Management of Nitrogen in Almonds and Pistachios

New Leaf Sampling and Nutrient Budgets for Almond and Pistachio

- Questions
- Opportunities

Patrick Brown, Professor, Department of Plant Sciences
University of California, Davis
Nitrogen is essential for productivity but when managed poorly N results in environmental problems.
Historical N applications have Exceeded Crop Demand Resulting in Groundwater Contamination

Nitrogen is essential for productivity but when managed poorly N results in environmental problems.

30% of wells exceed EPA drinking water levels (45 mg/L nitrate) and 250,000 people in SJV do not have access to ‘safe’ water.

Agriculture is a major source of N_2O and CH_4

CO_2 eq (Million tonnes)

- 0.6%
- 55%
- 60%

(Ekdahl and others, 2009; Harter Report, 2012)
Legislative Response: Mandated Nitrogen Management Planning

- Application rates will be based upon field specific crop N budget estimations, accounting for all applied N x ‘efficiency factor’ (60-80%).
  - New techniques for N budgeting
  - Maximizing nitrogen use efficiency will be critical

- Certified Crop Advisor sign off required.
  - Training and certification process under development
  - Post season verification and reporting.

- Will require enhanced efficiency of N use. Site (orchard) specific management. In season monitoring and adjustment.
  - New techniques for leaf sampling

- In the short term this will be a self-reporting industry driven activity.
  - However, if improvements in ground water resources are not realized then a tightening of these regulations can be expected.
Whenever there is a problem, there is also an opportunity...

...Improving the Efficiency of Nitrogen use will Reduce Production Costs and Reduce Environmental Impact
Efficient Nitrogen Management
-the 4 R’s-

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

Apply at the **Right Time**
- Apply coincident with tree demand and root uptake.

Apply In the **Right Place**
- Ensure delivery to the active roots.
- Minimize movement below root zone

**Use the Right Sampling and Monitoring Procedures**

*The 4 R’s are specific to ever individual orchard and every year.*
How do we estimate the 4 R’s in Almonds?

Manipulative Experiment for five years

- Treatments
- 4 Nitrogen rates – 125, 200, 275 and 350 lb/ac
- 2 Nitrogen Sources: UAN 32 and CAN 17
- 3 Potassium Rates: 100, 200, and 300 lb/ac
- 3 Potassium Sources: SOP, SOP+KTS and KCl @ 200 lb/ac
- Irrigation Types
- Fan Jet and Drip

Fertilization

- 4 times during the season
  - 20, 30, 30 and 20% 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

Large experiment covering approximately 100 acres.

768 trees individually monitored for nutrients, yield, light interception, disease, water.

Trees were 9 leaf in 2008.

Nonpareil - Monterey

Observational Experiment for four years

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)
Efficient Nitrogen Management
-the 4 R’s-

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

Apply at the **Right Time**
- Apply coincident with tree demand and root uptake.
- CONTROLLED RELEASE?

Apply In the **Right Place**
- Ensure delivery to the active roots.
- Minimize movement below root zone
Determining the Right Rate and Timing

Nutrient Budget Approach

• What is the total annual tree demand?
• When during growth and development does uptake occur?

Approach:

• Whole tree excavation, trunk coring, sequential nut collection and analysis, yield measurements- 1000’s of individual trees at multiple sites and years
Total Nutrient Demand and Timing

Bar chart showing nitrogen demand (lb/ac) by developmental stage and date. The chart includes stages such as Dormant, Bloom, Fruit Set, Kernel Fill, Hull Split, Harvest, and Leaf Fall. The y-axis represents nitrogen demand, and the x-axis represents dates from January 26 to December 17.
Total and Annual Dynamics of N in Mature Almond Tree (data from 12 year old trees)

Annual accumulation (Yield: 4,700 lbs)

2011: (320 lb N total)

Nuts = 90%
Leaves = 2%
Bloom = 4%
Perennial = 5%

Around 20 lbs/acre of N were needed to support growth in this 12 year old 85% canopy cover orchard. In younger orchards and in low yield years the demand for N for growth may reach 40 lbs/acre.
# Nutrient Demand is Determined by Yield

