Almond Orchard Profitability & Longevity Under Differential N Fertility & Irrigation

Project No.: **13-HORT11A-Sanden**

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Objectives:

This project is a follow-up to the earlier Brown fertility trials in the same orchard. After pushing these trees with high inputs resulting in high yields and disease incidence we will attempt to document:

1. The degree of long-term alternate bearing, which may develop after several years of high yields followed by a very low yield. Is this a one year carbohydrate recovery or the start of a regular “on-year / off-year cycle”?

2. Determine the impact of differential N fertilizer rates and two irrigation rates (conservative vs. full irrigation) on long-term yield, tree health/decline and orchard longevity.

3. Track nitrogen and water use efficiency (NUE and WUE) of respective treatments.

4. Estimate overall profitability and final efficiency of each treatment for 18 to 24 years of orchard life given achieved yields and tree decline.

Interpretive Summary:

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 (Teviotdale, et al., 1994, Goldhamer and Viveros, 2000, Goldhamer et al., 2005). The 2002-2008 Spur Dynamics Trial by Bruce Lampinen et al. (2007) 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.

Fast forward to the recently completed 2008 - 2012 Brown Fertility Trial (Brown, 2012) in Kern County that examined the yield impact of varying types and rates of nitrogen and potassium fertilizers (125 to 350 lb/ac N and 100-300 lb/ac K). The secondary objective of this trial was to insure non-stressed water status in the orchard through optimal irrigation scheduling and document actual tree ET. Very careful records of site applied water, soil moisture to a depth of 9 feet and in-orchard daily ET using Eddy covariance heat flux were tracked over 5 years. The result was an average January through December measured almond ET for microsprinklers with no cover crop for the southern San Joaquin Valley for 2008 through 2011 was 54.3 inches. (The average for truly unstressed conditions is probably closer to 58 inches, but was reduced for this study due to an attempt to reduce hull rot through deficit irrigation from July-August 2011 and minimal irrigation during Monterey harvest due to rain and trying to dry out nuts for pickup. This resulted in a season long ET of only 50.3 inches for 2011. However, hull rot was still a problem and the trees exhibited significant chloride toxicity and defoliation by early October.)

This season long ET of 54.3 inches is 29% 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). Individual tree ET estimated by soil water content change and applied water, regardless of N fertilizer level, ranged from 48.3 to 63.1 from 2008 to 2011 (10^{th} through 13^{th} leaf) for individual trees. The same individual tree kernel yields over the same period ranged from the equivalent of 1,700 to more than 6000 lb/ac. There was no relationship between yield and ET at the individual tree level – indicating that 48 inches maybe all the ET you need. (NOTE: As long as salt is not a problem, our best current estimate will be around 50 to 54 inches of in-season irrigation / ET may be sufficient for maximum yields.)

One of the disadvantages of increased water use by the trees has been increased disease incidence. Hull rot has been a significant problem since 2009 even though soil moisture was kept around 65% available, and has been positively correlated with increasing N fertilizer rates. Deficit irrigation prior to and during hull split (about 6 weeks prior to harvest) was implemented during 2010 and 2011, achieving tree stem water potentials (SWP) in the -14 to -18 bar range, but hull rot was still a problem both years. In 2011, scattered rains starting at the time of the Nonpareil harvest and continuing through the Monterey harvest necessitated reduced irrigation frequency in order to dry the orchard floor to get the nuts out. This resulted in complete depletion of soil moisture in the upper 4 feet of the root zone and forcing the trees to take up stored moisture below the 5 foot depth. Excessive chloride and sodium accumulations at this depth caused significant chlorosis and defoliation in addition to defoliation from hull rot. In addition to hull rot, rust, scab and alternaria were seen for the first time in this orchard in 2011. A four-spray fungicide program this year has minimized the incidence of these pathogens in 2012, but the lower canopy is still sparse in much of the orchard. 2012 Nonpareil yields declined severely from the previous 4,055 lb/ac three year average for the 275 and 350 lb/ac N rates to <1,000 lb/ac due to frost, alternate bearing and possible stress from the 2011 season.

