University of California
Agriculture and Natural Resources

Almond Orchard Nitrogen and Potassium Nutrition

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Nitrogen Sources:

Sources of Nitrogen

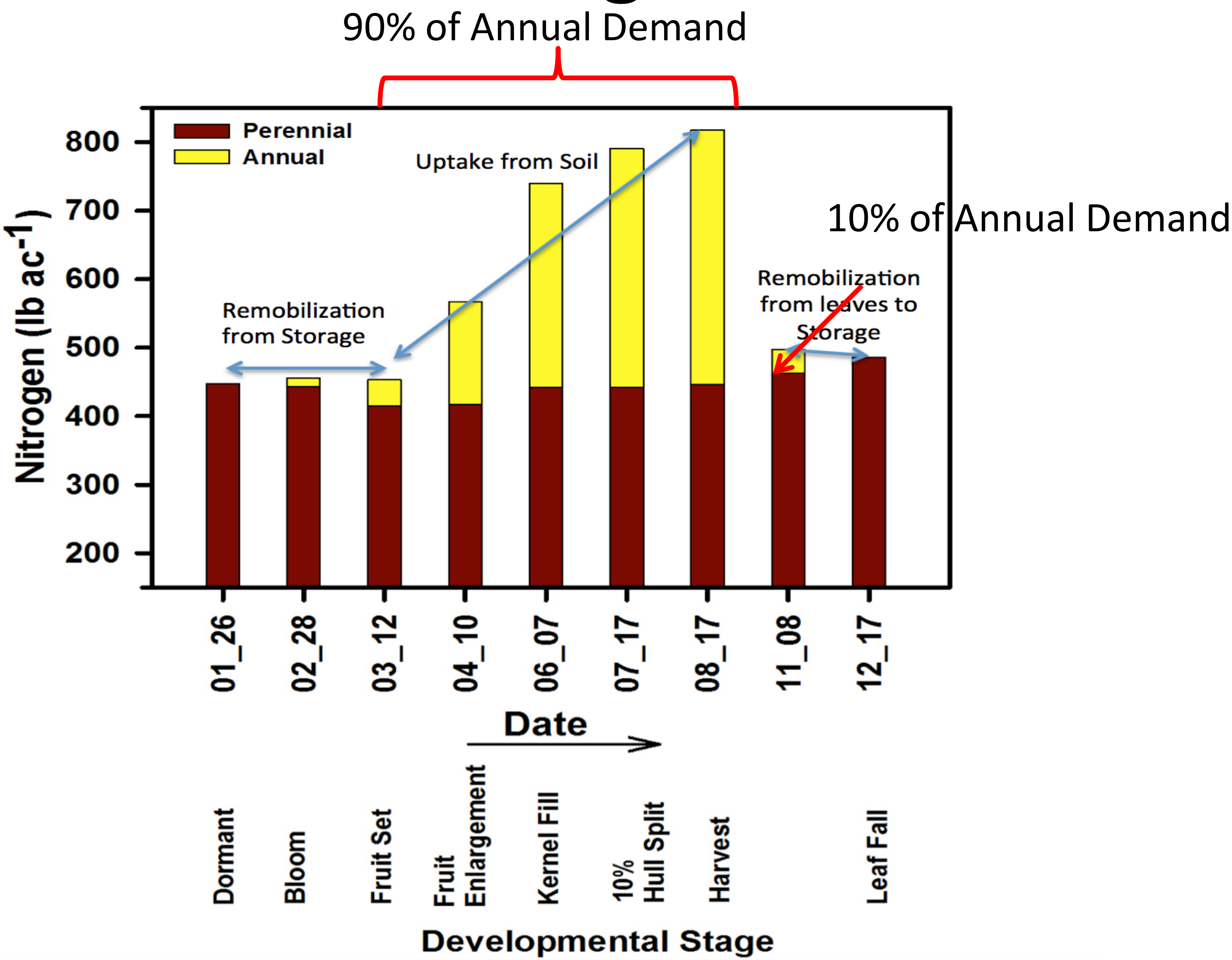
- **Urea** – produced through Haber-Bosch process, must be converted to nitrate, can volatilize, water soluble, stable (~46% N)
- **Ammonium (NH_4^+)** – Can be used by plants in anaerobic conditions, positively charged in neutral, acidic soils
  - Ammonium Sulfate
- **Nitrate (NO_3^-)** – Plant available form of nitrogen, negatively charged, easily leached
  - Calcium Nitrate
  - Potassium Nitrate
- Blends:
  - Urea Ammonium Nitrate (UN-32) – liquid blend
  - Calcium Ammonium Nitrate (CAN-17) – liquid blend

