Nitrogen Efficiency and BMPs for Nut Crops

Nut and Grape Nutrient and Water Management November 8, 2018 Kings River Water Quality Coalition

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Outline:

- Establish crop requirements
 - Almonds
 - Pistachio
 - Walnut

Research background on nutrition guidelines

Establish application rate and timing for young and mature bearing trees

 Example: Estimate demand, account for inputs and efficiencies, finalize and adjust management plan through the year

Nutrient Management of Nut Crops

- Most of California nutrient management plans are based on nutrient removal
- Rates of macro and micro-nutrients take into account soil characteristics, cropping history, tissue analysis and field observations



14 Essential Elements for tree crops

Macronutrients

- Nitrogen
- Potassium
- Phosphorous
- Magnesium
- Calcium
- Sulfur

Micronutrients

- Zinc
- Boron
- Iron
- Manganese
- Copper
- Chloride
- Nickel
- Molybdenum





Nutrients are best applied when the tree can use it efficiently in amounts that will not leach past the root zone.

First application of fertilizer during spring when rapid growth occurs followed by applications throughout the growing season and post harvest

Average Crop Requirement 68 > 28 > 15 > 1.4 > 1

lbs of N exported for every 1000 lbs of crop

Walnut

Stone Fruit

Citrus



Pistachio

Almond

Initial budget and adjustment

- Estimate demand:
 - Last year's yield, this year's estimated yield, tree age
 - Measure and account for N inputs (fertilizer, water, soil, amendments)
 - Adjustments:
 - Revised yield estimate and leaf sampling



Average Crop Requirement

68 lbs of N exported for every 1000 lbs of crop

Where did this estimate come from?



UC Nitrogen Rate Study

- Methods
- 8-10 year old trees, excellent productivity
- 15 trees per treatment, 6 replicates
- Nitrogen sourced with CAN-17 and UAN-32
- N applied in 4 fertigations 20%, 30%, 30%, and 20% for February, April, June, and October
- Leaf and nut samples pulled multiple times during season
- Field and kernel weights for 4 lb sub-samples determined

UC Nitrogen Rate Study: Yield Effect

		UAN 32					CAI	N 17	
Year	Irrigation	125 lbs	200 lbs	275 lbs	350 lbs	125 lbs	200 lbs	275 lbs	350 lbs
2009	Drip	2689 b	2977 b	3327 ab	3507 a	2512 b	2634 b	3064 b	3605 a
	Fanjet	2776 b	3111 al	3263 ab	3380 a	3143	3130	3248	3216
2010	Drip	2859 c	3426 b	3909 ab	4332 a	2624 c	3191 ba	3967 ab	3995 a
	Fanjet	2872 b	3581 a	3810 a	3776 a	3030 b	3410 ak	3993 a	3898 a
2011	Drip	3811 c	4272 b	4643 a	4735 a	3640 c	4336 b	4864 a	4852 a
5	Fanjet	3870 b	4014 b	4480 a	4425 a	3803 c	4159 b	4452 a	4398 a

Conclusions:

P<0.05, differing letters mean different statistical groupings

Maximal yields reached with 275 lb, no gain from 350 lb treatment;

No difference between nitrogen source

No difference between irrigation system

UC Nitrogen Rate Study: Nitrogen Removal

			N Removed/1000
Site	Variety	Year	kernel lbs
Modesto	Nonpareil	2009	62
(185 lbs/acre)		2010	58
Madera	Nonpareil	2009	69
(250 lbs/acre)		2010	76
Arbuckle	Nonpreil	2009	*
(190 lbs/acre)		2010	51
Belridge 2	Nonpareil	2009	62
(275 lbs/acre)		2010	62

Average N removed/1000 kernel lbs – 62 lbs (assume ~68)

UC Nitrogen Rate Study: Nitrogen Use Coefficient

NUE = Nitrogen Removed Nitrogen Applied

N Rate (lb/ac)	Drip	Fan Jet
125	1.43	1.30
200	1.03	1.03
275	0.93	0.88
350	0.82	0.70

Almond NUE ~70%

Rate and Timing 'Demand': Almond Example



From dormancy to mid-March there is very little N uptake.

Uptake commences at mid-leaf out and is essentially complete by hull split.

