

Fall Irrigation Management in a Drought Year for Almonds, Pistachios and Citrus

September 2007

Well, we're almost through the irrigation season; certainly past the period of peak demand. There really haven't been any surprises. The State Water Project districts got a 60% allocation and the federal Friant (eastside) districts got 50% with the announcement of a little 10% boost the end of July, and everyone is sucking hard on the groundwater wells to make up the difference.

So why put out an irrigation management letter now? There are really two reasons: 1) To give a brief practical review of what we do and don't know about water saving techniques like deficit irrigation and eliminating post-harvest irrigations, and 2) To start people thinking about options for fall plantings and how to handle probable water shortages in 2008.

ALMONDS

Ah yes, the poster child of annual to permanent crop conversion in the San Joaquin Valley. Almonds are about the best example of what we do and don't know about how to irrigate permanent crops. During the late 1980's and through the 1990's Dave Goldhamer did some excellent almond irrigation trials looking at the impact of increasing preharvest irrigation cutoff duration, post-harvest irrigation and different scenarios of "regulated deficit irrigation" (RDI).

POST-HARVEST IRRIGATION: Do not scrimp on post-harvest and September irrigation of almonds.

The most telling result of all these trials was that the old practice of ceasing irrigation of almonds after harvest had the single worst impact on yield (Goldhamer and Viveros, 2000). Unlike many other stone fruits, peaches for example, almonds differentiate their fruiting buds during and after harvest. So it is imperative to relieve the stress on the tree as soon as you get the nuts off. This means that early varieties like Nonpareil need 8 to 10 inches of post-harvest irrigation while the late hard shells like Fritz may need only 4 to 5 inches post-harvest (assuming full irrigation till the normal harvest cutoff). The bottom line is almonds should be non-stressed during September. In the Goldhamer/Viveros trial, imposing a complete post-harvest irrigation cutoff resulted in an 800 lb/ac yield loss the following year.

REGULATED DEFICIT IRRIGATION: Almond yield can be reduced by deficit irrigation imposed any time during the season.

In a five year trial from 1992 to 1996 Goldhamer, Viveros and Salinas (2005) imposed 10 various scenarios applying 55, 70, 85 and 100% of full ET. The least damaging deficit treatment was the 85% application where only 50% of ET was applied during June and the first half of July prior to hull split. (This is now the general strategy recommended for hull rot control as explained later.) The difference between this treatment and the 100% control was not statistically significant.

Table 1. Simplified average results of 5 year regulated deficit irrigation (RDI) trial in almonds.

ET Treatment	Irrigation (inch)	Kernal Weight (g)	Yield (lb/ac)	*Predawn LWP	
				July (bars)	August (bars)
55%	22.8	1.13	1503	-17	-24
75%	28.3	1.17	1639	-11	-22
85%	33.8	1.24	1722	-10	-23
100%	42.1	1.30	1870	-6	-15

*Approximate average of treatment leaf water potential for the month as measured within 1 hour of dawn.

ALMOND WATER USE, EVAPOTRANSPIRATION (ET): Why was 100% almond ET estimated to be about 42 inches in the 1980’s and 1990’s while most growers now apply 48 to 56 inches? Were the earlier numbers wrong?

The short answer is NO – the earlier numbers weren’t wrong, but many of our earlier assumptions about the performance potential and management of almonds were wrong. We assumed that a flood irrigation event every 2 weeks was plenty to recharge the rootzone and let the trees pull out water under non-stressed conditions. We also assumed that full cover mature orchards with micro systems had 15 to 20% less ET because there was not an active cover crop in the middle, and we watered accordingly. We pruned trees back to 3 scaffolds, whacking off lots of potential fruit wood and assumed we needed that much light and “shape” to the tree. We fertilized with only 150 to 200 lb/ac N and we thought that 2,000 lb/ac was a top-drawer yield. So under these assumptions of almond potential using that kind of tree it’s not a big surprise that neutron probe studies by the California Department of Water Resources and several University of California trials came up with the 40 to 42 inch number for ET. So that number was “right” for the ET of those trees, but the management assumptions for maximum production were wrong.

CHANGES IN ALMOND MANAGEMENT AND ET: Long-pruning, more precision of high frequency micro-irrigation, increase applied water and increasing fertility have increased yield, ET.