## Almonds

### Nutrient removal Per 1000 lb Kernels

<table>
<thead>
<tr>
<th>Variety</th>
<th>N removal</th>
<th>K removal</th>
<th>P removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonpareil</td>
<td>68 lb per 1000</td>
<td>80 lb per 1000</td>
<td>8 lb per 1000</td>
</tr>
<tr>
<td>Monterrey</td>
<td>65 lb per 1000</td>
<td>76 lb per 1000</td>
<td>7 lb per 1000</td>
</tr>
</tbody>
</table>

### Growth Requirement

<table>
<thead>
<tr>
<th>Yield (1000 to 4000)</th>
<th>N removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield 2,000 to 4,000</td>
<td>= 0 lb N</td>
</tr>
<tr>
<td>Yield 1,000 to 2,000</td>
<td>= 20 lb N</td>
</tr>
<tr>
<td>Yield &lt;1,000</td>
<td>= 30 lb N</td>
</tr>
</tbody>
</table>

## Pistachios

### Nutrient removal Per 1000 lbs (Dry CPC Yield)

- Valuable for estimating demand or replacing nutrient export
- Provides insight into efficiencies
  - N removal 28 lbs per 1000
  - K removal 24 lbs per 1000
  - P removal 3 lbs per 1000
- 25 lb N and 22 lb K per acre, per year is required for tree growth (Rosecrance et al 1998)
Applying at the Right Time

- When during the season should I apply my N and in what proportion?

- Need to:
  - Understand fruit development
  - Know the shape of nitrogen demand through the season
  - Know when uptake from the roots occurs
  - Know the periods of higher leaching potential
What is the shape of N demand through the season?

**Almonds**

80% of total N in fruit is accumulated by 130 DAFB.

80% of total K in fruit is accumulated by 160 DAFB (hull split).

**Pistachios**

Fresno County

Days after full bloom

Nutrient Removal per 1000 lbs dry yield (CPC)
What is the shape of N demand through the season?

80% of total N in fruit is accumulated by 130 DAFB

Almonds
Correction to FREP Report
Page 27

Sequential analysis of annual and perennial organs demonstrates that the majority of whole tree macro and micronutrient uptake occurs between anthesis and kernel fill with 35-50% of total N uptake occurring before 40 days after full bloom (DAFB) and 80-90% of the total N being accumulated by 112 DAFB coinciding with kernel filling. Over 70% of the total P and 65-80% of the total K was accumulated in fruits by mid season. Ninety percent of total S, 80-90% of total Ca and

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatment</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>S</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>T1</td>
<td>56</td>
<td>6.5</td>
<td>53</td>
<td>2.3</td>
<td>8.6</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>59</td>
<td>6.9</td>
<td>56</td>
<td>2.4</td>
<td>8.2</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>T3</td>
<td>61</td>
<td>6.7</td>
<td>59</td>
<td>2.4</td>
<td>7.4</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>T4</td>
<td>62</td>
<td>6.3</td>
<td>60</td>
<td>2.5</td>
<td>7.2</td>
<td>4.7</td>
</tr>
</tbody>
</table>

...
Sequential analysis of annual and perennial organs demonstrates that the majority of whole tree macro and micronutrient uptake occurs between anthesis and kernel fill with 35-50% of total N uptake occurring before 40 days after full bloom (DAFB) and 80-90% of the total N being accumulated by 112 DAFB, coinciding with kernel filling. Over 70% of the total P and 65%-80% of the total K was accumulated in fruits by mid season. Ninety percent of total S, 80-90% of total Ca and

- Change 112 DAFB to 130 DAFB
- Change 35-50% to 30%
What is the shape of N demand through the season?

[Graph showing nutrient removal per 1000 lbs dry yield (CPC) over days after full bloom for Nitrogen and Potassium in Fresno County.]

Pistachio
Summary Right Rate

• How much Nitrogen do I need to apply for each pound of yield produced?

➢ Account for fruit demand
➢ Account for vegetative demand
➢ Account for total N inputs (water N; fertilizer N; organic N):
   ➢ Consider N in water and other sources.
➢ Optimize application efficiency:

How efficient can we be?
How efficient can we be?

