Managing Nitrogen Efficiently
Patrick Brown

Background
Why the focus on Nitrogen?
- Essential for plant growth and critical for crop yield
  • N is critical for photosynthesis, protein formation and growth
  • Almonds are among the most N demanding of any crop.
- Nitrogen that escapes the orchard is a pollutant
  • Negative impacts of N on Californian water and air resources are well documented.
  • Regulatory controls on its use are imminent.
- Nitrogen management is complex
  • Application of fertilizer N (inorganic and organic) is a major cost
  • Current tools for monitoring and management are inadequate

Satisfy Demand - Prevent Losses - Maximize Efficiency?

Environmental concerns
Nitrate concentrations in various California wells measured in 2007. Many exceed drinking standards

$44 \text{ mg/L NO}_3 = 10 \text{ mg/L NO}_3-N$
(some from animal manure)

(Ekdahl and others, 2009)

Nitrogen is essential for Almond yields

The Nitrogen Cycle: Nitrogen is essential for all agriculture and all forms of nitrogen (N-fixation, chemical and biological) are subject to loss to varying degrees.

Efficient Nutrient Management Approach -the 4 R's-

Applying the Right Rate
- Match demand with supply (all inputs- fertilizer, organic N, water, soil).

At Right Time
- Maximize uptake minimize loss potential.

In the Right Place
- Ensure delivery to the active roots.

Using the Right Source
- Maximize uptake minimize loss potential.
The basic scientific principles of managing crop nutrients are universal (4 R’s)

1. Supply in plant available forms
2. Suit soil properties
3. Recognize synergisms among elements
4. Blend compatibility

1. Assess all available nutrient inputs (water, legumes etc)
2. Determine plant demand
3. Optimize fertilizer use efficiency
4. Blend compatibility

1. Assess timing of crop uptake
2. Assess dynamics of soil nutrient supply and movement
3. Incorporate weather factors
4. Evaluate logistics of operations

1. Determine root distribution and dynamics
2. Manage spatial variability
3. Optimize fertigation
4. Limit potential off-field transport

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What do we know and how do we manage?
Leaf Sampling and Critical Value Analysis

- Sampling protocols are well defined
- Non fruiting spur leaves
- July/August
- South West quadrant at 6'
- Contrast leaf analysis with standard Critical Values published in Almond Production Manual

Yield trials (N, K, B)
Leaf symptoms (P, S, Mg, Ca, Mn, Zn, Fe, Cu, Ni, Cl, Mo)
Interpretation of results (NO R’S!)

- Leaf analysis can indicate a shortage but cannot define how to respond.
- Thus: Fertilizer decisions are currently based on experience and an ‘estimate’ of fertilizer needs.
- No guidance on Rate, Timing, Placement or Source.

Are tissue samples collected and if so how often?

On one of your typical almond orchards, how often are plant tissue samples collected? (Choose all that apply)

- Never
- Less than once/year
- Once/year
- More than once/year
- When problems are detected
- I don’t know

Brown et al, 2004

Are tissue samples being used to guide fertilizer management?

Do you think the University of California critical values are adequate to ensure maximal productivity in almonds?

- Yes
- Somewhat
- No
- I don’t know

Brown et al, 2004

Problem with leaf sampling: Sampling challenges.

Deficient Fruiting Spur (F2)
Non Deficient NF Spur

Which leaf is the best leaf?

Standard Sample: Fully Exposed non-fruiting leaves in late summer

Shoot Zn Distribution Through A Dormant Peach Tree (ppm)

Shoot Zn Distribution Through A Dormant Peach Tree (ppm)

47.9 - shaded
39.7 - sun exposed
16.3 - water sprout
32.6 - water sprout
70.3 - shaded
19.1 - sun exposed
28.5 - sun exposed
47.9 - shaded

>80% compliance
Critical Values are based on July/August sample. Early season CV’s have not been validated.

