Fertigation: interaction of water and nutrient management in almonds – monitoring water use (ET), stress & yield impacts (12.HORT11A)

(Joint project with Shackel: Advanced sensing & management technologies in specialty crops: case studies of water & N in almonds under normal & resource-limited conditions.
Brown: Development of a Nutrient Budget Approach To Fertilizer Management In Almond)

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Introduction

Competition for fresh water in California has in-creased dramatically over the last 30 years. Municipal and environmental water demands over this period have increased by 2 million ac-ft (MAF) per year, while water exports to agriculture have declined by nearly the same amount. Ag has made up the difference by fallowing acreage, pumping more groundwater and increasing water use efficiency.

Almonds have been one of the bright spots in this setting as worldwide markets have expanded to keep pace with higher yields due to improved irrigation and production practices (Figure 1) that have maintained price and profitability for the grower.

Improved varieties, planting, pruning and pollination practices have all contributed to this increase, but some of the most significant yield increases have been realized through the use of micro-irrigation, fertigation and improved understanding of the crop water use (ET) of almonds. In an era when regulators are stressing water conservation it is essential to scientifically document this ET potential that is essential for achieving high yields and is 25% more than the University of CA estimates from 30 years ago (Figure 3).

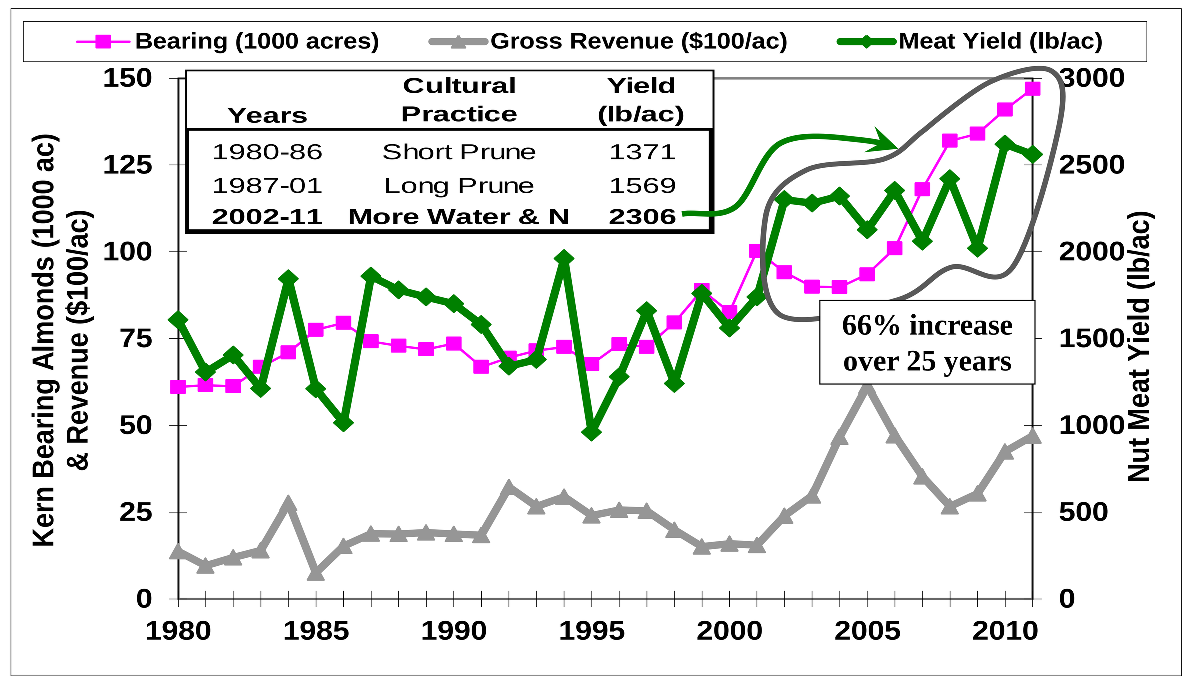

Fig 1. Changes in Kern almond acreage and yield, 1980-2011.

