Development of a Nutrient Budget Approach to Fertilizer Management in Almond

Project No.: **08-WATER3-Brown**
(Continuation of Project 07-ENVIR3-Brown)

Project Leader: Patrick Brown
Department of Plant Sciences
University of California, Davis
Mail Station #2
One Shields Avenue
Davis, CA 95616
(530) 752-0929
phbrown@ucdavis.edu

Co-Investigator: Saiful Muhammad
Department of Plant Sciences
University of California, Davis
Mail Station #2
One Shields Avenue
Davis, CA 95616
(530) 752-8499
smuhammad@ucdavis.edu

Project Cooperators: John Edstrom, Farm Advisor, University of California Cooperative Extension, Colusa County
Roger Duncan, Farm Advisor, University of California Cooperative Extension, Stanislaus County
Bob Beede, Farm Advisor, University of California Cooperative Extension, Kings County
Franz Neiderholzer, Orchard Systems Farm Advisor, University of California Cooperative Extension, Sutter & Yuba Counties
Almond Board of California
Paramount Farming Company
Yara Fertilizer Company

Interpretive Summary:

It has been many years since an in depth integrated analysis of almond fertilization has been conducted and evidence from the recent CDFA-FREP nutrition focus group and survey of industry leading consultants, growers and Farm Advisors suggests our current approach to managing plant nutrition in almond is inadequate to meet production goals.

Ninety percent of growers and consultants felt that UC Critical Values (CV's), especially for N and K, were not appropriate for current yield levels and that the link between the results of leaf and soil sampling and specific fertilizer recommendations are poor. The survey suggests that growers would like to know exactly what the use of the nutrients are in the tree and when. How much the optimum tree needs of every element and the time of year as a growth curve from beginning to the high point or multiple peaks of development. Currently nutrient management in trees is based on Critical Values (CVs). The alternative approach is to use knowledge of growth and development to derive nutrient demand curves that guide the quantity and timing of nutrient application.

The experiment has been set up in Paramount Farms, Bakersfield, under fan jet and drip irrigation systems with 12 treatments each replicated in five units. Collection of tissue samples are in progress and crop was harvested in August and individual tree yield recorded.

Objectives:

1. Develop a phenology and yield based nutrient model for almond.
2. Develop fertilizer response curves to relate nutrient demand with fertilizer rate and nutrient use efficiency.
3. Determine nutrient use efficiency of various commercially important N and K fertilizer sources.
4. Validate current CV's and determine if nutrient ratio analysis provides useful information to optimize fertility management.
5. Develop and extend an integrated nutrient BMP for almond.

Materials and Methods:

In order to develop a phenology and yield based nutrient model for almond, four trials have been initiated in four sites (Arbuckle, Salida, Madera and Bakersfield) in 8 to 9-year-old microsprinkler-irrigated almond orchards of good productivity planted to Nonpareil (50%) on uniform rootstock in soils representative of the region. All plots are contiguous blocks of 10-15 acres. Leaf samples were collected in April, May, June and July and one more sample will be collected in October. In addition to the four sites, leaf and nut samples are also being collected from the N and K treated blocks to allow for determination of the effect of tree nutrient status on nutrient uptake and whole tree nutrient budgets.

Tissue analyses for the major elements (N, P, K, S, Ca, Mg, B, Zn, Fe, Mn, and Cu) in all the collected nut samples and leaf samples are being processed by the DANR analytical laboratory at UC Davis. All nutrient and biomass data will be cross-referenced to individual tree yield, phenology, environment and other variables to develop a phenology and yield based nutrient model for almond.

The experimental trial has been set up in Paramount Farms in Bakersfield. The orchard is 8-years old and planted on 50% Nonpareil and 50% Monterrey. Trees are spaced 24' between rows and 21' between trees, accommodating 87 trees per acre.