Experiment initiated in 2008 – 2013 utilizing best practices based on 4 R’s and detailed monitoring:

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

At **Right Time**
- Fertigate coincident with demand.

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

Using the **Right Source**
- Soluble, compatible and balanced.

New Sampling Methods
Nitrogen Use efficiency 2008 – 2010 under optimum treatment (N 275) was >80%.

ALMONDS

NUE = N Export in Fruit/N Applied
Pistachios

Yield and Nitrogen Demand in Pistachio

(SITE 1)

Overall NUE 62%

Av yield: 4300 (lbs/ac)
Av N removed: 125 (lbs/ac)

NUE 51%

NUE 93%

NUE 43%

Current annual N application rate (1.54 lbs/tree)
Three years averaged N removal (0.96 lbs/tree)

Fate of unused N? - Lost? In Profile? In high EC sub-soil?
How do we monitor our trees?

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

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Deficient below</th>
<th>Adequate</th>
<th>Excessive over</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td></td>
<td>2.0%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Adequate</td>
<td>2.2%–2.5%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>Adequate over</td>
<td>0.1–0.3%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Adequate over</td>
<td>2.0%</td>
<td>0.25%</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Adequate over</td>
<td>0.25%</td>
<td>0.25%</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>Excessive over</td>
<td>0.25%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>Excessive over</td>
<td>30 ppm</td>
<td>30–65 ppm</td>
</tr>
<tr>
<td>Boron (B)*</td>
<td>Deficient below</td>
<td>30 ppm</td>
<td>300 ppm</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>Adequate</td>
<td>4 ppm</td>
<td></td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>Adequate over</td>
<td>20 ppm</td>
<td></td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>Deficient below</td>
<td>15 ppm</td>
<td></td>
</tr>
</tbody>
</table>

*Critical values for boron deficiency and toxicity are currently being revised. Hull boron >300 ppm is excessive. Leaf sampling is not effective to determine excess boron.
Three Problems exist with the summer leaf sampling practices

➢ No guidance on how to take sample to properly represent field

➢ Timing of the sampling is to late to make in season adjustments

➢ Variability of the orchard was not included in the interpretation of the leaf nutrient values
Improved Leaf Sampling and Interpretation

- Develop methods to sample in Spring and relate that number to Summer critical value.
- Improve sampling guidelines

**Almonds**

**Pistachios**
In Almonds....
Predicting July N leaf concentration from April Leaf Samples.

This model requires the collection of non fruiting Spur leaves in April.
Sampling Criteria

- Collect leaves from 18 to 28 trees in one bag (depending of the confidence level and on the number of acres).

- 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.

- SUBMIT SAMPLES TO A LAB THAT HAS ADOPTED THE UCD-ESP GUIDELINES FOR EARLY SEASON SAMPLING OR A VALIDATED INTERNAL METHOD OR GO TO THE UCD MODEL PAGE TO CALCULATE JULY LEAF N

- If you would like to collect samples in July, then collect samples at 143 DAFB +/- 4 days. SAME RULES!