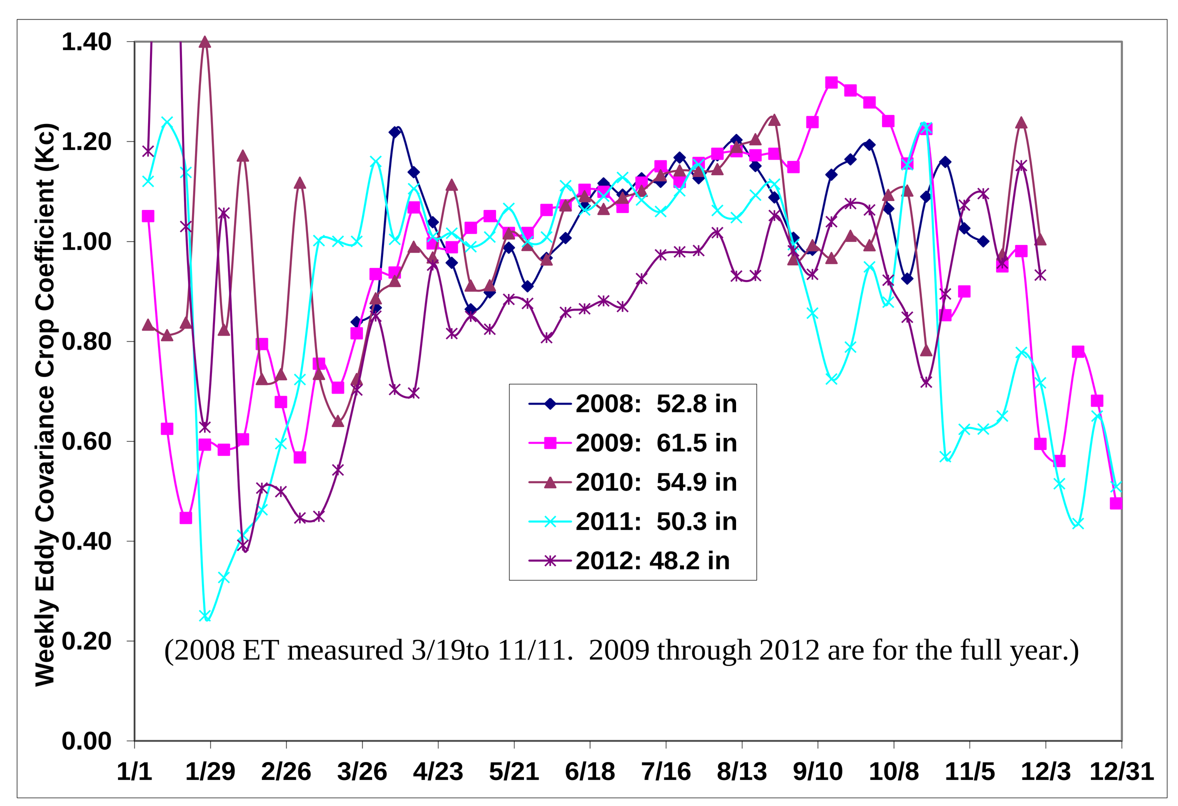

Fig. 2. Comparison of 4 years of mature almond crop coefficients (Kc) generated from EDDY COVARIANCE heat flux estimates of crop ET divided by the modified Penman ETo from the Belridge CIMIS station #146, 1.5 miles due west of orchard.