Nitrogen Sources:

Source of Nitrogen

- **Groundwater-** sourced as nitrate, should be considered in budget,
  - 0.228 x Nitrate-N (ppm) x acre inches of water applies
- **Manures/Compost –** Percentage varies by source, age of compost, Food safety issues
  - Mineralizes most of N within first year (up to ~85%)
- **Fulvic/Humic Acids, Compost teas–** efficiencies relatively unknown, thought to be high

Almond Tree Nitrogen Demand



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

UC Nitrogen Rate Study

Methods:

- Trees were 8-10 years old, excellent productivity
- Each treatment had 15 trees, 6 blocks
- Nitrogen was sourced using CAN-17, UAN-32
- N applied in 4 fertigations – 20%, 30%, 30%, and 20% for February, April, June, and October, respectively
- Leaf samples were pulled at multiple times
- Trees were harvested, and individual tree yields were determined for all data trees, 4 lb sub-samples were collected from two data trees/plot and cracked out to determine kernel weights from field weights

UC Nitrogen Rate Study: Yield Effect

		UAN 32				CAN 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 ab	3263 ab	3380 a	3143	3130	3248	3216
2010	Drip	2859 c	3426 bc	3909 ab	4332 a	2624 c	3191 bc	3967 ab	3995 a
	Fanjet	2872 b	3581 a	3810 a	3776 a	3030 b	3410 ab	3993 a	3898 a
2011	Drip	3811 c	4272 b	4643 a	4735 a	3640 c	4336 b	4864 a	4852 a
	Fanjet	3870 b	4014 b	4480 a	4425 a	3803 c	4159 b	4452 a	4398 a

