Almond Orchard Nitrogen and Potassium Nutrition

David Doll
UCCE Merced
SSJV Almond Symposium
5/29/2014
Nitrogen Sources:

Sources of Nitrogen

• **Urea** – produced through Haber-Bosch process, must be converted to nitrate, can volatilize, water soluble, stable (~46% N)

• **Ammonium** \((\text{NH}_4^+)\) – Can be used by plants in anaerobic conditions, positively charged in neutral, acidic soils
  – Ammonium Sulfate

• **Nitrate** \((\text{NO}_3^-)\) – 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,
  - \( 0.228 \times \text{Nitrate-N (ppm)} \times \text{acre inches of water} \) 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

90% of Annual Demand

10% of Annual Demand

Date

Developmental Stage

01.26 02.28 03.12 04.10 06.07 07.17 08.17 11.08 12.17

Dormant Bloom Fruit Set Fruit Enlargement Kernel Fill 10% Hull Split Harvest Leaf Fall

Nitrogen (lb ac$^{-1}$)

Perennial Annual

Uptake from Soil

Remobilization from leaves to storage

Remobilization from storage
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

<table>
<thead>
<tr>
<th>Year</th>
<th>Irrigation</th>
<th>UAN 32</th>
<th></th>
<th></th>
<th></th>
<th>CAN 17</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>125 lbs</td>
<td>200 lbs</td>
<td>275 lbs</td>
<td>350 lbs</td>
<td>125 lbs</td>
<td>200 lbs</td>
<td>275 lbs</td>
<td>350 lbs</td>
</tr>
<tr>
<td>2009</td>
<td>Drip</td>
<td>2689 b</td>
<td>2977 b</td>
<td>3327 ab</td>
<td>3507 a</td>
<td>2512 b</td>
<td>2634 b</td>
<td>3064 b</td>
<td>3605 a</td>
</tr>
<tr>
<td></td>
<td>Fanjet</td>
<td>2776 b</td>
<td>3111 ab</td>
<td>3263 ab</td>
<td>3380 a</td>
<td>3143</td>
<td>3130</td>
<td>3248</td>
<td>3216</td>
</tr>
<tr>
<td>2010</td>
<td>Drip</td>
<td>2859 c</td>
<td>3426 bc</td>
<td>3909 ab</td>
<td>4332 a</td>
<td>2624 c</td>
<td>3191 bc</td>
<td>3967 ab</td>
<td>3995 a</td>
</tr>
<tr>
<td></td>
<td>Fanjet</td>
<td>2872 b</td>
<td>3581 a</td>
<td>3810 a</td>
<td>3776 a</td>
<td>3030 b</td>
<td>3410 ab</td>
<td>3993 a</td>
<td>3898 a</td>
</tr>
<tr>
<td>2011</td>
<td>Drip</td>
<td>3811 c</td>
<td>4272 b</td>
<td>4643 a</td>
<td>4735 a</td>
<td>3640 c</td>
<td>4336 b</td>
<td>4864 a</td>
<td>4852 a</td>
</tr>
<tr>
<td></td>
<td>Fanjet</td>
<td>3870 b</td>
<td>4014 b</td>
<td>4480 a</td>
<td>4425 a</td>
<td>3803 c</td>
<td>4159 b</td>
<td>4452 a</td>
<td>4398 a</td>
</tr>
</tbody>
</table>

**Conclusions:**

- Maximal yields reached with 275 lb, no gain from 350 lb treatment;
- No difference between nitrogen source;
- No difference between irrigation system.

P<0.05, differing letters mean different statistical groupings.
UC Nitrogen Rate Study: Nitrogen Removal

Nutrient accumulation by 1000 kernel lbs (lbs)

- N 125lb/ac
- N 200lb/ac
- N 275lb/ac
- N 350lb/ac

Days after Full Bloom

Mid-July: 128 DAFB
Harvest: 156 DAFB
<table>
<thead>
<tr>
<th>Site</th>
<th>Variety</th>
<th>Year</th>
<th>N Removed/1000 kernel lbs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modesto</td>
<td>Nonpareil</td>
<td>2009</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>58</td>
</tr>
<tr>
<td>(185 lbs/acre)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Madera</td>
<td>Nonpareil</td>
<td>2009</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>76</td>
</tr>
<tr>
<td>(250 lbs/acre)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arbuckle</td>
<td>Nonpareil</td>
<td>2009</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>51</td>
</tr>
<tr>
<td>(190 lbs/acre)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belridge 2</td>
<td>Nonpareil</td>
<td>2009</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>62</td>
</tr>
<tr>
<td>(275 lbs/acre)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Average N removed/1000 kernel lbs – 62 lbs (assume ~68)
**UC Nitrogen Rate Study: Nitrogen Use Coefficient**

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

<table>
<thead>
<tr>
<th>N Rate (lb/ac)</th>
<th>Drip</th>
<th>Fan Jet</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>1.43</td>
<td>1.30</td>
</tr>
<tr>
<td>200</td>
<td>1.03</td>
<td>1.03</td>
</tr>
<tr>
<td>275</td>
<td>0.93</td>
<td>0.88</td>
</tr>
<tr>
<td>350</td>
<td>0.82</td>
<td>0.70</td>
</tr>
</tbody>
</table>

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

Change in Trunk Diameter (mm) vs. Pounds of Nitrogen/Acre

- Conventional
- 120 Day Controlled Release
- 180 Day Controlled Release
Almond Potassium Needs:
What does K do in plants?