Figure 1 illustrates changes in almond acreage and yield in Kern County since 1980. The inset box identifies major changes in agronomic practice. The average yield for 2002-2006 increased by 706 lb/ac compared to the previous 14 years. While weather conditions and pest pressure have been good for most of these years, the major difference was the application of more water and N fertilizer applied in a timelier manner through micro-irrigation systems.

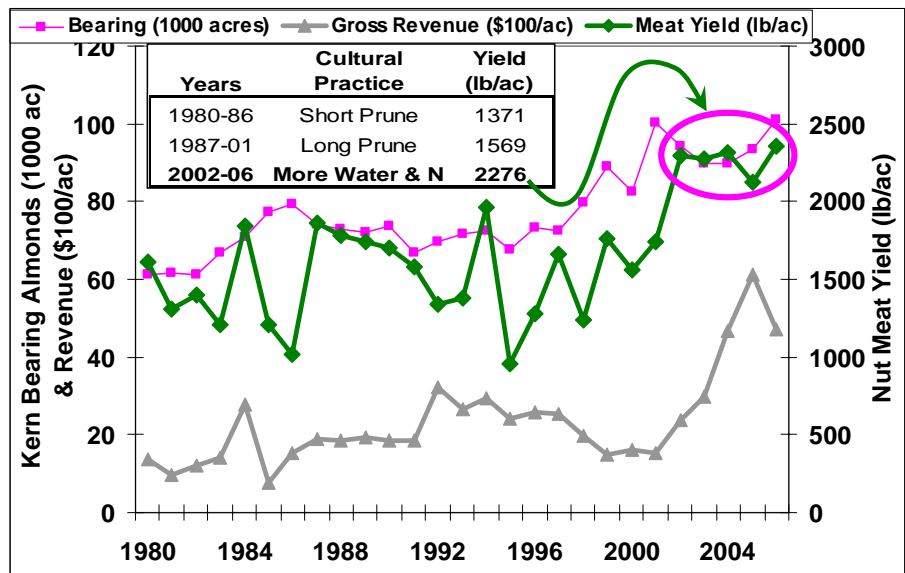


Fig. 1. Changes in Kern County almond acreage, gross revenue and yield from 1980 through 2006.

Starting in 2002 I began a program of soil moisture monitoring demonstrations in various crops around the county with a significant focus on almonds. The neutron probe and soil moisture tension data that I recorded showed that vigorous orchards were losing stored soil moisture by June even though our irrigations were keeping up with the old crop coefficients (Kc) and calculated 42 inch demand. Some of our best Kern farmers and managers saw the same thing in their own orchards and began increasing irrigation applications to finish the season with 50 to 54 inches of applied water. Average almond yields have increased beyond anyone’s expectation from ten years ago.

Spur Dynamics The best illustration of this change comes from a long-term trial initiated by Bruce Lampinen in 2001 with Paramount Farming in a Lost Hills block of almonds. The main point of this trial is to track spur development and decline starting with a 5th leaf orchard. The treatments compare the ranch “Full” irrigation, averaging 54.4 inches/year, to a “25% Reduced” irrigation that has averaged 44.0 inches/year and two rates of Nitrogen @ 250 or 125 lb/ac. The results are very striking. Loss of fruiting spurs on the lower canopy is accelerated by decreased light from more vigorous tree growth from higher amounts of applied water and fertilizer, but the tree more than compensates with development of new spurs. Average kernel yields from 2002-6 for the “Full” irrigation at 2,646 lb/ac at the 250 lb/ac N rate are significantly greater than the 2,150 lb/ac for the “Reduced” irrigation at the same N rate.

Westside Almond Irrigation & N trial – Yields, applied water, & 2003 soil moisture.