http://fruitsandnuts.ucdavis.edu/Weather_Services/Nitrogen_Prediction_Models_for_Almond_and_Pistachio/
In Pistachios...
<table>
<thead>
<tr>
<th>Site</th>
<th>County</th>
<th>Year</th>
<th>Summer Observed leaf N</th>
<th>Summer predicted leaf N (from spring samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buttonwillow (B1)</td>
<td>Kern</td>
<td>2012</td>
<td>2.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Buttonwillow (B2)</td>
<td>Kern</td>
<td>2012</td>
<td>3.0</td>
<td>2.8</td>
</tr>
<tr>
<td>Buttonwillow (B3)</td>
<td>Kern</td>
<td>2012</td>
<td>2.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Buttonwillow (NO1)</td>
<td>Kern</td>
<td>2012</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Buttonwillow (NO2)</td>
<td>Kern</td>
<td>2012</td>
<td>3.0</td>
<td>2.8</td>
</tr>
<tr>
<td>KammAvenue (B1)</td>
<td>Fresno</td>
<td>2012</td>
<td>2.7</td>
<td>2.6</td>
</tr>
<tr>
<td>KammAvenue (B2)</td>
<td>Fresno</td>
<td>2012</td>
<td>2.7</td>
<td>2.6</td>
</tr>
<tr>
<td>KammAvenue (B3)</td>
<td>Fresno</td>
<td>2012</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Madera (B1)</td>
<td>Madera</td>
<td>2012</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Madera (B2)</td>
<td>Madera</td>
<td>2012</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Madera (B3)</td>
<td>Madera</td>
<td>2012</td>
<td>2.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Paramount (B1)</td>
<td>Kings</td>
<td>2012</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Paramount (B2)</td>
<td>Kings</td>
<td>2012</td>
<td>2.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Paramount (B3)</td>
<td>Kings</td>
<td>2012</td>
<td>2.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Paramount (NO1)</td>
<td>Kings</td>
<td>2012</td>
<td>2.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Paramount (NO2)</td>
<td>Kings</td>
<td>2012</td>
<td>2.7</td>
<td>2.7</td>
</tr>
</tbody>
</table>

AN EFFECTIVE MODEL HAS BEEN ALSO DEVELOPED TO PREDICT JULY TISSUE N FROM AN EARLY SEASON SAMPLE IN PISTACHIO
Sampling Strategies for Pistachio

🔹 **What leaf type**: Sub terminal exposed non-fruiting branches. Collect 10 leaves per tree at 6-7 ft height- around the tree canopy.

🔹 **Leaves from**: 18-20 trees for NPKMg.

🔹 **At what distance**: Samples should be 25 yards apart in an orchard of average variability.

🔹 **When**: Between 30-45 days after full bloom.

🔹 Samples can be pooled in one bag for analysis (SAVE MONEY).

🔹 Analysis of the plant nutrients required: N, P, K, Ca, Mg, Cu. APPLY UCD-PPM MODEL

**Non-Uniform Orchard:**

🔹 Repeat this process in each orchard zone of similar performance.

Efficient Nitrogen Management

-the 4 R’s-

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

Apply at the **Right Time**
- Apply coincident with tree demand and root uptake.

Apply In the **Right Place**
- Ensure delivery to the active roots.
- Minimize movement below root zone

Use the **Right Sampling and Monitoring Procedures**

*The 4 R’s are specific to every individual orchard and every year.*
Conclusions: Managing Nitrogen in Almond and Pistachio

*Base your fertilization rate on realistic, orchard specific yield, account for all N inputs and adjust in response to spring nutrient and yield estimates.*

- Make a preseason fertilizer plan based on expected yield LESS the N in irrigation and other inputs.
  - 1000lb almond kernel removes from 68lb N, 8lb P and 80lb K.
  - Pistachio 1000 lbs CPC yield removes 28 lbs N, 24 lbs K and 3 lbs P
  - Apply 20% of seasonal demand during or after leaf out
- Conduct (properly!) a leaf analysis following full leaf out.
- In May, review your leaf analysis results and your updated yield estimate, then adjust fertilization for remainder of season.
- Time application to match demand in as many split applications as feasible
  - 80% N uptake occurs from full leaf out to hull split in Almond or by fruit maturity in Pistachio.
  - Apply up to 20% immediately post harvest, corrected for actual yield - but only if trees are healthy. Use foliars if N loss is possible.
- Every field, every year, is a unique decision
Almond Early-Season Sampling and In-Season Nitrogen Application Maximizes Productivity, Minimizes Loss

Protocol for Early-Season Sampling and In-Season Nitrogen Budgeting

Authors: Sebastian Sao Silva, Saiful Muhammad, Blake Sanden, Ennio Laca, Patrick Brown (UC Davis and UC Cooperative Extension, Kern County)

Please note corrected calculations on pages 6 + 7.