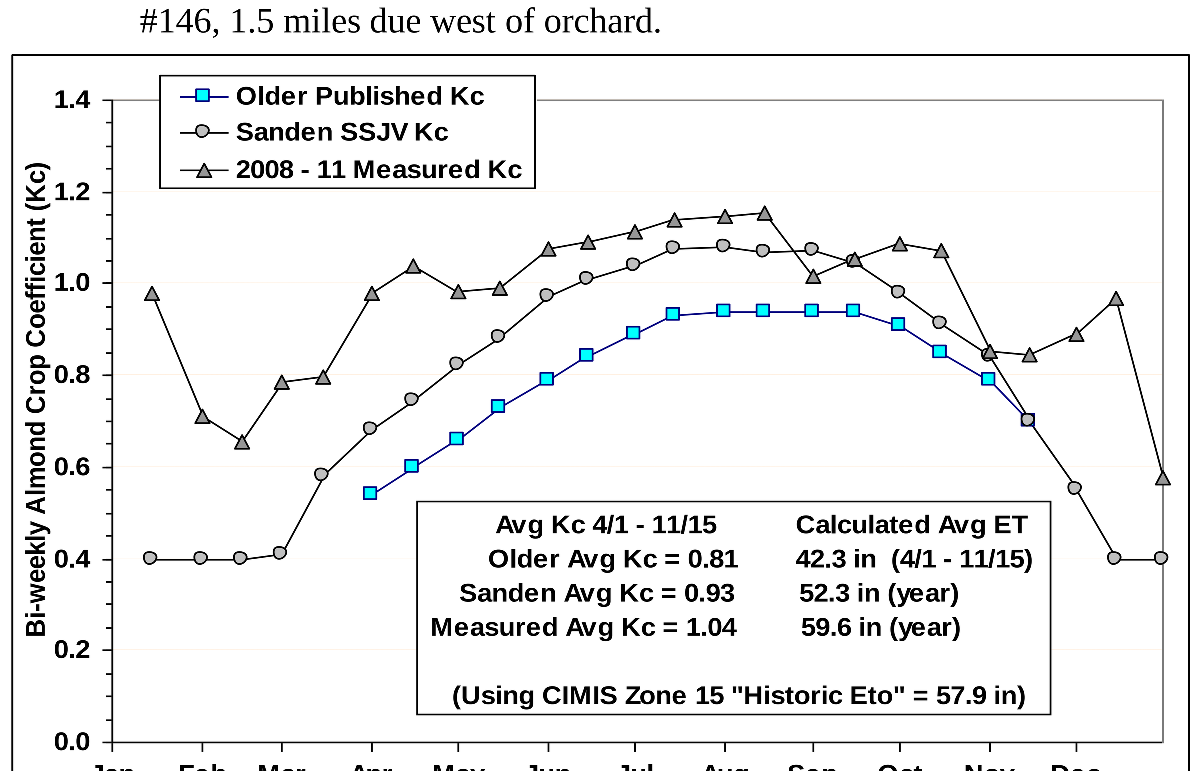

Fig. 3. Comparison of older published crop coefficients, Kc, for almonds to current practice (Sanden SSJV) and the average of actual 2008-2011 measured values.

Objectives

- Determine actual almond ET under truly non-stressed conditions using 3 different 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.

Materials and Methods

Site Layout: 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 (2400+ 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 (see Brown, et al for a fuller description).

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)

4 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, 40 sites total (20 each for microsprinkler and double-line drip)

Annual soil sampling to 9 feet @ 1 foot from neutron probe tube, Dec-Jan.

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, 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

Bagged stem water potential (SWP) values over five years were less negative (less stress) for the double-line drip compared to the fanjet due to decreased water lost to surface evaporation. 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 886 lb/ac (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 hullsplit. 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 accompanied by substantial leaf drop over the season. However, the orchard was virtually unstressed the whole 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 is 93 to 95%.

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 2 and Table 1) except for 2011 and 2012, due to likely calibration errors in heat flux for those years. The average measured seasonal Kc value was 1.04 (excluding 2012, Figure 3), with peak season values reaching as high as 1.18. N fertilizer rates were just starting to impact yield in 2009, but there is no correlation with crop load/kernel yield and tree ET for individual trees in this study (Figure 6).

Conclusions

More water likely went to actual transpiration in the Drip than the Microsprinkler – as indicated by less negative SWP. Almond ET is much greater than earlier published values and can exceed 52 inches/year, but individual tree ET above 52 inches does not consistently result in higher yields (Figure 6).

