1.68 in/day) was selected for this trial starting February 2008. The eastern 2 sets are a uniform Milham Sandy Clay Loam. Past tissue tests showed uniformly low K levels, but fairly good yields (2,400+ lb/ac). The eastern set was retrofitted with double-line drip applying 1.67 in/day irrigation. A total of 40 water monitoring sites (4 replications each treatment, 20 drip, 20 fanjet) have been established over 5 different fertility treatments.

FERTILITY TREATMENTS TO BE MONITORED WEEKLY FEBRUARY - NOVEMBER:

	N (lb/ac)	K (lb/ac)		N (lb/ac)	K (lb/ac)
1.	125	200	**2.**	200	200
3.	275	200		(Grower standard)	
4.	275	300	**5.**	350	200

(UAN32, K from base 125 lb/ac banded K2S04, balance KTS)

3 REPLICATED NEUTRON PROBE SOIL MOISTURE & SAMPLING SITES / TREATMENT

One 2 inch x 9 foot deep Class 125 PVC tube in middle of the emitter pattern, 30 sites total (15 for each microsprinkler and double-line drip).

Annual soil sampling to 9 feet @ 1 foot from tube, December – January.

INTENSIVE SOIL WATER CONTENT MONITORING

4 additional access tubes installed at one of the high fertility sites to monitor water content change in all sectors of the wetted area.

1 site each for microsprinkler and drip systems.

SOIL WATER TENSION MONITORING

1 replication of each treatment to be outfitted with Watermark blocks at the 18, 36 and 60 inch depths adjacent to the NP access tube.

2 Irrometer loggers to be used to record readings @ 3 hour intervals.

SOIL MONITORING FREQUENCY

All neutron probe sites and flow meters read weekly March – November.

PLANT STRESS MONITORING

Weekly stem water potential (pressure chamber) May-October.

METEOROLOGIC HEAT FLUX MONITORING for ET (continuous)

A sonic anemometer, net radiometer, and high response air temperature thermocouples were installed above the canopy mid-March. In combination with soil heat flux plates and thermocouples installed at a 2 inch depth in 3 locations in the orchard floor these devices measure ET from the orchard by Eddy Covariance and Surface Renewal heat flux.

Results and Discussion:

Midseason (May – September) orchard ET, expressed as a Kc value to account for day-to-day differences in weather, consistently approached values of about 1.2 from 2008 to 2011, although it was substantially below this (about 1.0) in 2012 (**Figure 1**). Previous estimates for almond Kc showed a peak value of about 0.95 (**Figure 2**), so it is clear that the previous estimates for Kc, and hence almond ET, were substantial underestimates, particularly for the southern San Joaquin Valley. The large variations in measured Kc in the winter and spring (**Figure 1**) and large differences to the previous estimates at this time of year (**Figure 2**) have a relatively minor effect on annual orchard ET because overall evaporation rates at this time are low. It is important to note that the fundamental assumption of the Kc and ET approach to water management is that the 'true' Kc should only be established under non-water-limited conditions because plants generally reduce ET when soil water is limiting. Hence, our measured average Kc (1.04) and corresponding annual ETc (59.6 inches, **Figure 2**) should be the most correct estimate of non-soil-water-limited almond Kc. On an individual tree basis, ETc values approaching 64 inches per year were measured, but these high rates of ETc were not associated with any increases in tree yield (**Figure 3**), and hence it appears that while almonds can use this amount of water, yield may not respond to the increasing water use above about 52 inches. Our current Kc recommendation, then, is shown as the "Sanden SSJV Kc" (**Figure 2**), which corresponds to about 52 inches per year.