Background:

Efficient and profitable nitrogen (N) application demands that N be applied at the right rate, with the right timing and in the right location, so that productivity is maximized and the potential for N loss to the environment is minimized. The goal of N management is to apply adequate but not excessive amounts of N. You cannot enhance orchard productivity by providing N in greater amounts than is demanded by the crop. With proper management, optimal productivity and minimal N loss can be achieved simultaneously. To help growers achieve the goal of efficient and profitable nitrogen application, a new method of tissue testing and yield-driven fertilization has been developed. The following approaches are based on four years of research at multiple sites and were validated in additional trials in 2012.

Right Rate:

For mature almonds (> 7 years), nut yield in the current year is the primary determinant of N demand. The amount of N that will be removed from the orchard for a given yield ranges from 60 to 75 lbs N per 1,000 lbs of kernel yield, depending on the N status of the tree. In four years of experimentation at multiple sites, the ideal N removal rate averaged 68 lbs N per 1,000 lbs of kernel yield. This removal rate corresponds to maximal yield and optimal use of N resources, and coincides with a whole-fruit N% of 1.8%. (Note: This conversion stated as kernel pounds also factors in the N removed with shells and hulls to equal the "total fruit" N removal). Higher fruit N removal rates (>68 lbs N/1,000 lbs kernel) occur when trees have received N in excess of demand. The amount of N required for vegetative growth in a yielding tree is small in contrast to that required by the fruit, and averages 20 to 40 lbs per acre per year in orchards with 70% or greater orchard light interception.

The amount of N required (from fertilizer or other amendments) is determined by crop size (yield x 68 lbs N per 1,000 lbs kernel yield) less N supplied from water and other N sources including manures, composts, nitrogen-fixing cover crops, etc. Previous N applications in excess of crop N removal can also enhance soil and tree N reserves, thereby reducing current fertilizer N demand.

Nitrogen in irrigation water is an excellent and free N 'fertilizer' and should be included in your total annual N budget. The supply of N (lbs/acre) from water is calculated by multiplying nitrate concentration in water (ppm) x acre feet irrigation applied x 0.61. If the N concentration in irrigation water is reported as Nitrate-N, then the

http://fruitsandnuts.ucdavis.edu/Weather_Services/Nitrogen_Prediction_Models_for_Almond_and_Pistachio/
Nitrogen Prediction Models for Almond and Pistachio

These models are based on research conducted through Advanced Sensing and Management Technologies, a 4-year, multi-state project with goals to optimize resource use in deciduous tree crops. For project details, including investigatory team, methodology and support, see project link.

Nitrogen Management Tools for Almond

1) Guidelines for Early Season Sampling and In-Season Nitrogen Budgeting (pdf)
2) Estimating Tree Demand: Almond Model for Calculating Nitrogen Demand
3) Interpreting Early Season Leaf Samples:
   Download these spreadsheets: N-Prediction Model for Almond (2ZK) and N-Prediction Model for Almond: large datasets (317K) from this page: Crop Nutrient Status & Demand in Almond (Advanced Sensing & Mgmt. Technologies website)

N & K Prediction Model for Pistachio

Leaf sampling data (collect in mid-May) provides N and K value predictions for July. Download the article below for Protocol for Early-Season Sampling and In-Season Nitrogen Budgeting.

Pistachio Early-Season Sampling and In-Season Nitrogen Application Maximizes Productivity, Minimizes Loss (pdf)
Muhammad Taisai Siddiqui and Patrick Brown

PISTACHIO PREDICTION MODEL. Leaf Sampling and Model Protocol and link to interactive model.

http://fruitsandnuts.ucdavis.edu/Weather_Services/Nitrogen_Prediction_Models_for_Almond_and_Pistachio/
Crop Nutrient Status & Demand in Almond: Patrick Brown

Development of Leaf Sampling Methods & Nutrient-Budget Fertilization

Patrick Brown, Saiful Muhammad and Sebastian Saa Silva

Growers of tree crops apply a range of different nutrient management strategies. One of the simplest forms of nutrient management bases fertilization decisions on the 'Critical Value' (CV) concept, where fertilizers are applied to ensure that leaf nutrient concentrations exceed what has been determined as the critical concentration for good yield levels. In this approach, leaf nutrient analysis only provides an indication of adequacy or deficiency, rather than specific information on appropriate fertilizer rates or timing of applications.