$P<0.05$, differing letters mean different statistical groupings

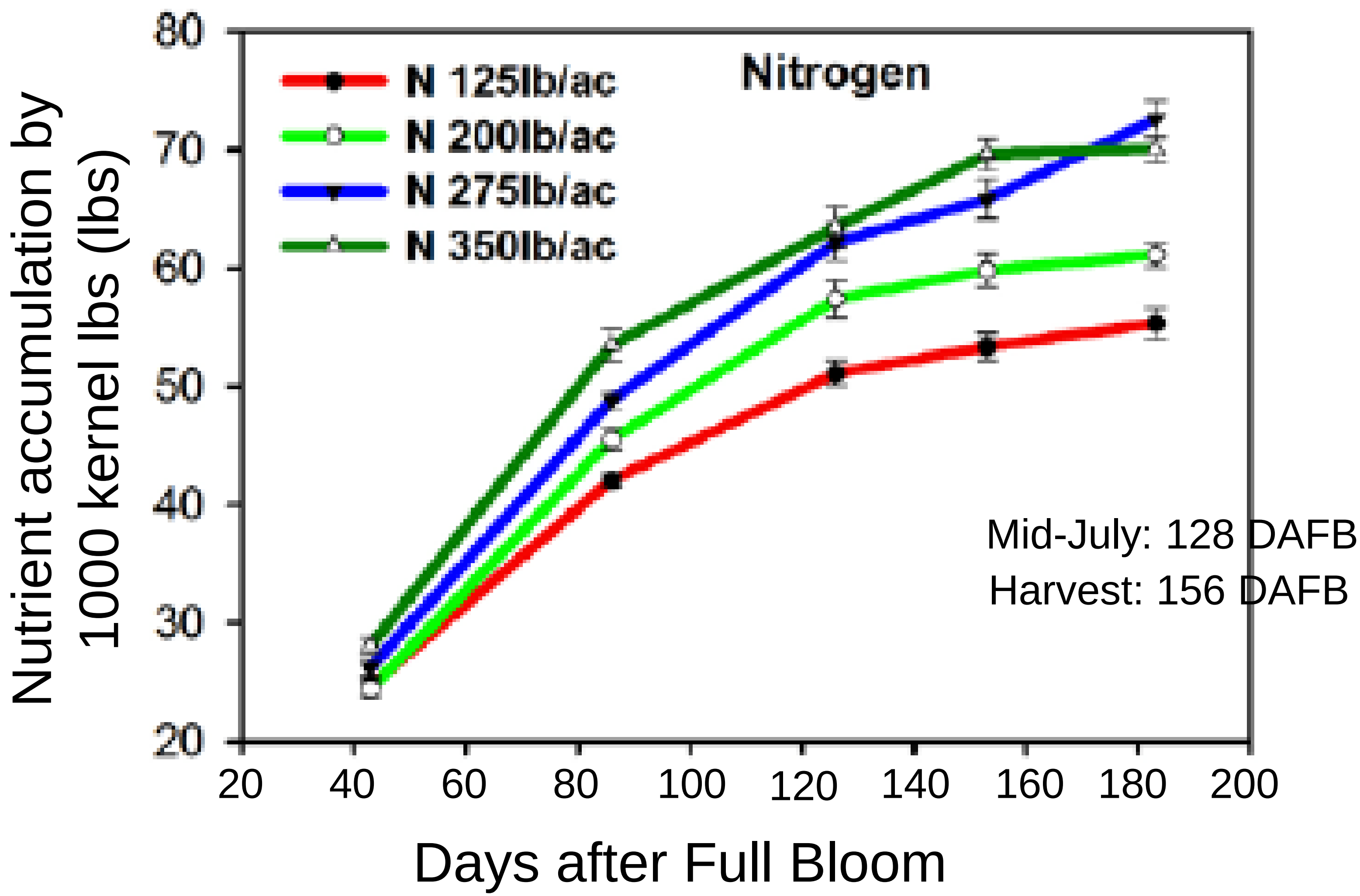
Conclusions:

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



UC Nitrogen Rate Study: Nitrogen Removal

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

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

UC Nitrogen Rate Study: Nitrogen Use Coefficient

$$NUE = \frac{\text{Nitrogen Removed}}{\text{Nitrogen Applied}}$$

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%

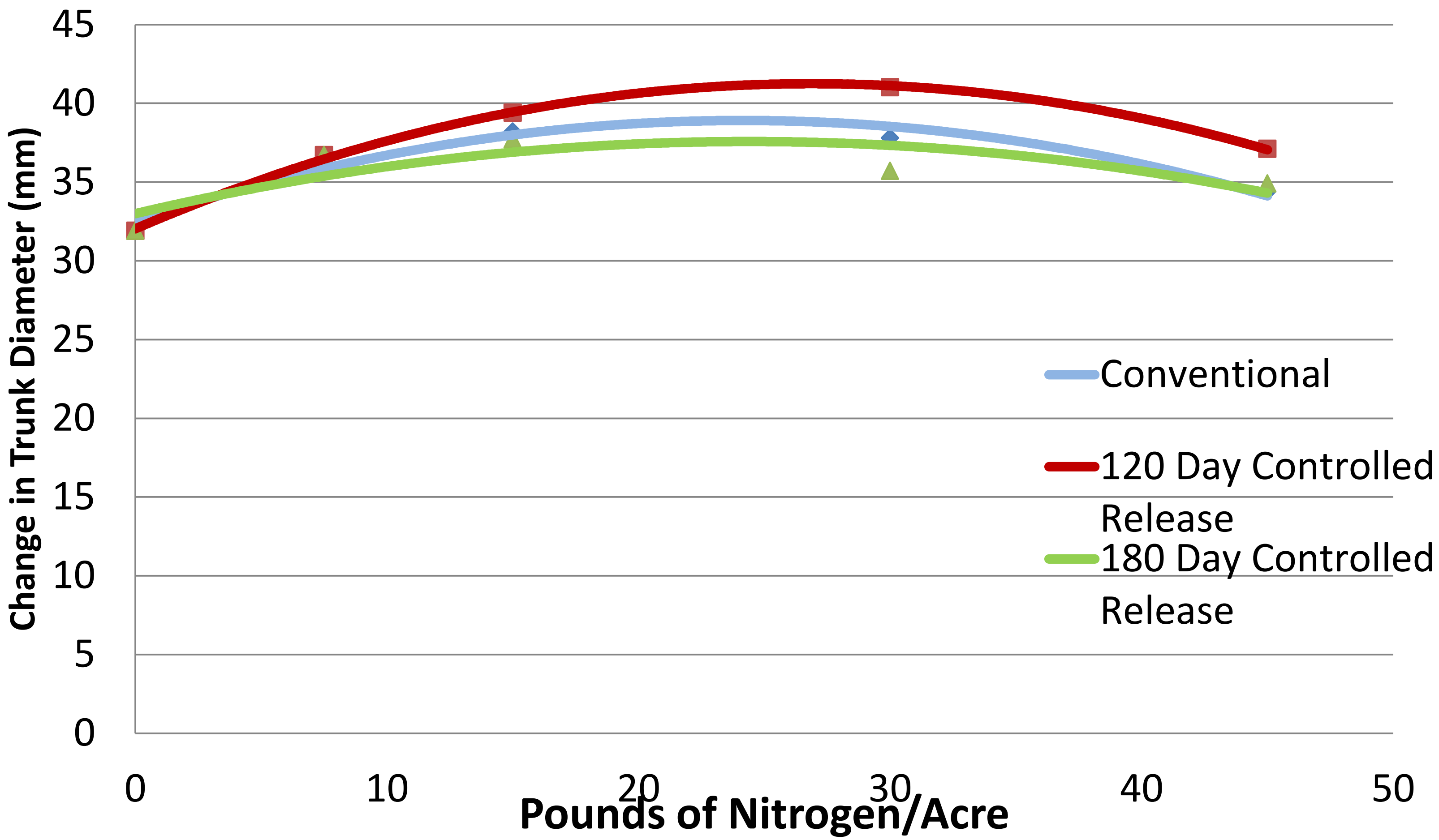
Bringing it All Together:

- Determining Total Crop Demand in lbs N
  - Expected yield divided by 1000 and multiplied by 62
- Subtract nitrogen applied through water
  - Nitrate-nitrogen (ppm) x acre inches applied x 0.228
- Leaf Tissue Based Adjustment
  - If April N concentrations exceed 3.5%, it is likely that June fertilization can be omitted
- Determining N application rate
  - Subtract N applied through water from crop demand, multiply by 1.4 (assumes 70% efficiency factor)
- Timing of application should vary by soil type.
  - More “feeds,” the better

Developing Almond Orchards

- Nitrogen needs look to be around 25-30 pounds for growth
- Needs to be added to crop requirements
- For mature trees (10+ years), enough slack in calculations to make up for growth
- Be careful with the rate

Merced Trials – First Year Almond Fertilization



Almond Potassium Needs: What does K do in plants?

- Large amount of processes
  - Enzyme activation
  - Photosynthesis
  - Sugar translocation
  - Protein and starch synthesis
  - Stomatal Conductance

Photo from cestanislaus.ucanr.edu

Major nutrient within plants!

Potassium in Almonds

Table 1. Effects of K applications on leaf K concentrations and yields

Treatment	Leaf K (% dry wt.)[x]			Nut yield (meats, lb/A)		
(lb K_2O/A)	1998	1999	2000	1998	1999	2000
0	1.1	0.7	0.7	780	3930	2410
240	1.3	1.3	1.2	890	3840	2860
600	1.3	1.6	1.4	830	4380	2860
960	1.3	1.7	1.7	1070	4020	2770
	**	**	**	ns	ns	*

*,** Significant differences among treatment means at $p<0.05$ and $p<0.01$, respectively.