Concerns over disease and increasing tree loss (which has been no greater than tree loss in the block planted on the southern border of the test block in the same year from the same stock) have raised concerns that we may be “killing the trees with kindness” using higher rates of N and applied water, which may significantly shorten orchard life. The purpose of this trial is to follow this orchard over the next 5 to 7 years looking at 3 nitrogen fertilizer rates (125, 200 and 275 lb/ac) and 2 rates of applied water (48 and 56 inches) and track disease incidence, tree decline / death and overall orchard profitability. 2013 is the 15th leaf year for this orchard. 2013 kernel yield averaged 3,824 lb/ac for the plots receiving 275 lb/ac N and 56 inches of water and averaged 3,478 lb/ac for the 275 lb/ac N plots receiving 48 inches of water. A statistically significant reduction of 9.1% kernel yield for a 15.3% reduction in water. No difference was seen in tree mortality or disease ratings.

Materials and Methods:

Treatments: 3 N rates: 125, 200 and 275 lb/ac (on same rate plots from last 5 years)
2 irrigation rates: 48 inch (PFC standard), 56 inch (Sanden ET)

Additional Fertility**:** Entire block gets 200 lb/ac K as 125 lb/ac winter SOP and 75 lb/ac KTS as fertigation over the season and 60 lb/ac P per year using UN32 and 10-34-0 (15 rows of spoon feed trial in Set 1 treated separately.) Fertigate 4 times/year reduced N rates achieved by turning off hoses.

Plot size, replication and irrigation: This study uses previous Brown N rate plots which are 15 trees long by 3 rows wide – one Nonpareil row in the middle with 2 Monterey buffer rows. For the 56" plots, add 1, 2-gph Netafim PC drip emitter adjacent to each Bowsmith A-40 fanjet (2/tree) to increase the flow from the standard 21.6 gph to 25.6 gph/tree (18.5% increase). The balance of the orchard will be scheduled to irrigate at the PFC westside ranch standard of 48". A total of 8 replications over the 100 acres of former Brown test plots are selected; giving a total of 360 trees (1.39 ac Nonpareil, 2.77 ac Monterey, 4.16 ac total) per treatment. Nonpareil yield will be computed on a total per acre basis (not trees harvested) and thus reflect decreased yield due to tree loss over time.

Soil Moisture Monitoring**:**
4 REPLICATED SITES for EACH ABOVE TREATMENT for NEUTRON PROBE SOIL MOISTURE & SOIL SAMPLING:

These sites consist of one 2 inch x 9 foot deep Class 125 PVC access tube in middle of the emitter pattern to monitor soil moisture with the neutron probe (24 sites total) with a small flow meter placed in the hose adjacent to this tube to monitor applied water. All neutron probe sites and flow meters are read weekly March – November. Annual soil sampling at 1 foot intervals to 9 feet @ 1 foot from tube is done Dec-Jan. Nitrate and chloride content will be analyzed to 9 feet to quantify leaching.

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.

Plant Monitoring**:**
STRESS:

Weekly stem water potential (pressure chamber) May-October at neutron probe sites.

TISSUE ANALYSIS:

Leaf tissue samples will be pulled in July for all treatments.

YIELD:

Nonpareil trees will be shaken and harvested by standard commercial equipment and each plot (0.174 acres) in-field green weight will be recorded using a gondola equipped with load cells. Four to six lb. subsamples grabbed from the harvester discharge chain will be used to determine kernel turnout for each plot.

DISEASE/CANOPY RATINGS:

Brown data trees have already been rated for approximate % barking, trunk "health" (amount of ceratocystis/gumming/viable cambium) and tree "shoot density/vigor". These ratings along with the incidence of hull rot, alternaria, etc. during the season will be continued with the help of Mario Viveros. NDVI analyses will be made using aerial imagery coinciding with tissue sampling. These analyses will be compared to Lampenin's estimate of PAR (July only).

METEOROLOGIC HEAT FLUX MONITORING for ET (continuous)

A sonic anemometer, net radiometer, high response air temperature thermocouples were installed above the canopy mid-March, 2008. In combination with buried soil heat flux plates and thermocouples installed at a 2 inch depth in the orchard floor these devices measure ET from the orchard by Eddy covariance and surface renewal heat flux.