Current Practice: Late summer sample. Too late for current season response. Too early for next season planning (yield potential is defined by winter and spring weather)

Challenge: Develop early season sampling and interpretation methodologies.

Challenges of Sampling: Field Variability

(768 individual tree samples. High producing uniform orchard)

Typical Sampling: 1 pooled sample per management unit

(Hypothetical) Field Mean 2.2% N (June): Critical Value 2.2% = OK?

No!

Full productivity can only be achieved when all individuals are above 2.2%

What is the right target mean? (variability:response:cost:returns:yield)

2.0%

2.2%

Challenge: Develop sampling protocols that incorporate variability, have a clear cost:returns basis, while remaining cost effective.

Summary: Tissue Testing for Almonds

Problems:

• Difficult to sample properly and hard to interpret. Current practice is a waste of money. Too few samples collected too late.

• Does not inform management practice

• UC critical values are probably correct but do not provide enough information at an orchard level

Solutions:

• Develop methodology for early season sampling and interpretation

• Establish statistically valid sampling patterns and interpretation

• Develop improved lower cost (remote sensing, hand held meters etc).

• Integrate sampling with a nutrient budget approach.

Alternatives?

Alternate Approach: Nutrient Budgeting

Efficiently replace the nutrients removed from the field

Estimate current year demand

• Last years yield, this years estimated yield, tree age, common sense

• Improved techniques are under development (remote sensing, modeling etc)

• Nutrient content of samples.

Measure and control inputs and losses

• Soil, fertilizer, irrigation, leaching, volatilization

Manage efficiencies and interactions

• Synchronization and location of nutrient applications

• Monitoring crop response

How?

What do we currently do to manage our orchards?

Sample in July

Leaf Sampling And Interpretation Methods For CA Almond Orchards.

Sebastian Saá, UC Davis
Problem Statement: Recall to Dr. Brown’s lecture

Are tissue samples being used to guide fertilizer management?

Possible Reasons for this problem:

- Current Sampling Protocol is too late in year to make in-season adjustments.
- Samples collected do not always represent the true nutrient status of the orchard as a whole.
- Our current CV’s may not apply in all cases or may be wrong.

Objectives:

- Develop methods to sample in April and relate that number to July critical value.
- Develop method for grower to sample his field (recognizing that typical practice is only 1 sample per field is generally collected).
- Reevaluate the current CV’s.

Experiment:

- Four sites from California’s major almond producing regions

<table>
<thead>
<tr>
<th>Location</th>
<th>Arbuckle</th>
<th>Modesto</th>
<th>Madera</th>
<th>Belridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varieties</td>
<td>NP – 50%</td>
<td>A – 25%</td>
<td>C – 12.5%</td>
<td>NP – 50%</td>
</tr>
<tr>
<td>Spacing</td>
<td>22’ x 18’ (110 trees/ac)</td>
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Design and Sampling

- 114 trees x 4 Sites x 3 years.
- Yield. (About 1,130 data points)
- 5 in-season nutrient samples. (8,500 x 11 = 93,500 data points)

Time of Sampling Problem.

Can we sample in April and predict July?
Two Models to answer the same Q.

- Model one uses all the April information from F2 spurs to predict the July nitrogen value.
- Model two uses the nitrogen NF information from April to predict the July nitrogen value.
- Both models also predict what percentage of the trees are above or below the current July nitrogen critical value.
- Both models work well but we do not yet.

Results Model 1

<table>
<thead>
<tr>
<th>Site</th>
<th>Year</th>
<th>April Nitrogen Predicted</th>
<th>July Nitrogen Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arbutus</td>
<td>8</td>
<td>2.6</td>
<td>2.3</td>
</tr>
<tr>
<td>Belridge</td>
<td>8</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Madera</td>
<td>8</td>
<td>2.5</td>
<td>2.4</td>
</tr>
<tr>
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<td>8</td>
<td>2.4</td>
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<td>9</td>
<td>2.6</td>
<td>2.6</td>
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<td>Modesto</td>
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<td>2.4</td>
<td>2.5</td>
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Results: Model 2

Expected % of trees below 2.2% in July

- <3.1 in April likely to be deficient in July
- >3.2 in April unlikely to be deficient in July
- ALL DEPENDS ON YOUR YIELD!