Experimental plots have been set up both under fan jet and drip irrigation systems (plot map attached). Fifteen individual trees and their immediate 30 neighbors are considered as a single uniformly treated unit with all measurements taken on the central six Nonpareil trees individually. Eight treatments (ABDEFHIJ) have been replicated in 5 units while 4 treatments (CGKL) have been replicated 6 times for each irrigation system; a total of 64 experimental units and 384 experimental trees under each irrigation system. There are 128 experimental units and 768 trees in the whole experiment. A fertigation system has been installed and a digital flow meter has been fixed which allows a constant concentration of fertilizer during fertigation. Basal potassium sulfate (SOP) applications were made in early February and fertigations were done in February, April and June. The last fertigation will be done in mid-October after harvest. All the fertigations have been done according to the irrigation schedule to avoid nutrient leaching.

Products are being fertigated using the irrigation cycle in four applications optimized based on current knowledge of tree demand cycle. Treatments include 4 rates of N (125, 200, 275, 350lb/A, all other elements held constant) applied as UAN32; 3 rates of K (100, 200, 300 lb/A, applied as 60% SOP as basal and 40% Potassium Thiosulfate (KTS) fertigated; all other elements held constant), plus 4 contrasting rates of CAN17, one potassium chloride (KCl) and one SOP treatments. Effectiveness of each treatment will be determined by changes in leaf tissue analysis, yield, and soil residual N and K over a 3-5 year period.

Specific treatments as follows applied in the following increments (late February 20%, April 30%, June 30%, October 20%):

Treatment A: Nitrogen Rate Trial 1
UAN32, applied at 125 lb N/A in 4 intervals. K at 200 lb/A (60%SOP, 40%KTS)

Treatment B: Nitrogen Rate Trial 2
UAN32, applied at 200 lb N/A; K at 200 lb/A (60%SOP, 40%KTS)

Treatment C: Nitrogen Rate Trial 3
UAN32, applied at 275 lb N/A; K at 200 lb/A (60%SOP, 40%KTS)

Treatment D: Nitrogen Rate Trial 4
UAN32, applied at 350 lb N/A; K at 200 lb/A (60%SOP, 40%KTS)

Treatment E: Nitrogen Material Trial 5
CAN17, applied at 125 lb N/A; K at 200 lb/A (60%SOP, 40%KTS)

Treatment F: Nitrogen Material Trial 6
CAN17, applied at 200 lb N/A; K at 200 lb/A (60%SOP, 40%KTS)

Treatment G: Nitrogen Material Trial 7
CAN17, applied at 275 lb N/A; K at 200 lb/A (60%SOP, 40%KTS)

Treatment H: Nitrogen Material Trial 8

CAN17, applied at 350 lb N/A; K at 200 lb/A (60%SOP, 40%KTS)

Treatment I: Potassium Rate Trial 1

K at 100 lb/A as SOP 60 lb/A banded and 40 lb/A KTS fertigated; N (UAN32) at 275 lb/A

Treatment J: Potassium Rate Trial 3

K at 300 lb K/A as SOP 180 lb/A banded and KTS 120 lb/A fertigated; N at 275 (UAN32) lb/A

Treatment K: Potassium Material Trial 4

K at 200 lb/A as SOP banded; N at 275 (UAN32) lb/A

Treatment L: Potassium Material Trial 5

K at 200 lb/A as KCL fertigated; N at 275 (UAN32) lb/A

The fertigation of each experimental block and also the non-experimental trees are controlled by valves installed on each lateral line allowing for individual control of sets of 15 trees. An automatic bypass valve allows experimental plots to receive normal irrigation water. The plot is instrumented with water mark and neutron probes for irrigation scheduling and monitoring.

Leaf and nut samples were collected at four different dates: April, May June, and July and will also be collected in October, to contrast tissue nutrients levels to different fertilizer treatments and tree yield.

Leaf and nut samples were collected in six individual trees from each replicate unit in all treatments in May and July. Leaf and nut samples were also collected in April and June in all the N and K rate treatments in fan jet and drip and will also be collected in October. Total annual samples for this project will be 3972.

Crop was harvested in August and yield was determined for individual trees in each treatment; also cumulative yield of the remaining 9 non-data trees in each treatment was determined. A total of 768 trees were individually harvested and an additional 128 combined plot yields were collected.