TREE HEALTH & PROFITABILITY:

A cumulative index of tree health and profitability as the years continue will be developed to evaluate N and water use efficiency and profit to hopefully find the optimal mix of these factors for almond orchard longevity and management.

Results and Discussion:

Yield and Water Use Efficiency**:** Actual applied water in 2013 was 48.0 inches and 55.4 inches for the low and high irrigation treatments. 2013 kernel yield averaged 3,824 lb/ac for the plots receiving 275 lb/ac N and 56 inches of water and averaged 3,478 lb/ac for the 275 lb/ac N plots receiving 48 inches of water (**Table 1, Figure 1**). A statistically significant reduction of 9.9% kernel yield for a 15.4% reduction in water. There was no statistical difference in yield between the 200 and 275 lb/ac N rates for a given level of irrigation, but the 56" irrigation treatment provided a significant yield benefit for the 200 and 275 lb/ac N rates over the 48" 'standard' irrigation. Using the Brown average N removal rate of 68 lbs/1,000 lbs of kernels **Table 2** shows that the 125 and 200 lb/ac N applications were less than the total N exported by the fruit (i.e., >100% nitrogen use efficacy). Even at 275 lb/ac N fertilizer rate we have an 86 and 95% nitrogen use efficiency (NUE) for the 48" and 56" irrigation treatments, respectively. Calculated water use efficiency (WUE) as lbs kernels/inch water was greater for the 48" irrigation than for the 56". But this was only a net average 6.0% gain in WUE for all N rates while the reduction in applied water resulted in an average yield loss of 9.0%.

Table 1. Kernel yield and % differences by treatment.

Nitrogen Treatment (lb/ac)	Kernel Yield (lb/ac) 48"	56"	Irrigation Increase (%)	Nitrogen Increase Over 125N 48" (%)	Nitrogen Increase Over 125N 56" (%)
125	3086	3227	4.6% a	-- a	-- a
200	3241	3649	12.6% b	5.0% a	13.1% b
275	3478	3824	9.9% b	12.7% b	18.5% b

(Different letters indicate results significantly different, P<0.5)

Table 2. Calculated nitrogen export, nitrogen and water use efficiency by treatment.

Nitrogen Treatment (lb/ac)	[1]N Export in Fruit (lb/ac) 48"	56"	Fertilizer Nitrogen Use Efficiency (%) 48"	56"	[2]Water Use Efficiency (lb 48"	56"
125	210	219	168%	176%	64.3	58.2
200	220	248	110%	124%	67.5	65.9
275	237	260	86%	95%	72.5	69.0

[1]Calculated using 68 lb/ac N exported for 1,000 lb/ac kernel yield (P.H. Brown)

[2]Actual applied water 48.0 and 55.4 inches.

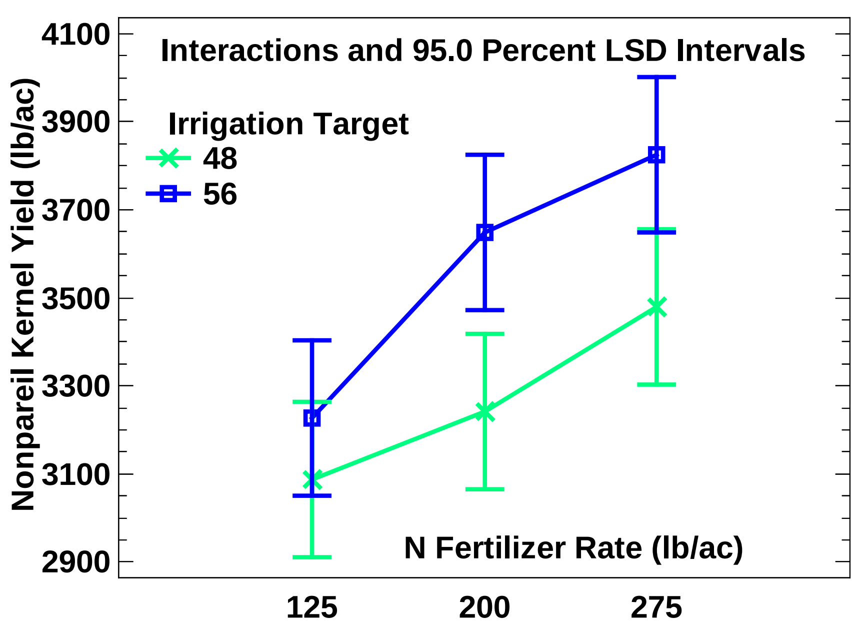

Figure 1. 2013 kernel yield and 95% LSD error bars for 48 and 56" irrigation treatments and various N fertilizer rates.