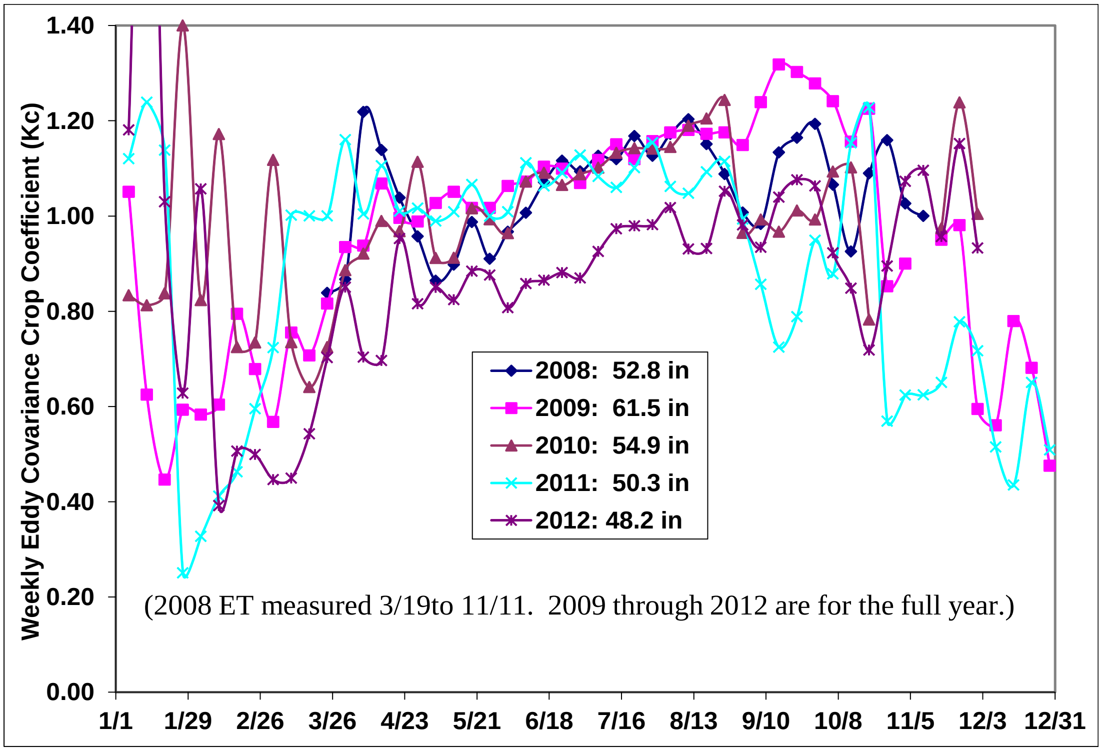

Figure 1. Comparison of 4 years of mature almond crop coefficients (Kc) generated from EDDY COVARIANCE heat flux estimates of crop ET divided by the modified Penman ETo from the Belridge CIMIS station #146, 1.5 miles due west of orchard.

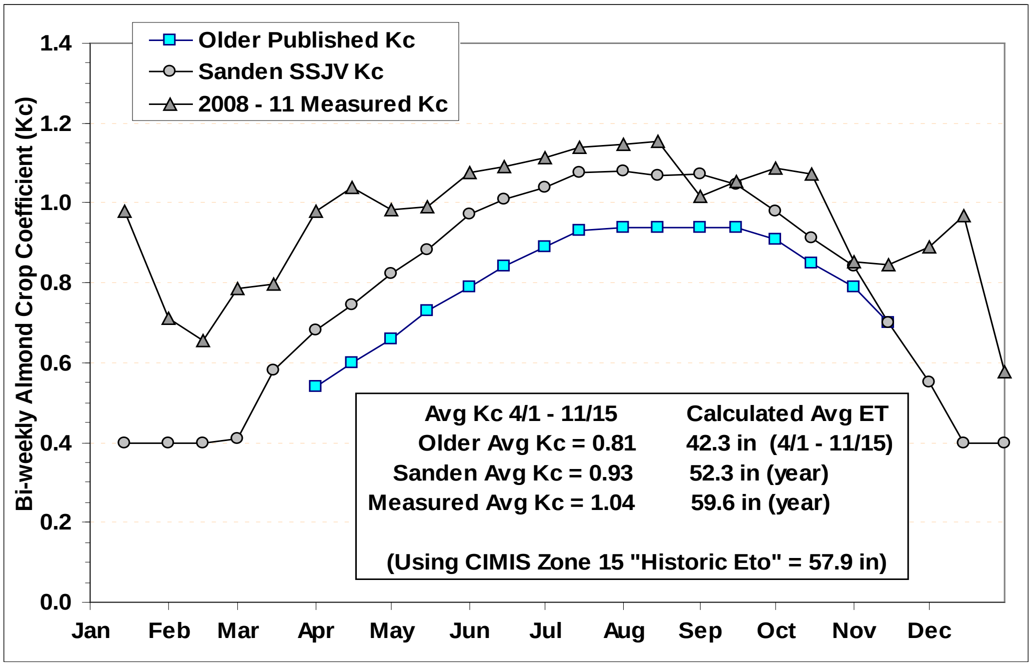

Figure 2. Comparison of older published crop coefficients, Kc, for almonds to current practice (Sanden SSJV) and the average of actual 2008-2011 measured values.