[x]Samples taken in the last week of July.

Reidel, et al, 2000 - ABC

Potassium in Almonds?

Level of treatment lb K_2O/A	Fruit set (%) 1999	Fruit set (%) 2000	Nodes/ shoot	Weight -- 1999 (g)	Return bloom (%)
0	27 ± 2.4	21 ± 2.2	1		
960	26 ± 1.8	25 ± 2.2	1		

[z] means ± SE..

* Denotes means which differ at p<0.1

Table 3a. Effect of tree K status on subsequent productivity of *fruiting* spurs tagged in 1999

Level of treatment (lb K_2O/A)	N=	Spur status in 2000 (% of total sample) Vegetative	Fruiting	Dead
0	133	26	18	56
960	172	31	27	42 *

* *Denotes means which are significantly different at $p < 0.05$.*

Potassium Deficiency in Almond

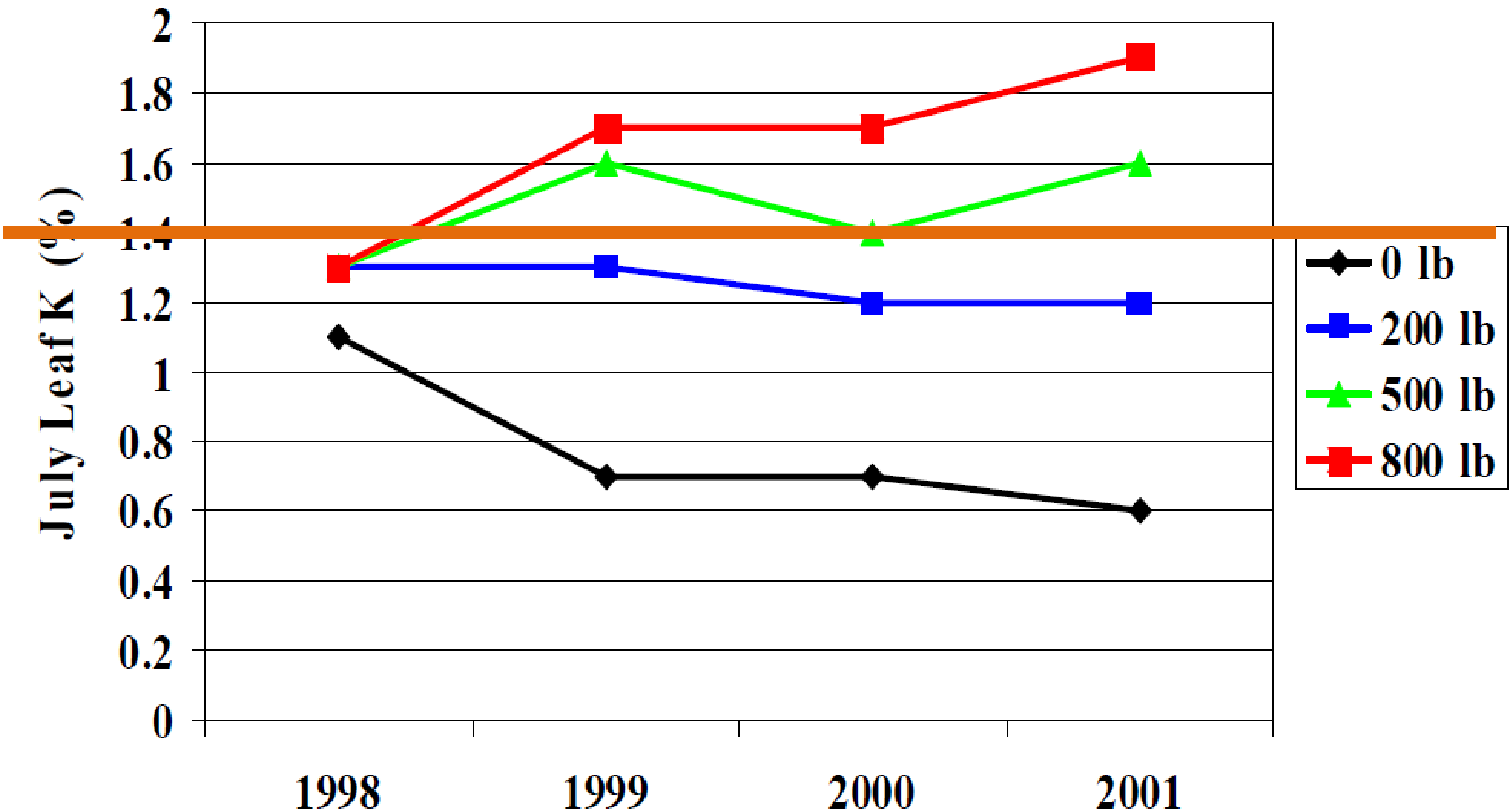
- Reduces growth, spur longevity and formation
  - Reduction of floral buds and yield
- Does NOT affect nut size or PERCENTAGE of nut set
- Deficiency in new growth, off-colored, tip and subterminal margins will become necrotic, folded leaf and curled tip