Recommended N Split:

20% Leaf Out-Fruit Enlargement

30% Fruit Enlargement 30% Kernel Fill

20% Hull-split through early Post-Harvest

Almond Nitrogen Timing

- Should be soil dependent
 - Sandier soils should wait until leaf out
 - Clay, Silt, Loam soils may apply earlier
- 80% should be delivered before hull-split, 20% in the post harvest
 - Majority should be prior to kernel fill
- Example program: 20% March, 30% April, 30% May, 20% August/September

Pistachio



UC CE University of California Agriculture and Natural Resources Cooperative Extension Mature pistachio tree is relatively determinate in growth pattern.

Majority of nutrients are partitioned to fruit.



Brown and Siddiqui

Determining Rates/Needs

Nutrient removal Per 1000 lbs (CPC yield)

- Valuable for estimating demand or replacing nutrient export
- Provides insight into efficiencies
 - N removal 28 lbs per 1000
 - K removal 25 lbs per 1000
 - P removal 3 lbs per 1000

Nitrogen Applications in Pistachios

Timing of uptake:

- Spring Flush
 - 33% of budget
- Nut Fill
 - 66% of budget
- Post Harvest
 - Applications to bring into sufficiency

Determining need

- Crop estimation
 should occur based on
 cropping history and
 cluster counts
- Applications of 28 lb of N for every 1000 lbs/ac

About 50:50 in off-year



Nitrogen Management within **Pistachios**

Nitrogen Deficiency:

- Young leaves are pale and old leaves drop
- Reddish petioles and mid-ribs of the leaves







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Nitrogen Applications in Pistachio

- Nitrogen assists with vegetative development, bud development, but does not put more buds on a tree
- Make limited applications through the spring (April-June), with the majority being applied in July
- Late season tissues should be in the 2.6-2.9% N range for young trees and greater than 2.3% N for mature trees
- Minimize postharvest applications to reduce frost risk



Walnut





Methods – NPK Demand Model





Slide: Katherine Jarvis-Shean

Walnut N Rate Trials 2013-2015

Site	2013	2014	2015
N Chandler	25	28	28
D Chandler	29	30	34
S Chandler	23	29	32
N Tulare	27	29	23
D Tulare	30	31	31
S Tulare	26	27	35
Grand Mean		29	

Katherine Jarvis-Shean

Nitrogen Added per Month 2013 & 2014, Chandler & Tulare



Right Rate: Soil and Water Testing Reports

N is also supplied from soil, water, and other N sources including manures, composts, nitrogen fixing cover crops, etc

Testing provides more accurate accounting of N sources

Improves N Efficiency, reduces production costs and environmental impact





Soil Sampling to establish N credits

- Should be conducted regularly
- 3-10 sub-samples from a identified depths for each paddock or block
- Sample active irrigation zone more frequently, deeper depths occasionally
- Be aware of different soil types within fields and sample differently.

Almond soil analysis, sandy loam

Material: SOIL - ALMONDS GROWER: 805 KF - DRW 306

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Submitted By: DAVID R. WOODRUFF

		-		••																	
		%				n	neq/L-				%	LIME					-PPM-				
		SP	рН	EC	Ca	Mg	Να	K	Cl	ESP	CaCO3	PRESENCE	В	NO ₃ N	PO₄P	K	Zn	Mn	Fe	Cu	SO₄S
DESCRIPTIC	ON			d\$/m	Sc	il Solut	ion Co	nstiuer	nts		QUANT	LP				AA					
1. Weak	er 0-15	28	4.9	0.67	<u>4.9</u>	1.3	0.5	0.1		<1.0			0.1	8.8	16.7	188	0.2	32.1	36.3	1.1	55
2.	15-30	23	6.1	0.40	2.4	0.8	0.7	0.1		<1.0			0.1	5.8	3.1	120	0.1	12.3	12.9	0.6	25
3.	30-45	25	6.6	0.50	<u>3.3</u>	0.6	0.8	0.1		<1.0			0.1	9.2	1.6	114	0.1	5.0	6.7	0.4	19
4.	45-60	26	7.6	0.63	<u>3.7</u>	0.8	1.9	0.1		<1.0		•	0.1	5.0	1.5	141	0.1	2.1	5.2	0.3	37
5.	60-72	28	7.9	0.62	1.7	0.5	<u>3.9</u>	0.1		4.0		++	0.1	5.8	2.0	116	1.0	1.6	3.2	0.3	35
6. Strong	0-15	23	5.1	0.58	<u>3.6</u>	1.4	0.6	0.1		<1.0			0.1	4.8	17.7	231	0.2	39.5	29.7	0.8	49
7.	15-30	23	7.8	0.70	<u>5.0</u>	1.0	0.9	0.1		<1.0		++	0.1	8.6	2.1	69	0.1	3.6	3.1	0.3	31
8.	30-45	19	7.9	0.75	<u>5.2</u>	0.8	1.1	0.1		<1.0		+++	0.1	9.2	1.5	73	0.1	2.0	4.9	0.2	23
9.	45-60	20	7.8	0.54	<u>3.6</u>	0.7	1.0	0.1		<1.0		•	0.1	5.0	1.2	78	0.1	1.2	4.0	0.2	20
10.	60-72	18	8.0	0.62	<u>4.0</u>	1.0	1.2	0.1		<1.0		•	0.1	4.1	1.3	51	1.5	1.2	5.6	0.1	26
OPTIMUM I	RANGES		6.0- 7.5	<4.00 >0.60	Ca>	2x (Mç	g+Na)	>0.4	<10	<5	<1.5%		>0.2 <1.5		>16.0	>150	>2.0	>5.0	>8.0	>1.0	>50