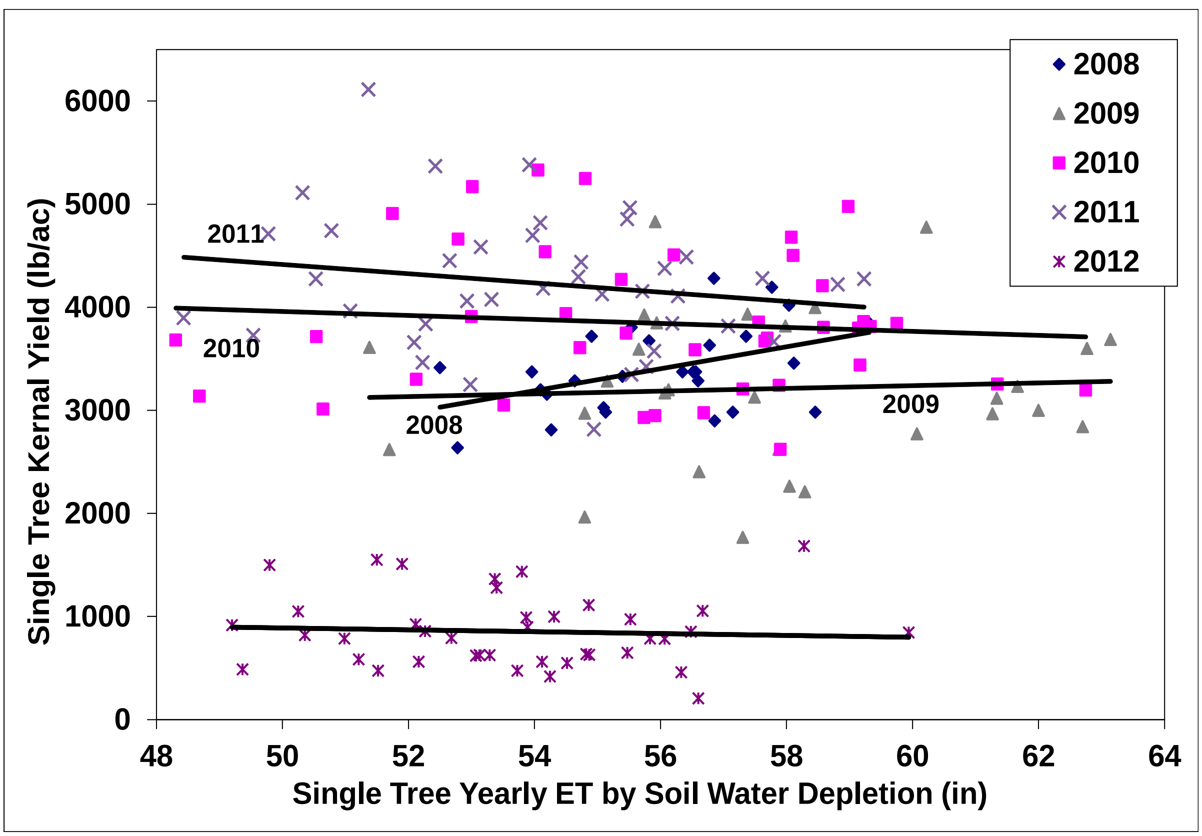

Figure 3. Yield variation as a function of tree specific ET estimated by weekly measurements of applied water and soil water content change.