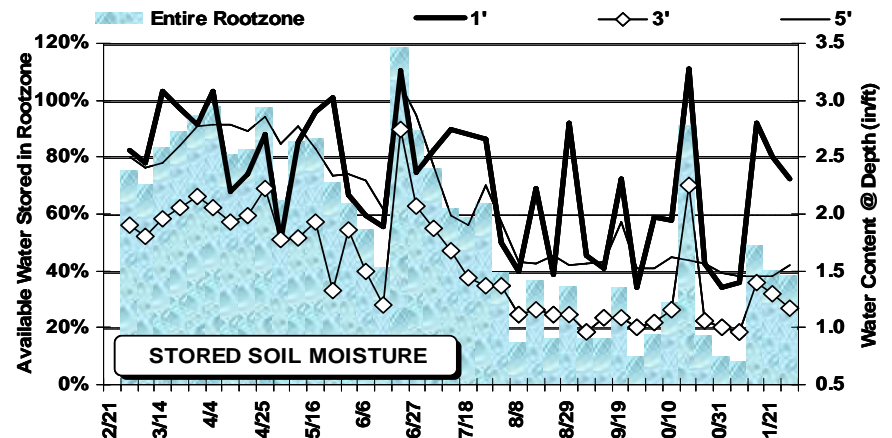
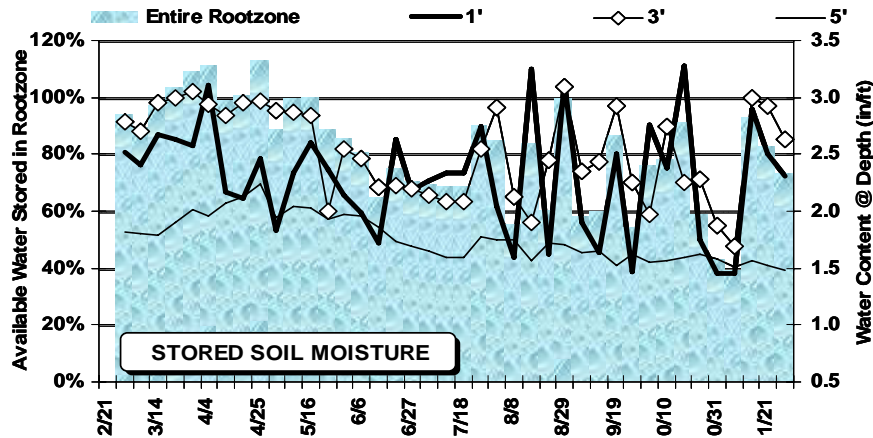
Full Irrigation
57.6 Total for 2003
3.2" Dormant Refill
54.4" In-Season

Nonpareil yields (lb/ac) by applied irrigation & N fertilizer
(lb/ac) (starting year 5th leaf, NW Kern)

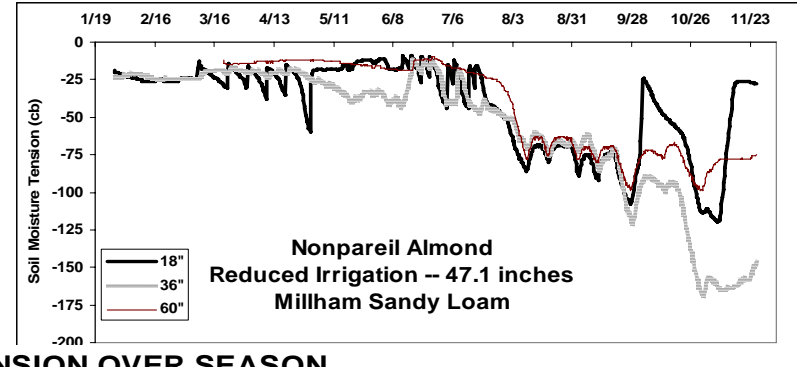
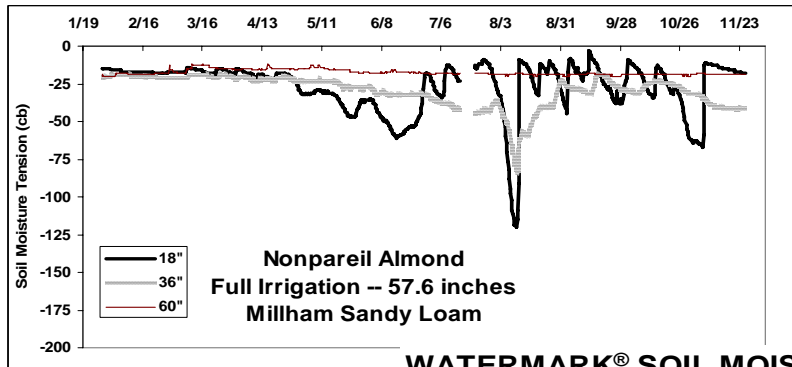
	Full Irrigation			Reduced Irrigation		
	(in)	N~250	N~125	(in)	N~250	N~125
2001	?	1926	1898	(-25%)	1979	1992
2002	48.5	1922	1275	38.8	1593	1215
2003	57.6	3004	2030	47.1	2352	1901
2004	59.7	2838	2752	47.9	2307	2209
2005	53.8	2227	1493	44.5	1758	1538
2006	52.5	3241	2697	41.5	2739	2330
2002-6	272.1	13232	10247	219.8	10749	9193
Wtr Use Eff (lb/in)	48.6	37.7		48.9	41.8	

Lampinen, B., T.Dejong, S.Weinbaum, S.Metcalf, C. Negron, M.Viveros, J. McIlvane, N.Ravid, and R.Baker. 2007. Spur dynamics and almond productivity. CA Almond Board 2006 Conference Proceedings, 18pp.