RED = LOW BLUE = HIGH DOMINANT SOLUBLE SALT IS UNDERLINED. SEE ENCLOSED INTERPRETATION GUIDES.

Fertilizing Young Almond Orchards: Other Considerations?

Nitrate-nitrogen (NO³-N) in the soil:

NO³-N concentration (ppm) * 2 * soil sample thickness (in.) N (lbs/acre) = 6 inches

Depth	5 PPM	10PPM	/	15 PPM	20 PPM
0-6″	10	20		30	40
0-12″	20	40		60	80
University of	of California				

Agriculture and Natural Resources

ESTIMATING SOIL N CREDIT: The lab reports an average 3 ppm NO_{3-N} down to a 4 foot depth for your fanjet irrigated almonds. How much available NO_{3-N} is in the profile?

At roughly 4 million lbs soil/ac-ft, and going down to 4 feet:

Total NO_{3-N} = 3.0 parts/million*4 million lb/ac-ft*4 ft = 48 lb/ac

BUT ONLY IN THE WETTED AREA OF THE ROOTZONE

FINAL N CREDIT = 48 LB/AC * 60% WETTED ROOTZONE VOLUME * 70% NUE = 20 LB/AC



Water Sampling

- Water should be sampled to determine contribution of N from water
 - Well and surface water
- Water sampling should occur at various times of the year
 - Wells should run 30 minutes prior to sampling





Source of N in irrigation water

Nitrate-nitrogen (NO³-N) in the water:

N (lbs/acre inch) = NO³-N concentration (ppm) *0.23

					_
Acre inches applied	3 PPM	5 PPM	10 PPM	15 PPM	
1	0.7	1.15	2.3	3.45	
6	4.1	6.9	13.8	20.7	
12	8.3	13.8	27.6	41.4	
24	16.6	27.6	55.6	82.8	
48	33.2	55.2	112	166	

Cover crops and residues

Residue N content predicts N mineralization behavior



- Greatest activity occurs in the initial 6-8 weeks after incorporation
- Soil temperature / moisture effects can be significant

Estimating N content of a cover crop

Cove	r crop total N	Predicted	available N
	lbs N / ton dry	4 weeks	10 weeks
% N	matter	lbs N / ton	dry matter
1	20	<0	0
1.5	30	3	9
2.0	40	7	14
2.5	50	12	20
3.0	60	19	28
3.5	70	28	37

OSU Organic Fertilizer and Cover Crop Calculator

Sullivan and Andrews, 2012

https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw636.pdf

ANNUAL NITROGEN BUDGET

	Member ID# <u>1234</u>	APN: <u>111-00-222</u>	
	Owner/mgr	Field # A, B, C	
	CROP NITROGEN DEMAND Crop Nitrogen Needs / Uptake	NITROGEN SUPPLY Credits and Application	ons
Rate and Source	Crop Expected yield (Lbs of production/ acre) Nitrogen Crop Needs to meet expected yield (lbs of Nitrogen per acre)	Nutrients: Total N applied to field Nitrogen fertilizers (conventional and organic) Spring Summer Fall Foliar fertilizers Other fertilizers Manure Compost Bacterial extracts/Compost teas Other nutritional products	Time and Place
		Soil Nitrogen Credits Soil N ppm ³ Nitrogen from previous legume crop	Nitrogen Credits
		Crop N needs: Balance Ratio	

N budget

N source	N budget for 3000 lb Cropload
Crop N removed	3*68= 204
N credits (irrigation water + compost) @ 70% NUE	-57
Net Crop N requirement after credits	147
Total fertilizer N for the season to apply (70% NUE)	210=(147/0.7)
Extra N to apply due to 70% efficiency	63=(210-147)

Right Time: When during the growing season should I apply the 210 lbs of N fertilizer?