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

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

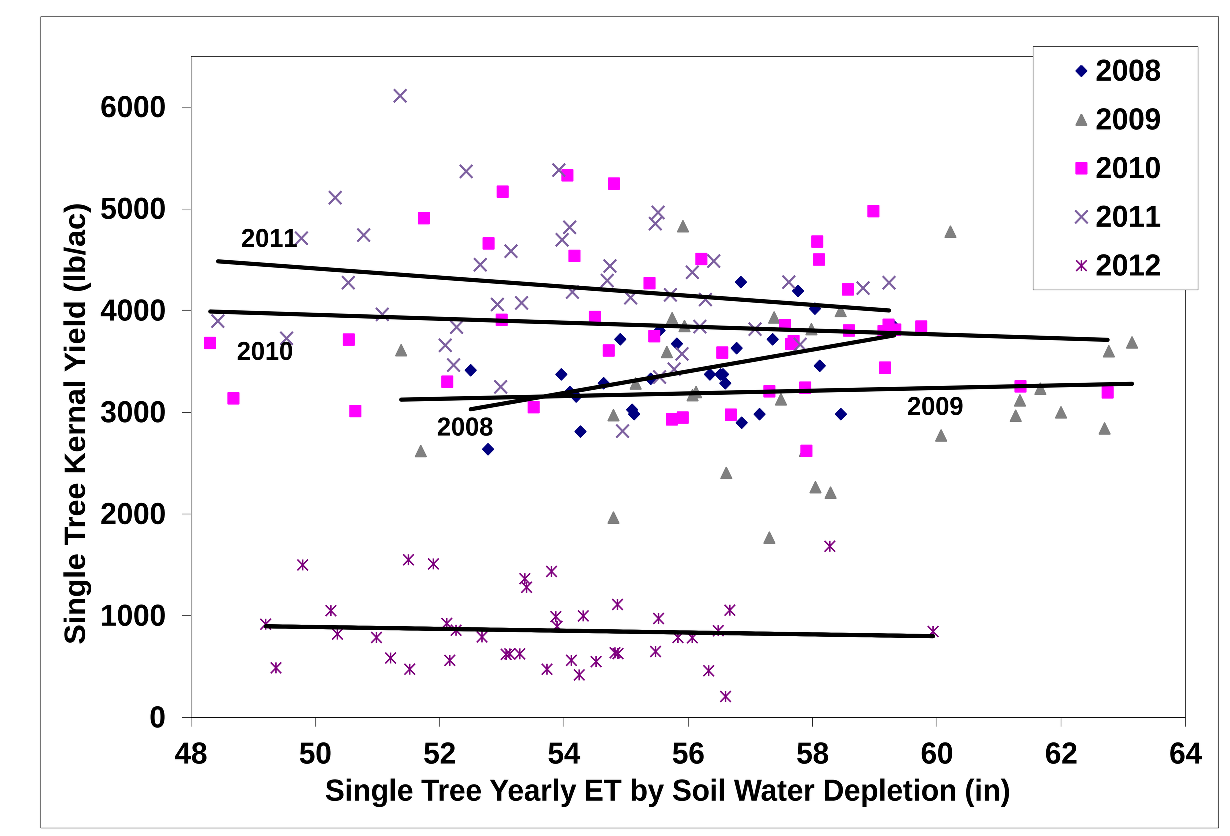

Fig 6. Yield variation as a function of tree specific ET estimated by weekly measurements of applied water and soil water content change.

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) Drip	Stem Water Potential (bars) Fanjet	Soil Water Content to 9 feet (in) Drip	Soil Water Content to 9 feet (in) Fanjet	Total Neutron Probe ET (in) Drip	Total Neutron Probe ET (in) Fanjet	SWP-NP Tree Kernel Yield (lb/ac) Drip	SWP-NP Tree Kernel Yield (lb/ac) Fanjet	Whole Plot Kernel Yield (lb/ac) Drip	Whole Plot Kernel Yield (lb/ac) 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) Drip	Stem Water Potential (bars) Fanjet	Soil Water Content to 9 feet (in) Drip	Soil Water Content to 9 feet (in) Fanjet	Total Neutron Probe ET (in) Drip	Total Neutron Probe ET (in) Fanjet	SWP-NP Tree Kernel Yield (lb/ac) Drip	SWP-NP Tree Kernel Yield (lb/ac) Fanjet	Whole Plot Kernel Yield (lb/ac) Drip	Whole Plot Kernel Yield (lb/ac) 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*