Nitrogen Prediction Models for Almond
(Excel files for download)

These models, available in Excel format, were developed from 4 years of research in Nonpareil almond orchards. Download the Models for more information, including leaf sampling (collect in mid-April) and N values (predicted for July).

- N-Prediction Model for Almond (.xlsx, 22K)
- N-Prediction Model for Almonds: large almonds (.xlsx, 317K) up to 1000 values

For questions regarding these models, contact:
Sebastian Saa Silva, Dept. of Plant Sciences, UC Davis

For a pdf file providing protocol for use of the models: early-season leaf sampling and in-season N budgeting:
Almond Early-Season Sampling and In-Season Nitrogen Application Maximizes Productivity, Minimizes Loss
Download the Excel Spreadsheet for either individual or Bulk analyses

All Testing Labs have been provided this model: Some labs continue to use their own approaches: These have not been validated by UC Research.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MODEL FOR INTERPRETATION OF EARLY SEASON TISSUE SAMPLING AND PREDICTION OF N VALUES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creators: Sebastian Saa, Emilio Laca, Patrick Brown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UC Davis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Version 1 UC, Davis Last Update: 11/04/2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** This model was developed from 4 years of research conducted from 2008-2011 in mature Nonpareil almonds grown at four locations. The model was then validated at six different almond orchards in 2012. Results show an excellent fit between leaf N concentrations predicted utilizing the model and those observed by subsequent leaf sampling. Two outputs are provided: 1) Estimated leaf N in July. 2) Predicted percentage of trees in July that will meet or exceed the specified critical value.

The results generated utilizing this approach represent the best available model for prediction of July leaf N values. Please note that results have not been validated under all conditions and hence must be used with care.

Please complete the following: Enter the tissue nutrient values for leaves collected in spring.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Units</th>
<th>Value in April</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>%</td>
<td>2</td>
</tr>
<tr>
<td>K</td>
<td>%</td>
<td>4</td>
</tr>
<tr>
<td>P</td>
<td>%</td>
<td>0.3</td>
</tr>
<tr>
<td>B</td>
<td>ppm</td>
<td>55</td>
</tr>
<tr>
<td>Ca</td>
<td>%</td>
<td>1</td>
</tr>
<tr>
<td>Mg</td>
<td>ppm</td>
<td>1</td>
</tr>
<tr>
<td>Zn</td>
<td>ppm</td>
<td>0.2</td>
</tr>
<tr>
<td>Fe</td>
<td>ppm</td>
<td>0.5</td>
</tr>
<tr>
<td>Mn</td>
<td>ppm</td>
<td>0.2</td>
</tr>
<tr>
<td>Cu</td>
<td>ppm</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Note:*
1) For greatest accuracy leaves should be collected in mid-April from non-fruited sprout leaves and all elements listed at the left should be included.
2) If value for any nutrient is missing please leave the cell empty.
3) The program will automatically correct any values that are missing or contain nutrient concentrations that are indicative of contamination.

Enter the July Critical Value (C.V.) (Default setting 1 = 2.2)

<table>
<thead>
<tr>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>2.2</td>
</tr>
</tbody>
</table>

*Note: The currently accepted critical value for N in July in Almond is 2.2%.
This may be adjusted if you refer a lower % value to help minimize disease incidence. Selection of higher critical values is not recommended. This data is used to estimate the percentage of trees in the region from which the sample were collected that will be above the CV in July based upon the spring values entered.

Your Estimated July Nitrogen % is:

<table>
<thead>
<tr>
<th>Predicted July N</th>
<th>Predicted % of Trees that will be above C.V.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.23</td>
<td>60.36</td>
</tr>
</tbody>
</table>
Nitrogen Prediction Models for Almond and Pistachio

These models are based on research conducted through Advanced Sensing and Management Technologies, a 4-year, multi-state project with goals to optimize resource use in deciduous tree crops. For project details, including investigational team, methodology and support, see project link.