(Given 4 fertigation periods through year).

% of Total	lbs of N
20	42
30	63
30	63
20	42
	% of Total 20 30 30 20

<u>+ 210 lbs of N</u>

Adjust for changing yield estimates and efficiency



University of California, Division of Agriculture and Natural Resources Fruit & Nut Research & Information Center University of California UCDAVIS **FRUIT & NUT RESEARCH & INFORMATION** Home About Find an Expert Weather-Related Models Websites of Interest **FNRIC Blog** HOME Nitrogen Prediction Models for Almond and Pistachio EXTENSION CLASSES N & K Prediction Model for Pistachio WEATHER-RELATED MODELS These models are based on 1) Guidelines for Pistachio Early-Season Sampling and In-Season Chilling Accumulation Models research conducted through Nitrogen Application Maximizes Productivity, Minimizes Loss (pdf). Advanced Sensing and By Muhammad Ismail Siddiqui & Patrick Brown Prune Chilling Prediction Management Technologies to 2) Estimate pistachio tree demand: Pistachio Model for Optimize resource Use in Nitrogen Prediction Models for Calculating Nitrogen Demand Almond and Pistachio Deciduous Tree Crops, a 4year, multi-state project. For 3) Interpret early season pistachio leaf samples: Pistachio Irrigation Scheduling project details, including Prediction Model (PPM). The Pistachio Prediction Model (PPM) is investigative team, an update released July 2014 in Excel format. PPM is also Harvest Prediction for Peaches, methodology and support, incorporated in the N & K Prediction Model for Pistachio linked in Plums & Nectarines see project link. item 2) above. Almond Hull-Split Prediction Pistachio Bloom Cast Nitrogen Management Tools for Almond About CIMIS Weather Stations 1) Guidelines for Early Season Sampling and In-Season Nitrogen Budgeting (pdf) Station Map & Information 2) An integrated model that calculates your N budget utilizing predicted yield, irrigation water, amendment and leaf nutrient samples can be found at: https://www.sustainablealmondgrowing.org FIND AN EXPERT Note: This is a joint UC Davis, Almond Board and SureHarvest web site. You will be requested to enter an FRUIT & NUT INFORMATION email address which will only be used to send you a password for access. The site will not retain your data unless you specifically request it to do so. EDUCATIONAL RESOURCES: INDIVIDUAL CROPS 3) Interpret early season almond leaf samples: Download these spreadsheets: N-Prediction Model for Almond (22K) and N-Prediction Model for Almond: large datasets (317K) from this page: Crop Nutrient ORCHARD MANAGEMENT Status & Demand in Almond. The website https://www.sustainablealmondgrowing.org also contains FRUIT & NUT CENTER UPDATES the tools to conduct the N prediction procedure. http://fruitsandnuts.ucdavis.edu/Weather Services/Nitrogen

Enter Search lenns

Prediction Models for Almond and Pistachio/

Tissue Sample Analysis

• Send to a reputable lab

- Order a FULL NUTRIENT ANALYSIS (N, P, K, B, Ca, Zn, Cu, Fe, Mg, Mn, S) and application of the UCD-ESP program if early season sampling
- Submit for testing within 24 hours or dry as soon as possible



Tissue Sample Analysis

	ALMOND	PISTACHIO	WALNUT		
Sampling date	April, July	May, Mid-July to early August	May?, Mid-July		
# OF TREES	18-28, 90 ft apart	18-28, 75 ft apart	29, 90 ft apart		
<pre># leaves per tree (non- fruiting well exposed spur)</pre>	5-8	4-10 terminal leaflets	6 terminal leaflets		
Combine leaves	Group similar soils, irrigation blocks, varieties etc.				

Interpreting Tissues and Adjusting Management Plan

	ALMOND	PISTACHIO	WALNUT
% N sufficiency range early season	3.5%	April	In development
Mature trees	2.2 – 2.	5% July	2.3 – 2.7% July
Excessive	> 3.5 % > 2.6%	% April % July	> 3.2 % July

Too much N provides little or no beneficial yield response! Consider reducing or eliminating late season N applications if tissue analysis in excessive range

Nitrogen in Plants: Excess N Example

Almond hull rot incidence increased as N increased:



F0, F1, F2 = Zero, Single, and Double Fruited Spurs.

(Elana Peach-Fine, MSc. 2013)

Modifying the plan example: Almonds

• It is May 1st. You have already applied half of your planned fertilizer (by early spring during fruit growth).