Objectives:

- Develop methods to sample in April and relate that number to July critical value.
- Develop a protocol for growers to sample their fields properly (recognizing that only 1 sample per field is generally collected).

If you can only collect one sample...

How do you represent the true nutrient status of your orchard as a whole? What is the best way to sample?

Distance from Tree to Tree

Number of trees

Criteria

Spatial Correlation Concept

We attempt to test if and when trees are giving independent information.
Number of pooled trees needed in April to estimate the true mean of Nitrogen.

<table>
<thead>
<tr>
<th>Number of Acres</th>
<th>Trees needed at 95% Confidence</th>
<th>Trees needed at 90% Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>5</td>
<td>27</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>50</td>
<td>28</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>28</td>
<td>20</td>
</tr>
</tbody>
</table>

Note: 1 acre is assumed to be 100 trees

Preliminary Sampling Criteria

- Collect leaves from 18 to 28 trees in one bag.
- Each tree sampled at least 30 yards apart.
- In each tree collect leaves around the canopy from at least 8 well exposed spurs located between 5-7 feet from the ground.
- In April, collect samples at (43 days after full bloom (DAFB) ± 6 days). April 20 in 2011.
- If you would like to collect samples in July, then collect samples at 143 DAFB ± 4 days. July 27 in 2011.
- Always make note of date of sampling.

Objectives:

- Develop methods to sample in April and relate that number to July critical value.
- Develop method for grower to sample his field (recognizing that only 1 sample per field is generally collected).
- Even if you sample well and predict from April to July IT IS STILL NOT GOOD ENOUGH.

ALTERNATIVE APPROACH

Nutrient Budgeting

Efficiently replace the nutrients removed from the field

Estimate current year demand

- Last year's yield, this year's estimated yield, tree age, common sense
- Improved techniques are under development (remote sensing, modeling etc)
- Nutrient content of samples.

Measure and control inputs and losses

- Soil, fertilizer, irrigation, leaching, volatilization

Manage efficiencies and interactions

- Synchronization and location of nutrient applications
- Monitoring crop response

How?
Sequential Harvest: Potassium Aerial Accumulation Wheat - California

Sequential Whole Tree Harvest: 5 mature trees x 5 times in a year

Whole Tree N Contents by Organ in Almond.

The scale of nutrient demand is determined by yield.

Determining the Right Rate and Timing

Nutrient Budget Approach
- Provides information on total annual demand
- Develops knowledge of growth and development and derives nutrient demand curves
- Provides information on knowledge of nutrient rate and timing

Suitability of Almond for Nutrient Budget Management
- Mature almond tree is relatively determinate in growth pattern
- Majority of nutrients are partitioned to fruit
- Irrigation systems and fluid fertilizers have made on demand fertilizer application easy
- Theoretically, continuous nutrient feeding is better than 2 or 3 fertigation events.
- More work on relative efficiency of fertilizer source is needed.

Fertility Experiment

Treatments
- 4 Nitrogen rates – 125, 200, 275 and 350lb/ac
- 2 Nitrogen Sources- UAN 32 and CAN 17
- 3 Potassium Source- 100, 200 and 300lb/ac
- 3 Potassium Sources- SOP, SOP+KTS and KCl @200lb/ac

Irrigation Types
- Fan Jet and Drip Fertigation
- 4 times during the season
  - 20, 30, 30 and 25% in February, April, June and October

Samples Collection
- Leaf and Nut samples collected from 768 individual trees five times in season
- All trees individually harvested