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

Major nutrient within plants!
# Potassium in Almonds

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

<table>
<thead>
<tr>
<th>Treatment (lb K$_2$O/A)</th>
<th>Leaf K (% dry wt.)$^*$</th>
<th>Nut yield (meats, lb/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.1</td>
<td>0.7</td>
</tr>
<tr>
<td>240</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>600</td>
<td>1.3</td>
<td>1.6</td>
</tr>
<tr>
<td>960</td>
<td>1.3</td>
<td>1.7</td>
</tr>
</tbody>
</table>

** ns *  

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

$^*$Samples taken in the last week of July.
<table>
<thead>
<tr>
<th>Level of treatment</th>
<th>Fruit set (%)</th>
<th>Nodes/shoot</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 lb K₂O/A</td>
<td>27 ± 2.4 21 ± 2.2 1 26 ± 1.8 25 ± 2.2 1</td>
<td></td>
</tr>
<tr>
<td>960 lb K₂O/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Potassium in Almonds?

* Denotes means which differ at p < 0.05.

** Denotes means which differ at p < 0.1.
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.

<table>
<thead>
<tr>
<th>Leaf % K</th>
<th>Tree K status</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1.0 % K</td>
<td>Deficient</td>
</tr>
<tr>
<td>1.0-1.4% K</td>
<td>Insufficient</td>
</tr>
<tr>
<td>1.6-1.8 % K</td>
<td>Orchard Target?</td>
</tr>
</tbody>
</table>
Potassium Sufficiency in Almonds

[Graph showing potassium levels from 1998 to 2001 for different treatments (0 lb, 200 lb, 500 lb, 800 lb).]

Courtesy of R. Duncan, UCCE Stanislaus
Potassium Sufficiency in Almonds

Pounds of sulfate of potash applied per acre each year.

- 0 lb
- 200 lb
- 500 lb
- 800 lb

Meat lb per acre

- B
- AB
- A
- A

Courtesy of R. Duncan, UCCE Stanislaus
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

Muhammad et al., 2012

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

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrogen Rate (lb/ac)</td>
<td>Nitrogen Rate (lb/ac)</td>
</tr>
<tr>
<td></td>
<td>125</td>
<td>200</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>53</td>
<td>56</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>7.5</td>
<td>7.4</td>
</tr>
<tr>
<td>K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>75</td>
<td>73</td>
</tr>
</tbody>
</table>

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\(_2\)O**
• Lbs of actual potassium removed needs to be converted to
  – Simple math: Lbs of K \( \times 1.2 = K\(_2\)O \)
  – Example: 76 lbs of K removed equals 91.2 lbs of K\(_2\)O

## Potassium fertilizer sources

<table>
<thead>
<tr>
<th>Potassium source</th>
<th>Pro</th>
<th>Con</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potassium chloride (60% K\textsubscript{2}O)</td>
<td>Least expensive, readily dissolved</td>
<td>Chloride risk</td>
</tr>
<tr>
<td>Potassium sulfate (50% K\textsubscript{2}O)</td>
<td>Source of sulfur, doesn’t increase “bad” salts</td>
<td>Expensive, some issues in fertigating</td>
</tr>
<tr>
<td>Potassium thiosulfate (25% K\textsubscript{2}O - 3 lbs K\textsubscript{2}O/gallon)</td>
<td>Source of sulfur, helps reduce soil pH, liquid</td>
<td>Can be toxic in high rates, pH change</td>
</tr>
<tr>
<td>Potassium nitrate (44% K\textsubscript{2}O)</td>
<td>Contains N, water soluble, can be used foliarly</td>
<td>Expensive, can raise pH</td>
</tr>
<tr>
<td>Potassium carbonate (64% K\textsubscript{2}O)</td>
<td>Buffers acidic soils, water soluble</td>
<td>Expensive, pH change</td>
</tr>
<tr>
<td>Potassium magnesium sulfate (22% K\textsubscript{2}O)</td>
<td>Doesn’t change pH</td>
<td>Not widely used in CA</td>
</tr>
</tbody>
</table>
Different K strategies for application.

<table>
<thead>
<tr>
<th>Practice</th>
<th>High CEC Soil (&gt;15 meq/100 g of soil)</th>
<th>Low CEC soil (&lt;15 meq/100g of soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dormant Applications</td>
<td>Yes – can be “slugged” on</td>
<td>Yes – but only partial budget</td>
</tr>
<tr>
<td>Banding of gypsum to move potassium</td>
<td>Yes, if heavy clay</td>
<td>NO</td>
</tr>
<tr>
<td>In-Season Applications</td>
<td>Yes, if needed</td>
<td>Yes- 40-60% of the budget</td>
</tr>
<tr>
<td>Fertigation of K</td>
<td>Yes</td>
<td>Yes – be cautious of large applications (toxicity)</td>
</tr>
<tr>
<td>Foliar Applications</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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$_2$O 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