Reduced Irrigation
47.9 Total for 2003
2.9" Dormant Refill
45.0" In-Season



NEUTRON PROBE WATER CONTENT OVER SEASON



WATERMARK® SOIL MOISTURE TENSION OVER SEASON

Fig. 2. Soil moisture water content (upper charts, inches/ft and % available) and soil moisture tension (lower charts, centibars as recorded by Watermark blocks) for Nonpareil trees in a mature block irrigated with micro sprinklers. Charts contrast soil water storage for the “Full” irrigation treatment (left) @ 57.6 inches with a 25% “Reduced” irrigation (right) @ 47.1 inches. The center table lists yields by irrigation and applied N.

The soil moisture charts pictured in Figure 2 are from 2003 but well represent what has happened over the course of this trial. You'll notice that stored soil moisture (the gray area) averages less than 50% available from July till the end of the season for the Reduced irrigation – even though this treatment received 45 inches of water during the growing season, which is 3 more inches than the old 42 inch standard. The Full irrigation was 54 inches of in-season water which allowed for average stored soil moisture of around 70% from July till the end of the year. The impact on nut yield speaks for itself.

MEASURING TREE STRESS – LEAF & STEM WATER POTENTIAL: We all know that dry soil stresses trees. We also know that we can measure the actual water potential (stress level) of plants using a pressure chamber (often called pressure “bomb”). What we don't know is the exact relationship between soil moisture storage and midday plant water potential because this is different for every field due to soil type, irrigation system and rootstock. We also know that too much water in the rootzone inhibits oxygen uptake, can promote phytophthora and other diseases like alternaria and hull rot. Much of the work in almonds and other tree crops in the last 15 years has focused on establishing appropriate tree water potential thresholds that identify different levels of stress to help in disease prevention (hull rot) and possibly improve harvest timing and quality (hull split/shell split for almonds and pistachios).

How does it work? LEAF WATER POTENTIAL (LWP) uses bare leaves, usually in full sun, to estimate the midday stress mostly in cotton and grapes, especially wine grapes. A continual moderate stress enhances fruiting and quality in these crops. The leaf is cut off near the cane or stem and the petiole (leaf stem) placed in a rubber seal in a metal top that twists onto the chamber with the leaf side placed in the chamber. Pressure is then applied to the leaf until the xylem sap becomes visible at the cut end of the petiole. The positive pressure it takes to force out the sap is equal to the negative “suction” on the water in the leaf. The greater the “suction” (actually the more negative the internal water potential) the more difficult it is for water to move through the leaf; reducing ET and photosynthesis and eventually causing the leaf to wilt. We usually measure this potential in “bars”. Essentially 1 bar is about equal to 1 atmosphere of pressure or 14.5 psi.

The preferred method for trees is to get an estimate of the water potential of the tree as a whole. The closest we can get to this is by measuring the STEM WATER POTENTIAL (SWP) by bagging or using a wet rag around interior, shaded leaves and letting them equilibrate with the water status of adjacent wood before cutting the leaf from the branch. A nice guide describing this technique has been prepared by Allan Fulton, UCCE Tehama County Irrigation Advisor, and can be found at the following link: <http://ucce.ucdavis.edu/files/filelibrary/2280/37294.pdf>. Through many different studies over the last 20 years we now have good guidelines for many tree crops as to what level of **midday (12 to 3 PM)** SWP indicates stressed or non-stressed conditions. These levels are different for different trees. For almonds: -6 to -10 bars is considered “no-stress”, -10 to -12 “mild stress” and -14 to -18 “moderate/increasing stress”. “Moderate stress” has been shown to reduce hull rot and cause earlier/more rapid hull split. At this point you are reducing crop ET. In the **Spur Dynamics** trial just mentioned, the seasonal average SWP was -9.6 bars for the “Full Irrigation” and -12.1 bars for the “Reduced Irrigation”. This produced a significant yield loss even though -12 bars is considered “mild stress”. SWP in the -20 to -30 bar range will lead to wilt and defoliation. A great summary table for almonds, walnuts and prunes can be found at: <http://ucce.ucdavis.edu/files/filelibrary/2280/37303.pdf>.