Photo from IPNI

July almond leaf tissue sampling index.

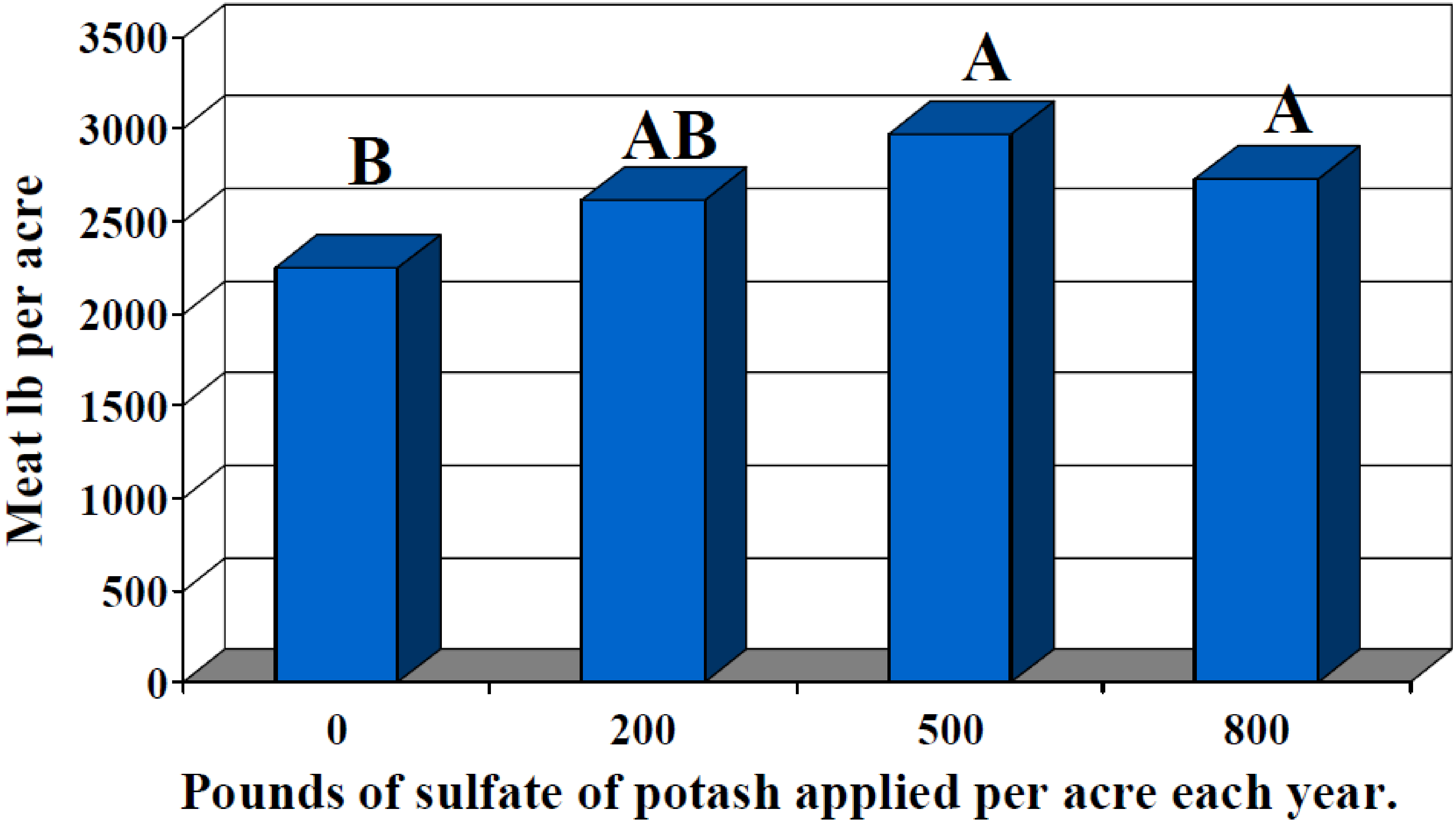
Leaf % K	Tree K status
<1.0 % K	Deficient
1.0-1.4% K	Insufficient
1.6-1.8 % K	Orchard Target?