Results and Discussion:

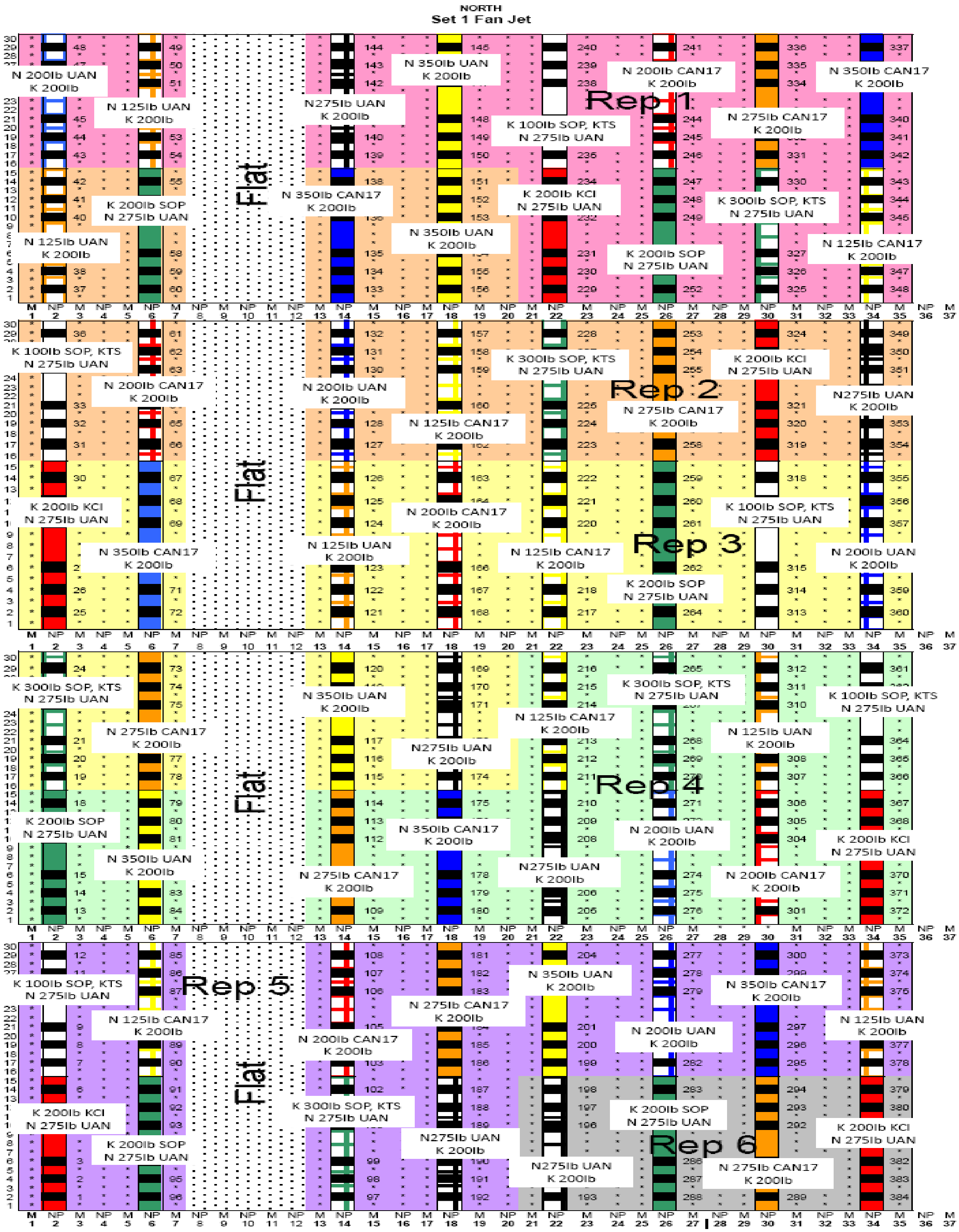
Currently the first four rounds of sampling have been completed and results of the tissue analyses for samples collected in April have been received. The remaining tissue analyses from the DANR laboratory are pending. Trees were harvested and individual yield of the data trees were determined. We have also collected 4 lb samples from each replication to determine the crack-out percentage; the cracking out is also in progress. Upon completion of crack-out and tissue analysis,statistical analysis will begin.