Nitrogen Management Tools for Almond

1) Guidelines for Early Season Sampling and In-Season Nitrogen Budgeting

2) Estimating Total Demand: Almond Model for Calculating Nitrogen Demand

3) Interpreting Early Season 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 Status & Demand in Almond (Advanced Sensing & Mgmt Technologies website)

N & K Prediction Model for Pistachio

Leaf sampling data (collect in mid-May) provides N and K value predictions for July. Download the article below for Protocol for Early Season Sampling and In-Season Nitrogen Budgeting.

Pistachio Early-Season Sampling and In-Season Nitrogen Application Maximizes Productivity, Minimizes Loss

Muhammad Ismail Siddiqui and Patrick Brown

Pistachio Prediction Model. Leaf Sampling and Model Protocol and links to interactive model.
Almond Nitrogen Model

Field Name: West 40
Address: County Rd 32

***** Yield History And Crop Load *****

Please type in your almond yields for the past 3 years below

- Last year's yield: 2300 lb/acre
- 2 years ago yield: 4000 lb/acre
- 3 years ago yield: 1500 lb/acre

CROP LOAD: Average

Estimated Yield: 2764 lb/acre

Override "Estimated Yield" (if you want to use other yield to estimate the fertilizer requirement, please enter new yield in box above and check mark overides)

*** Fertilizer Application ***

Fertilizer application method: Fertilization through low volume irrigation

***** Available N from Field *****

Soil type of Orchard: Fertile loam or clay
Acre feet of water applied per year: 2.5 feet/acre
Water Nitrate -N (NO₃-N) concentration*: 1 ppm (mg/liter)

*If you don't know your water NO₃-N level enter 0

Last July leaf total N level **: 2.3 % of dry weight

**If you don't know last leaf N enter 0

***** Organic N *****

Manure: Last year: Dry Cow Manure, 2.5% N
Two year prior: Chicken Manure

Compost: Amount (tons/acre)

Legume cover crop: No

***** Potassium Application *****

Potassium fertilizer type: Potassium Chloride (Muriate)

Last July leaf total K level**: 2.5 % of dry weight

**If you don't know leaf K level enter 2.5

Potassium Chloride (Muriate) requirement is 355 lb/ac

K recommendation

Potassium requirement is 217 lb/ac

Nitrogen Balance

Tree N Demand: 188 lb/ac
External N Supply and Adjustments: 27 lb/ac

Leaf Tissue Adjustments: 0 lb/ac
Irrigation Water: 7 lb/ac
Soil: 0 lb/ac
Manure: 20 lb/ac
Compost: 0 lb/ac
Cover crop: 0 lb/ac

Adjusted Orchard N Demand: 161 lb/ac

This program provides recommendations only and is not intended to be used as the sole source of information for making N and K fertilization decisions. Local environmental conditions can have a profound effect on fertilizer demands. The University of California, and the California State University are not responsible for the accuracy of this model.
We are currently developing digital software with SureHarvest to integrate the 4 R’s and correctly monitor the use of N.
Improving the Efficiency of Nitrogen Use is a Win-Win

Approaches to improve N use efficiency in Almond and Pistachio:

- Match orchard specific fertilizer rate and timing with orchard specific demand.
- Improve orchard sampling and monitoring techniques
- Adjust Fertilization IN-SEASON
- TO OPTIMIZE EFFICIENCY: MANAGE ALL FIELDS INDIVIDUALLY EVERY YEAR
- Manage irrigation to minimize losses.
- Optimize the nutrition for all other nutrients
- Manage in-field variability using: Variable Rate/Placement Methods, Modified Irrigation/fertigation systems design.

(Ekdahl and others, 2009; Harter Report, 2012)
Thank you!

- Historical Contributions: Weinbaum, Rosecrance, Uriu, Farm Advisors.
- Sebastian Saa
- Saiful Muhammad
- Ismail Muhammad
- Andres Olivos
- Blake Sanden
- Roger Duncan
- John Edstrom
- David Doll
- Bruce Lampinen
- Ken Shackel
- Emilio Laca
- Grower Cooperators
- Paramount Farming
- Almond Board of California
- USDA, CDFA