Midday stem water potential (SWP) values over five years showed somewhat less stress for the double-line drip compared to the fanjet, as well as small increases in soil water content and yield (last two years shown in **Table 1**). However, since the drip and fanjet blocks were separate areas of the field it is not clear if these small differences were due to decreased water lost to surface evaporation in the drip or small differences in soils, This question is currently under investigation. No statistical difference was seen in individual tree ET due to N rate or yield (**Table 1**). Average tree ET estimated by applied water and water content depletion (neutron probe method) was virtually the same as that estimated by meteorological energy balance (eddy covariance, **Figure 1** and **Table 1**) except for 2011 and 2012, due to likely calibration errors in heat flux for those years. From 2009 through 2012, hull rot has been a problem- generally increasing every year. Alternaria and rust appeared starting 2011, but kernel yields increased every year from 2009-11, averaging 4,056 lb/ac/yr over this three year period for the 275 lb/ac N treatment. In 2012, yields crashed to an average of 816 – 818 kernel pounds/ac across the plots (**Table 1**), most likely due to carbohydrate depletion, poor bloom conditions, and severe stress/defoliation starting in August 2011 (**Figure 4**) resulting from low levels of soil moisture after attempts to control hull rot with regulated deficit irrigation during hull split. Some tree SWPs reached -20 bars. During 2012 there were four fungicide applications, but still significant infestations of hull rot, some rust, and some alternaria were accompanied by substantial leaf drop over the season. However, the orchard was virtually unstressed the whole 2012 season (**Figure 5**); averaging a season-long SWP of -7.6 and -8.5 bars for the drip and fanjet irrigation, respectively. Net water use efficiency was 93% to 95%.

Table 1. Seasonal averages and totals for SWP, soil moisture, irrigation, ET, and yields by N-K rate for 2011 and 2012.

2011 Treatment (N-K lb/ac)	Stem Water Potential (bars)		Soil Water Content to 9 feet (in)		Total Neutron Probe ET (in)		SWP-NP Tree Kernel Yield (lb/ac)		Whole Plot Kernel Yield (lb/ac)	
	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet
125-200	-9.3 b	-10.3 a	17.1 ab	15.5 a	53.8 a	54.7 a	3917 a	3659 a	3653 a	3798 a
200-200	-9.5 a	-10.4 a	17.5 ab	15.5 a	53.7 a	53.4 a	4034 a	3951 ab	4123 ab	4012 a
275-200	-9.3 b	-10.5 a	19.4 b	18.0 a	54.1 a	54.2 a	4621 b	4365 bc	4670 b	4416 b
275-300	-9.3 b	-10.4 a	17.6 ab	16.1 a	54.6 a	53.7 a	4586 b	4702 c	4886	4447 b
350-200	-9.0 c	-10.5 a	15.3 a	16.5 a	55.2 a	52.8 a	4596 b	4273 bc	4854	4476 b
AVERAGE	**-9.3**	**-10.4**	**17.4**	**16.3**	**54.3**	**53.8**	**4351**	**4190**	**4437**	**4230**
LSD 0.05	*0.2*	*0.2*	*2.7*	*2.9*	*4.0*	*2.9*	*539*	*472*	*557*	*313*

2012 Treatment (N-K lb/ac)	Stem Water Potential (bars)		Soil Water Content to 9 feet (in)		Total Neutron Probe ET (in)		SWP-NP Tree Kernel Yield (lb/ac)		Whole Plot Kernel Yield (lb/ac)	
	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet	Drip	Fanjet
125-200	-7.5 a	-8.2 c	17.7 ab	16.3 a	53.3 a	53.5 a	754 a	865 a	894 a	757 ab
200-200	-7.6 a	-8.4 b	17.9 ab	16.3 ab	55.1 a	51.4 a	630 a	911 ab	680 a	765 ab
275-200	-7.5 a	-8.4 b	18.3 ab	20.0 b	54.9 a	54.2 a	860 a	1165 bc	833 a	939 b
275-300	-7.5 a	-8.8 a	18.3 ab	17.5 ab	56.2 a	52.2 a	744 a	810 a	767 a	677 a
350-200	-7.7 a	-8.4 bc	16.0 a	18.3 ab	54.2 a	51.4 a	943 a	1012 ab	903 a	954 b
AVERAGE	**-7.6**	**-8.5**	**17.6**	**17.7**	**54.7**	**52.5**	**786**	**952**	**816**	**818**
LSD 0.05	*0.3*	*0.2*	*2.9*	*3.7*	*2.9*	*3.8*	*317*	*282*	*228*	*229*

Figure 4. Defoliation in Nonpareil and Monterey (10/6/11).

Figure 5. Late Nonpareil harvest with significant leaf drop, but unstressed trees with full canopy and excellent shoot/spur development for 2013 (9/6/12).

Research Effort Recent Publications:

None at this time.