Though statistical analysis has not been performed, there appears to be small effects from the different nutrient levels and sources on nutrient status and yield. Full analysis of data is pending receipt of final tissue samples. Data showing average yield of fifteen trees from each replication unit under fan jet and drip are attached. Results of tissue analyses from the samples collected in April are also attached.

Recent Publications:

Preparation of publications for this project will commence after data from year one has been compiled and analyzed.

Plot Map


NORTH
Set 1 Fan Jet
N 200lb UAN K 200lb
N 125lb UAN K 200lb
N275lb UAN K 200lb
N 350lb UAN K 200lb
N 200lb CAN17 K 200lb
N 350lb CAN17 K 200lb
Rep 1
N 275lb CAN17 K 200lb
K 100lb SOP, KTS N 275lb UAN
Flat
K 200lb SOP N 275lb UAN
N 350lb CAN17 K 200lb
K 200lb KCl N 275lb UAN
K 300lb SOP, KTS N 275lb UAN
N 125lb UAN K 200lb
N 350lb UAN K 200lb
N 125lb CAN17 K 200lb
K 200lb SOP N 275lb UAN
K 100lb SOP, KTS N 275lb UAN
K 300lb SOP, KTS N 275lb UAN
K 200lb KCl N 275lb UAN
N 200lb CAN17 K 200lb
N 200lb UAN K 200lb
Rep 2
N275lb UAN K 200lb
N 275lb CAN17 K 200lb
N 125lb CAN17 K 200lb
Flat
K 200lb KCl N 275lb UAN
K 100lb SOP, KTS N 275lb UAN
N 200lb CAN17 K 200lb
N 125lb UAN K 200lb
N 350lb CAN17 K 200lb
N 125lb CAN17 K 200lb
Rep 3
N 200lb UAN K 200lb
K 200lb SOP N 275lb UAN
K 300lb SOP, KTS N 275lb UAN
K 300lb SOP, KTS N 275lb UAN
N 350lb UAN K 200lb
K 100lb SOP, KTS N 275lb UAN
N 125lb CAN17 K 200lb
N 275lb CAN17 K 200lb
N 125lb UAN K 200lb
N275lb UAN K 200lb
Rep 4
Flat
K 200lb SOP N 275lb UAN
N 350lb CAN17 K 200lb
N 200lb UAN K 200lb
K 200lb KCl N 275lb UAN
N 350lb UAN K 200lb
N 275lb CAN17 K 200lb
N275lb UAN K 200lb
N 200lb CAN17 K 200lb
K 100lb SOP, KTS N 275lb UAN
Rep 5
N 350lb UAN K 200lb
N 350lb CAN17 K 200lb
N 275lb CAN17 K 200lb
N 125lb CAN17 K 200lb
N 200lb UAN K 200lb
N 125lb UAN K 200lb
N 200lb CAN17 K 200lb
Flat
K 200lb KCl N 275lb UAN
K 300lb SOP, KTS N 275lb UAN
K 200lb SOP N 275lb UAN
K 200lb KCl N 275lb UAN
K 200lb SOP N 275lb UAN
N275lb UAN K 200lb
Rep 6
N275lb UAN K 200lb
N 275lb CAN17 K 200lb

Average Yield of 15 Trees 'Fan Jet Section'

Treatments	Replications						Total Average
	1	2	3	4	5	6	
	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	
Treatment A N 125lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	128	140	126	154	144		138
Treatment B N 200lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	146	145	145	160	148		149
Treatment C N 275lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	150	144	158	151	147	152	151
Treatment D N 350lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	136	133	170	174	156		154
Treatment E N 125lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	114	137	136	161	139		137
Treatment F N 200lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	137	142	141	172	164		151
Treatment G N 275lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	135	187	157	155	153	140	154
Treatment H N 350lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	132	131	143	149	155		142
Treatment I N 275lb/A (UAN32) K 100lb/A K (60%SOP, 40%KTS)	148	142	130	135	155		142
Treatment J N 275lb/A (UAN32) K 300lb/A K (60%SOP, 40%KTS)	129	137	171	145	154		147
Treatment K N 275lb/A (UAN32) K 200lb/A K (100%SOP)	129	141	155	173	148	149	149
Treatment L N 275lb/A (UAN32) K 200lb/A K (100%KCl)	136	150	140	155	139	147	144