Potassium Sufficiency in Almonds



Courtesy of R. Duncan,
UCCE Stanislaus

Potassium Sufficiency in Almonds



Courtesy of R. Duncan,
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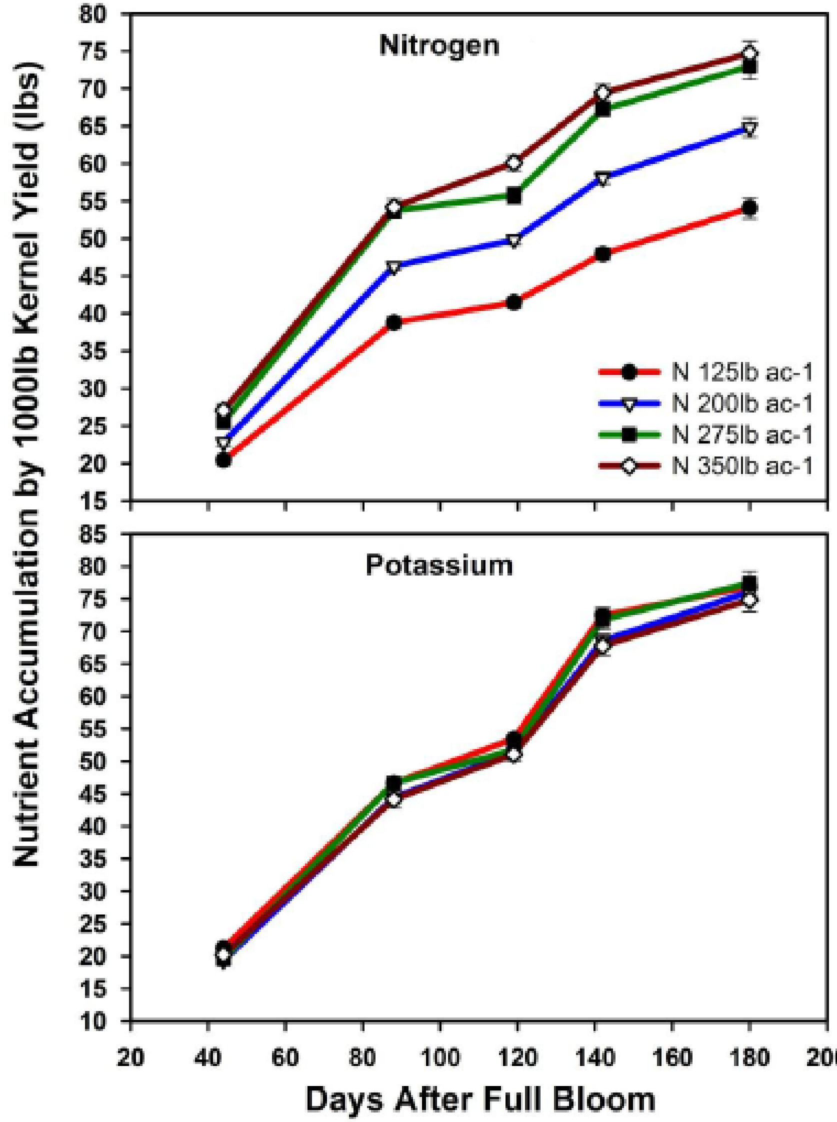
Potassium Uptake in Almonds