INTERACTION OF HULL ROT AND IRRIGATION: Hull rot is caused by two different fungi that can get a foot hold in almonds only when hull split starts. As soon as there is a tiny break along the suture this exposes a moist surface where the spore can germinate. The longer it takes for hulls to fully split to where the suture can then dry up, the more opportunity the fungus has to get a foot hold. The incidence of hull rot has increased in the San Joaquin Valley as we have increased irrigation and N to push up yield. Brent Holtz, Madera County UCCE Pomology Advisor, likes to call hull rot the “gout” of almonds since it is mostly seen in “well-fed, well-watered” orchards.

The first significant trial to zero in on the hull rot/irrigation interaction was done in 1990 through 1991 and built on Goldhamer's original harvest cutoff trial. The results were written up by UCCE disease

specialist Beth Teviotdale (1994) from the Kearney Ag Center. Pre-harvest irrigation cutoff of only 4 and 11 days had nearly 10 times the leaf strikes and inches of dead wood as in the other treatments that were 52 to 18 days of cutoff. No yield data was given. Detailed hull rot data was taken during two years (1994-5) of Goldhamer's RDI trial discussed earlier (Teviotdale, 2001). Hull rot in the 70% RDI treatment (reducing irrigation to 50% of normal from June 1-July 31, 100% the rest of the time) and 85% RDI treatment (50% irrigation from June 1-July 15 only, 100% all other times) was reduced by two to four times compared to "full" irrigation. The yield data reported in Goldhamer's study, however, shows the highest yield coming from the 100% irrigation (though not statistically different from the 85% RDI irrigation).

In these trials the reported "**predawn**" LWP was usually -10 to -20 bars. Using unbagged leaves just prior to sunrise should give a measure of the highest water potential (least negative, least stressed) condition for that tree for the coming day. The "**midday**" SWP, however, has become the standard as it reveals the maximum amount of stress experienced by the tree during the day, and of course this is the critical time for photosynthesis and crop development. Midday SWP can be 50 to 150% greater than predawn LWP depending on many factors. UC Davis crop physiology specialist Ken Shackel has built on these earlier hull rot trials along with other SWP data and, working with UC Farm Advisors from Kern to Chico, set up grower trials from 2001 to 2004 (Shackel, 2004). They attempted to maintain a SWP of -7 to -9 (no stress) till hull split and then maintain an SWP of -14 to -18 bars during hull split for the RDI treatment. In practice, the RDI averaged an SWP of -13.6 and the grower control averaged a SWP of -11.2. Hull rot strikes were reduced by about 1/2 on the average for the RDI treatment. The 2004 Madera site had a 5-fold reduction in strikes and a 17% increase in yield for the RDI treatment. But in general, there were no yield differences recorded for the other sites. I assume that the water savings was 3 to 6 inches (7 to 14%).

The most recent study by Shackel and others (2006) was a more carefully controlled experiment in Lassen County from 2004 to 2006. They successfully held the SWP at -14 to -18 bars during the RDI/hullsplit period each year, but this stress usually continued through August. In 2006, the fully irrigated trees used about 42 inches of water with the RDI using about 36, counting applied irrigation and soil moisture depletion. Yields for all treatments averaged about 2,000 lb/ac over all years, but in 2006 the RDI declined to 1,880 lb/ac with the grower control yielding 2,200 lb/ac. This difference was not statistically significant. No data on disease incidence was provided.

Does having hull rot reduce yields? Our own Kern County Almond Advisor Mario Viveros (recently retired, but still at the office most of the time) said last week that there has not yet been a trial designed that can truly answer that question. Most of the time the tree appears to compensate with new fruit wood higher up on the tree if water and N are adequate. However, if almond prices head south of \$1.20/lb growers may decide it's more profitable to tighten the belt for a couple years to reduce inoculums in the orchard, reduce costs and help stabilize prices with restricted supply – but this can be an "iffy" game. Just ask the raisin growers!!