Yellow	**Dry fruit weight**
White	**Green fruit weight**

Average Yield of 15 Trees 'Drip Section'

Treatments	Replications						Total Average
	1	2	3	4	5	6	
	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	Yield (lb)	
Treatment A N 125lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	159	140	143	160	155		151
Treatment B N 200lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	151	143	167	159	148		154
Treatment C N 275lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	165	157	164	155	151	151	157
Treatment D N 350lb/A (UAN32), K 200lb/A K (60%SOP, 40%KTS)	173	152	160	169	153		161
Treatment E N 125lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	170	139	156	155	149		154
Treatment F N 200lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	147	149	166	125	157		149
Treatment G N 275lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	153	156	154	177	159	170	162
Treatment H N 350lb/A (CAN17), K 200lb/A K (60%SOP, 40%KTS)	169	151	163	171	150		161
Treatment I N 275lb/A (UAN32) K 100lb/A K (60%SOP, 40%KTS)	166	150	161	190	159		165
Treatment J N 275lb/A (UAN32) K 300lb/A K (60%SOP, 40%KTS)	173	151	157	161	176		164
Treatment K N 275lb/A (UAN32) K 200lb/A K (100%SOP)	157	159	155	166	162	170	161
Treatment L N 275lb/A (UAN32) K 200lb/A K (100%KCl)	153	168	158	178	153	152	160

Yellow	**Dry weight**
White	**Green weight**

Leaf Nutrient Analysis April 2008 For Fan Jet

Treatments	Replications	Average of 6 trees		
		%N	%P	%K
A	A1	3.67	0.24	1.32
	A2	3.86	0.24	0.88
	A3	3.42	0.26	1.30
	A4	3.40	0.27	1.47
	A5	3.61	0.26	1.00
B	B1	4.11	0.25	0.97
	B2	3.44	0.26	1.30
	B3	3.61	0.26	1.29
	B4	3.47	0.27	1.32
	B5	3.72	0.25	1.02
C	C1	4.24	0.25	1.09
	C2	3.60	0.26	1.35
	C3	3.81	0.27	1.56
	C4	3.59	0.27	1.34
	C5	3.94	0.26	1.06
D	D1	4.32	0.25	1.08
	D2	4.20	0.26	1.00
	D3	3.78	0.26	1.30
	D4	3.83	0.29	1.17
	D5	3.98	0.27	1.03
I	I1	3.91	0.25	1.04
	I2	3.60	0.26	1.02
	I3	3.64	0.27	1.32
	I4	3.61	0.28	1.56
	I5	4.05	0.27	0.92
J	J1	4.05	0.26	0.99
	J2	3.54	0.26	1.67
	J3	3.74	0.27	1.23
	J4	3.71	0.28	1.45
	J5	4.19	0.26	0.99

Leaf Nutrient Analysis April 2008 For Drip

Treatments	Replications	Average of 6 trees		
		N %	P %	K %
A	A1	3.46	0.24	1.39
	A2	3.28	0.25	0.97
	A3	3.44	0.25	1.10
	A4	3.57	0.25	1.56
	A5	3.27	0.25	1.41
B	B1	3.55	0.25	1.26
	B2	3.51	0.25	1.04
	B3	3.32	0.25	1.32
	B4	3.49	0.25	1.34
	B5	3.44	0.24	1.41
C	C1	3.54	0.24	1.42
	C2	3.55	0.26	1.52
	C3	3.59	0.25	1.60
	C4	3.76	0.27	1.29
	C5	3.87	0.24	0.98
D	D1	3.68	0.25	1.29
	D2	3.48	0.25	1.05
	D3	3.64	0.26	1.83
	D4	3.78	0.24	1.04
	D5	3.75	0.25	1.05
I	I1	3.46	0.24	1.25
	I2	3.58	0.24	1.21
	I3	3.65	0.24	1.14
	I4	3.55	0.25	1.51
	I5	3.81	0.23	0.95
J	J1	3.38	0.24	1.19
	J2	3.44	0.25	1.45
	J3	3.59	0.26	1.40
	J4	3.65	0.25	1.67
	J5	3.72	0.25	1.13