- K accumulation is linear
  - 70% of season's accumulation occurs by mid-June (119 dpb)
- Uptake not influenced by N rate
- Luxury Consumption occurs



Potassium Removal in Almonds

NPK Export by 1000lb Kernel in 2009-10 (lb)

Nutrient	2009				2010			
	Nitrogen Rate (lb/ac)				Nitrogen Rate (lb/ac)			
	125	200	275	350	125	200	275	350
N	53	56	58	59	55	61	73	70
	b	ab	a	a	c	b	a	a
P	7.5	7.4	7.2	6.7	8.6	8.2	8.9	7.8
	a	a	ab	b	ab	ab	a	b
K	75	73	73	72	88	81	80	82

Means not followed by the same letter are significantly different at 10%.

Muhammad et al, 2012

Potassium Removal = 76 lbs/1000 kernel lbs!

Quick Clarification!

- Removal is documented in **pounds of potassium**
- Potassium is sold as pounds of **K_20**
- Lbs of actual potassium removed needs to be converted to
  - Simple math: Lbs of K X 1.2 = K_20
  - Example: 76 lbs of K removed equals 91.2 lbs of K_20

Image source: http://wpmedia.business.financialpost.com/2011/10/potash.jpg?w=620

Potassium fertilizer sources

Potassium source	Pro	Con
Potassium chloride (60% K_2O)	Least expensive, readily dissolved	Chloride risk
Potassium sulfate (50% K_2O)	Source of sulfur, doesn't increase "bad" salts	Expensive, some issues in fertigating
Potassium thiosulfate (25% K_2O -3 lbs K_2O/gallon)	Source of sulfur, helps reduce soil pH, liquid	Can be toxic in high rates, pH change
Potassium nitrate (44% K_2O)	Contains N, water soluble, can be used foliarly	Expensive, can raise pH
Potassium carbonate (64% K_2O)	Buffers acidic soils, water soluble	Expensive, pH change
Potassium magnesium sulfate (22% K_2O)	Doesn't change pH	Not widely used in CA

Different K strategies for application.

Practice	High CEC Soil (>15 meq/100 g of soil)	Low CEC soil (<15 meq/100g of soil)
Dormant Applications	Yes – can be “slugged” on	Yes – but only partial budget
Banding of gypsum to move potassium	Yes, if heavy clay	NO
In-Season Applications	Yes, if needed	Yes- 40-60% of the budget
Fertigation of K	Yes	Yes – be cautious of large applications (toxicity)
Foliar Applications	Yes	Yes

Tissue Sampling Recommendations

- Tissues should be sampled to determine sufficiency levels
- 3 sampling periods suggested:
  - Mid July – Provides sufficiency levels for all nutrients
  - Hull Analysis – Boron sufficiency levels
  - April Sampling for Nitrogen sufficiency
- Needs to follow a specific protocol (2-3 non fruiting spurs from 20 trees, 30 yards apart)

Concluding Thoughts:

- Adequate levels of potassium and nitrogen are critical to sustain high yielding orchards
- Nitrogen removal is high – around 65 lbs/1000 kernel lbs, need to apply 85 lbs due to inefficiencies
- Potassium removal is higher – around 92 lbs of K_20 for every 1000 kernel lbs, no inefficiencies
- Leaf sampling will provide guidance – April is useful for nitrogen, July is useful for N,P,K+micros

Questions?

- Thanks to:
  - Paramount Farming Company, The Almond Board of CA, USDA, CDFA
  - Sebastian Saa, Saiful Muhammad, Blake Sanden, and Patrick Brown
  - Brent Holtz, Andrew Ray

Shameless plug – Check out “The Almond Doctor,” weekly updates for almonds and other tree nuts -- www.thealmonddoctor.com