PISTACHIOS This amazing tree does not have nearly the same amount of irrigation related studies that have been done in California as the almonds. We had no idea of appropriate water use / crop coefficient (Kc) values for California when the first commercial orchards were starting to mature. The very first irrigation study (Dave Goldhamer early 1980's) done on these trees in the San Joaquin Valley was accomplished using hand-move sprinkler lines with irrigation applied once every 2 weeks on some fine-textured Panoche clay loam south of Kettleman City. The purpose was to determine pistachio crop water use/Kc values. Everyone was amazed when Goldhamer reported a peak season Kc that was a high as cotton – 1.19. The most amazing thing is that, unlike the almonds, as pistachio orchards have been converted primarily to drip, we find that these first Kc values – and the average SJV water use of about 42 inches for pistachios – has remained fairly accurate. Some orchards with extremely high yield history use closer to 48 inches, and others affected by higher soil salinity levels or adjacent to unlined canals where the very long roots of these trees can suck up water from sand stringers fed by the ditch appear to get by with 30 to 35 inches. These trees are much tougher than almonds. With a thick waxy leaf cuticle they

have some capacity for “osmoregulation” (like citrus). The key to production, of course, is building carbohydrates for the heavy ‘on-year’ fruit load and getting the nuts to split.

REGULATED DEFICIT IRRIGATION CAN WORK IN PISTACHIOS: Goldhamer did a three year RDI/cutoff trial in the mid 1980’s to examine stress periods and the impact on yield and split %. Next years fruiting buds and most of the carbohydrate storage is finished by harvest time, (Sept. 1-15). **SO THE GOOD NEWS FOR THIS DROUGHT YEAR IS THAT IF YOU HAVE RUN OUT OF DISTRICT WATER YOU CAN CUT OFF IRRIGATION NOW AND WAIT UNTIL WINTER TO REFILL THE PROFILE WITHOUT HURTING NEXT YEAR’S CROP.** This can potentially save 6 to 8 inches of water. Goldhamer has also been testing the potential benefit of a 50% RDI level during shell hardening (May 16 – June 30) as a possible aid to making a weaker shell and increasing split %, but results so far indicate that final nut weight may be decreased. However, as a drought year management strategy this practice along with decreased post harvest can save almost a foot of water without major consequence to the current or next year’s crop. Table 2 below is borrowed from the 2005 Pistachio Production Manual (Ferguson, 2005) and is highly applicable as a one to two year drought strategy if water supplies are tight.

Table 2. San Joaquin Valley pistachio water use (ET_c) for normal and proposed regulated deficit irrigation (RDI) regimes. Irrigation schedule early in the season must take into account stored winter rainfall.

Growth Stage	Approximate phenology	ET _c Period	Reference water use K _c (inches)	Crop Coeff. period	Normal ET _c level (inches)	Proposed RDI ET _c (%)	Proposed RDI (inches)
Stage 1	Bloom	Apr 1-15	2.36	0.07	0.17	100	0.17
	Leafout	Apr 16-30	2.36	0.43	1.01	100	1.01
	Shell Expansion	May 1-15	3.19	0.68	2.17	100	2.17
Stage 2	Shell Hardening	May 16-31	3.40	0.93	3.16	50	1.58
	Shell Hardening	June 1-15	3.84	1.09	4.19	50	2.09
	Shell Hardening	June 16-30	3.84	1.17	4.49	50	2.25
Stage 3	Nut Filling	July 1-15	4.13	1.19	4.92	100	4.92
	Nut Filling	July 16-31	4.41	1.19	5.25	100	5.25
	Nut Fill./Shell Split	Aug 1-15	3.54	1.19	4.21	100	4.21
	Shell Splitting	Aug 16-31	3.78	1.12	4.23	100	4.23
	Hull Slip	Sept 1-15	2.66	0.99	2.63	100	2.63
Harvest	Harvest	Sept 16-30	2.66	0.87	2.31	25	0.58
Postharvest	Postharvest	Oct 1-15	1.71	0.67	1.15	25	0.29
	Postharvest	Oct 16-31	1.83	0.50	0.91	25	0.23
	Postharvest	Nov 1-15	0.80	0.35	0.28	25	0.07
TOTALS					41.10		31.70

CITRUS

Citrus in the southern SJV is the elder statesman of our permanent crops. Some groves in Tulare County go back nearly 100 years. Most growers and consultants I know are fairly happy with our old standard K_c value for citrus of 0.65. This means that over the year a citrus grove that covers 60% or more of the orchard floor will use about 65% of what pasture grass does over the year. There is some evidence to say that this number is closer to 0.75 in the cool winter and spring months, but on the average, most of our southern SJV citrus groves seem fairly happy with 34 to 36 inches of water/year. That said, if you have been very efficient and irrigating around that amount for the last 15 years you could

have some salt build up and find that the trees really improved in appearance and vigor the next year after you put on say 42 or 45 inches of irrigation and finally achieved some needed leaching.