Patrick Brown unpublished data
Experimental Layout

Large experiment covering approximately 100 acres.
768 trees individually monitored for nutrients, yield, light interception, disease, water.
Trees were 9 leaf in 2008.
Nonpanel - Monterey

Experiment:

➢ Four sites from California’s major almond producing regions

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<td>A – 25%</td>
<td>C – 25%</td>
<td>M – 50%</td>
</tr>
<tr>
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<td>WC – 25%</td>
<td>M – 25%</td>
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Preliminary Findings

Yield Response to Nitrogen

Cumulative Kernel Yield 2009-11

<table>
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</tr>
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<td>Drip</td>
</tr>
<tr>
<td>Fan Jet</td>
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Means not followed by the same letter are significantly different at 10%. Statistics are only within irrigation type.

Nitrogen Fertilization and Fruit N Content (2010)
Nutrient Export by 1000lb Kernel

NPK Export by 1000lb Kernel at Harvest 2009-10

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>NPK Export by 1000lb Kernel in 2009-10 (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2009</td>
</tr>
<tr>
<td>N</td>
<td>53</td>
</tr>
<tr>
<td>P</td>
<td>7.5</td>
</tr>
<tr>
<td>K</td>
<td>75</td>
</tr>
</tbody>
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July Leaf N and Hull+Shell and Kernel N at harvest

Fruit and Kernel weight

Fruit weight (gram/fruit) Kernel weight (gram/kernel)

Effect of N fertilization on Hull Rot

N Fertilization increases Shelling Percentage

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</tr>
<tr>
<td>Drip</td>
</tr>
<tr>
<td>125</td>
</tr>
<tr>
<td>25.8</td>
</tr>
<tr>
<td>Fan Jet</td>
</tr>
<tr>
<td>b</td>
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Statistics are only within irrigation type.

Shelling percentage is on the basis of clean 4lb sample.
Conclusions

- 1000lb kernel removes from 55 - 70lb N (at a leaf N of 2.0 to 2.4% in July), 8lb P and 80lb K.
- 80% of N, 75% of P and K accumulates in the fruit before 120 DAFB (mid June in 2010).
- In this trial a N rate of 275lb/ac maximized yield (4,700 lb acre) and there was no benefit from N application in excess of this value.
- A Nutrient Use Efficiency (N removed in harvest/N applied) of 75-85% was observed for N rate 275lb/ac rate.

Conclusions: Managing Nitrogen

Base your Fertilization Rate on Realistic, Orchard Specific Yield
- Estimate your current yield and try to get as close to ‘replacement’ as possible.
- 1000lb kernel removes from 55-70 lb N (July leaf N 2.0 – 2.4%), 8lb P and 80lb K.
- Apply 70-80% from bloom to mid-June.
- Apply 20-30% post harvest but only if trees are healthy.
- Every field is a unique decision
- Include all inputs (fertilizer, water, manures etc)

Leaf analysis is useful to monitor orchards but it is NOT adequate to make fertilizer decisions.

Follow the sampling rules!
- 18 trees/one bag/each two trees apart. You can sample in April to estimate July. (Labs will have guidelines by April)
- Use leaf analysis in conjunction with yield estimate to adjust in-season fertilization.
- Keep good records and sample consistently (right) over the years.

Estimate yield, measure leaf nutrients in April, adjust accordingly
Efficient Nutrient Management Approach
-the 3 R's-

Applying the Right Rate
- Match supply with demand (yield estimation)
- Determine nutrient content (leaf sampling)

At Right Time
- In-season fertilizer adjustment (leaf sampling and fruit development)

In the Right Place
- Ensure delivery to the active roots. (Determine root distribution and activity. Determine water and nitrogen movement)

Thanks!
- Sebastian Saa
- Saiful Muhammad
- Blake Sanden
- Roger Duncan
- John Eddstrom
- David Doll
- Bruce Lampinen
- Ken Shockey
- Emilio Laca
- Art Bowman
- Lagoisty Farms
- Paramount Farming
- Lots more…….