You collected leaves in April and the model prediction for July was for "adequate or excessive N". You also re-estimate your yield, but it is down from 3,000 to 2000 kernel lbs/ac.

Time to adjust?



N budget

N source	N budget for 3000 lb Cropload	N budget for 2000 lb Cropload	
Crop N removed	3*68= 204	2*68= 136	
N credits (irrigation water + compost) @ 70% NUE	-57	-57	
Net Crop N requirement after credits	147	79	
Total fertilizer N for the season to apply (70% NUE)	210=(147/0.7)	112=(79/0.7)	
Extra N to apply due to 70% efficiency	63	33	
UC Iniversity of California			



How am I going to fix this?

Timing	% of Total	lbs of N (3000# est.)	Lbs of N (2000# est.)
Early Spring	20	42	42
Fruit Growth	30	63	63
Kernel Fill	30	63	
Hull split or Early Post-Harvest	20	42	3
Total for season	100	210	112

How am I going to fix this?

Timing	% of Total	lbs of N (3000# est.)	Lbs of N (2000# est.)
Early Spring	20	42	42
Fruit Growth	30	63	63
Kernel Fill	30	63	0
Hull split or Early Post-Harvest	20	42	7-8
Total for season	100	210	112

Take home messages

- Annual N applications should be determined based on historical yield performance, tissue sampling, and overall canopy conditions
- More N will not increase flower buds on the tree or compensate for poor practices that impact nut development



Take home messages

- Consider your N credits
- Get a good yield estimate
- Re-estimate your N budget several times/season
- Orchards use less N after harvest than before
- The longer you wait to adjust your fertility plan, the smaller the chances of fixing a problem
- Treat each orchard separately



Fertilizing Young Almond Orchards

Fertilizing Considerations:

- What type of fertilizer to apply?
- How much should be applied?
- How much should be applied in a single application?
- What are the other concerns for young orchards?



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First Year Fertilizer Studies: Merced County

Sandy loam soil, irrigated with micro-sprinklers, acidic soils, medium cation exchange capacity – 4 ozs total N, 6 applications of 1 oz/tree



University of **California** Agriculture and Natural Resources

Fertilizing Young Almond Orchards:



 3-4 ozs of actual N per tree for the first growing season, applied across the whole season

Fertilizing Young Almond Orchards: What rate?

- Study suggest somewhere between 3-4 ozs of Nitrogen per tree
 - Supported earlier work of John Edstrom
 - Supports Patrick Brown's work of 20-30 lbs/acre of vegetative growth requirement

Rate/Tree	18'x22' (110)	16'x22' (123)	14'x22' (141)
3 oz	20 lbs N	23 lbs N	27 lbs N
4 oz	28 lbs N	31 lbs N	35 lbs N



Fertilizing Young Almond Orchards: Efficiency Considerations



Application Efficiency of systems for young trees is dependent upon delivery to development root system.

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Fertilizing Young Almond Orchards: How much?

For 2nd leaf or older:

- Nitrogen needs look to be around 25-30 pounds for growth
- Needs to be added to crop requirements if yielding under 2000 lbs/acre



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Fertilizing Young Almond Orchards: How much?

BE CONSERVATIVE: Many little feeds are better than one "slug."

No More than one oz of N per tree's age for any application

- 1 year old: one oz of N per fertilization
- 2 year old: two ozs of N per fertilization

WHY?



Fertilizing Young Almond Orchards: How much?

Lanky Growth



Nitrogen Burn



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Fertilizing Young Pistachio Orchards

First Leaf 2nd Leaf 3rd Leaf 4th Leaf 5th Leaf 6th Leaf 7th Leaf

0 - 0.1 pounds/tree 0.15 - 0.2 pounds/tree 0.25 - 0.35 pounds/tree 0.5 - 0.6 pounds/tree 100 - 120 pounds/acre 120 - 130 pounds/acre 135 – 150 pounds/acre

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Fertilizing Young Walnut Orchards

Tree age	N application rate		
	(lbs/acre)	(lbs/tree) ¹⁾	(oz/tree)
First season	10 - 20	0.2 - 0.3	2 - 5
Second season	25 - 50	0.4 - 0.8	6 - 12
Third season	50 - 100	0.8 - 1.5	12 - 25
Fourth season	63 - 125	1 - 1.9	16 - 31
Fifth season	75 - 150	1.2 - 2.3	18 - 37
1) The application r 65 trees/acre.	ate per tree is	based on a tree	density of



Thank you!

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https://ucanr.edu/sites/Nut_Crops/