Plant Monitoring**:**

Stress**:** Weekly stem water potential (SWP, pressure chamber) measurements from May-October averaged -10.4 bars for the 48" irrigation and -9.4 bars for the 56" irrigation. This average difference was statistically significant – ranging anywhere from as little as 0.5 to 4 bars for a given week. Nitrogen rate made no difference. Previous work by Ken Shackel indicates that SWP values of -9 to -11 bars should essentially be in the "no-stress" zone and should provide for optimal ET and yield, which was not the case for this trial.

Tissue Analyses**:** Leaf tissue samples for 2013 were lost somewhere between Kern County and UC Davis, but samples from 2014 showed significant differences for all N rates (consistent with past Brown data) with no interaction for irrigation rate – averaging 2.9, 3.2 and 3.6 for April 22, 2014 and 1.9, 2.1 and 2.3% for 8/14/14 for the 125, 200 and 275 lb/ac treatments respectively.

Nonpareil Disease / Canopy Ratings: There were no differences between treatments. Hull rot was virtually non-existent for the 2013 season. All plots/trees were surveyed for general canopy health (0 = zero problems with full canopy, 5 = severe canopy loss / poor vigor), approximate percent barking of the trunk circumference, general gummosis as an indication of the severity of ceratocystis (0 = no gummosis, 4 = severe gummosis around entire trunk and lower portion of scaffolds) and number of missing trees. There was no real difference in any of these measures either by N rate or irrigation. The average canopy rating was 0.19, barking 7.51% of the trunk circumference, gummosis rating 0.48 and total tree loss after 15 years averaged 0.46 trees per plot. (Out of 48 plots, 44 were planted with 15 trees and 4 with 16 trees.)

No difference was seen in tree mortality or disease ratings. The question that we may be "killing the trees with kindness" – using higher rates of N and applied water which may shorten orchard life, is not supported by the 2013 data for this 15th leaf orchard.

Economic Analysis**:** Finally, even with an additional fungicide spray for hull rot @ $75/ac and an extra water cost of $667 at $1,000/ac-ft, the 56" irrigation treatment yields a net extra $320/ac return over the 48" irrigation for 2013 (**Table 3**).

Table 3. Cost return comparison for 48” versus 56” irrigation.

UCCE 2011 Almonds Costs and Return Study San Joaquin Valley North					
Total cost @ $3,974 Water cost @ $144				Total Production Cost	
Total Cost - water ($/ac) = $3,830	Water Cost ($/ac-ft)	48" cost	56" cost	48" cost	56" cost
Extra fungicide spray for 56" $75	100	$400	$467	$4,305	$4,422
Extra 75 lb/ac N $50	200	$800	$933	$4,705	$4,889
	500	$2,000	$2,334	$5,905	$6,289
	1000	$4,000	$4,667	$7,905	$8,622
	Water Cost ($/ac-ft)	**275-48**	**275-56**		
(346 lb/ac kernel difference between) KERNEL YIELD		**3478**	**3824**		
GROSS RETURN (ASSUME $3/LB for NONPAREIL)		**$10,435**	**$11,472**		
NET RETURN @ INDICATED WATER PRICE	100	**$6,130**	**$7,050**		
NET RETURN @ INDICATED WATER PRICE	200	**$5,730**	**$6,583**		
NET RETURN @ INDICATED WATER PRICE	500	**$4,530**	**$5,183**		
NET RETURN @ INDICATED WATER PRICE	1000	**$2,530**	**$2,850**		

Research Effort Recent Publications:

None.

References Cited:

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