SYSTEM PRESSURE, COVER CROPS CAN MAKE A BIG DIFFERENCE IN ET: Some unpublished work by Rick Snyder (UCCE statewide specialist for ET monitoring) has come up with some numbers to indicate higher water use in some groves, but this could be attributed to excessive pressure on the micro sprinklers, which caused the entire drive to get wet and produce an actively growing cover crop. Evaporation and cover crop use make a big difference in citrus ET. If you want to keep around that 35 inch ET then keep the wetting pattern under the skirt of the tree.

WHAT ABOUT RDI FOR CITRUS: Craig Kallsen, our Subtropical Horticulture and Pistachio advisor for Kern County put out a nice recap on this in his June 2007 Newsletter (<http://cekern.ucdavis.edu/newsletterfiles/newsletter632.htm>). RDI work by Dave Goldhamer showed a significant decrease in puff and crease in Frost Nucellar and held back excessive large size in Lane Late Navels that is a problem for the Tulare guys picking spring navels. Kern growers may be more interested in results from a trial that Craig and I are doing in early Becks down near Mettler. This is only the second year so the verdict is far from in, but the general objective is to irrigate the trees at about 50% ET starting around mid-August, maintaining a significant stress of -15 to -20 bars shaded LWP to accelerate the color break and increase the sugar-acid ratio to improve fruit quality for an end of October harvest. The treatments are: 1) 150% ET, -6 to -10 bars 2) 100% ET, -10 to -15 bars 3) 50% ET, -15 to -20 bars. Crop quality improvements in 2006 were limited to a higher level of “orange color” at harvest and more soluble solids in the RDI treatment. Stress levels did not reach our -20 bar target until harvest, but there was no adverse impact on tonnage or packout. Applied water from mid-August to mid-October harvest cutoff was 11.2, 8.1 and 5.0 inches for the 150, 100 and 50% ET treatments, respectively. So we saved 3 inches, which is \$45 when water costs \$180/ac-ft. We’ll keep you posted on this trial.

SPECIAL REQUEST TO ALMOND AND PISTACHIO GROWERS:

Are you happy with your fertility management?

Complete an online survey to help us, help you maximize your returns and optimize fertilizer use:

<http://education.ucdavis.edu/research/nutsurvey/>



This survey is being conducted by researchers at UC Davis with funding from the Almond Board, the Pistachio Commission, and the Fertilizer Research and Education Program.

UPCOMING MEETINGS YOU DON'T WANT TO MISS!! (most with PCA and CCA credits)

Kearney Alfalfa and Forage Field Day: Thursday, September 13, 2007 8am -12 pm

Kearney Research and Extension Center, 9240 South Riverbend Avenue, Parlier, CA 93648
Via Hwy 99, exit Manning Ave. Go east 8 miles to Riverbend Ave. Turn right, go one-quarter of a mile.

Shafter Research & Extension Center Cotton Field Day: Tues, Sep 18, 2007 9am -1 pm

Shafter Field Station, 17053 N. Shafter Ave, Shafter. BBQ lunch free!!

2007 California Alfalfa & Forage Symposium: Tour: Dec. 17. Meeting Dec. 18-19, 2007

Portola Plaza Hotel, Monterey **Details:** <http://alfalfa.ucdavis.edu/2007AlfalfaConference/>

2008 Annual Meeting California Irrigation Institute: "Warming to the Future- impacts on irrigation" January 31st & February 1st, 2008 Red Lion Hotel, 1401 Arden Way, Sacramento, CA

<http://www.caii.org/2008conftemp.htm>

2008 Plant & Soil Conference, CA Chapter American Society of Agronomy:

February 5-6, 2008 Holiday Inn Visalia, CA **Upcoming details:** <http://calasa.ucdavis.edu/>

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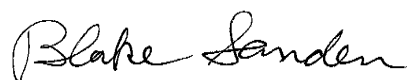
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