University of California

Nitrogen Management Training
for Certified Crop Advisers

Nitrogen Management for Permanent Crops
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

• **Using the Right Source and Monitoring**
  • Maximize uptake, maximize response and minimize loss.

*The 4 R’s are specific to every orchard each year.*
Optimizing N Use in Tree Crops

Supply (Rate) = Demand (Amount and Timing)

Nutrients

Fixation

Timing

Loss

Volatilization, denitrification from soil

Leaching

Organic matter

Mineralized N in soil

Cover crops, manures, composts

Irrigation water

Commercial N fertilizers

Harvested nuts

Husks, leaves, prunings removed from orchard
Right Rate
Plant N Demand
The Right Rate Equation: Demand Function

Demand Function

Supply Function

- N mineralized in the soil
- N in the water
- N in the fertilization

Efficiency Factors:
Determining N Demand

- Nutrient Budget Approach
  - What is the total annual tree demand?
  - When during growth and development does uptake occur?

Experimental Approach:

- Whole tree excavation, trunk coring, sequential nut collection and analysis, yield measurements- 1000’s of individual trees at multiple sites and years
# Plant N Demand

<table>
<thead>
<tr>
<th>Species</th>
<th>Age*</th>
<th>Quantity</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>6</td>
<td>49</td>
<td>From budbreak to fruit harvest; in 55L pots</td>
<td>Cheng and Raba, 2009</td>
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<tr>
<td>Apple</td>
<td>6</td>
<td>53</td>
<td>Include nutrient increase in tree framework</td>
<td>Scandellari et al., 2010</td>
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<tr>
<td>Cherry</td>
<td>1</td>
<td>8-11.5</td>
<td></td>
<td>Bonomelli et al., 2010</td>
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<tr>
<td>Orange</td>
<td>10</td>
<td>74</td>
<td>Include nutrient increase in above ground tree frame</td>
<td>Roccuzzo et al., 2012</td>
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<tr>
<td>Grape</td>
<td>42</td>
<td>34-53</td>
<td></td>
<td>Pradubsuk and Davenport, 2010</td>
</tr>
<tr>
<td>Grape</td>
<td>15</td>
<td>44</td>
<td>Fruits, shoot and leaves</td>
<td>Porro and Dorigatti, 2009</td>
</tr>
<tr>
<td>Peach</td>
<td>7</td>
<td>44-118</td>
<td>Excavation and modeling</td>
<td>Rufat and De Jong, 2001</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>mature</td>
<td>178</td>
<td>cv. Hort16A</td>
<td>Boyd et al., 2010</td>
</tr>
</tbody>
</table>

* years.

<table>
<thead>
<tr>
<th>Species</th>
<th>N lbs per 1000 lbs of fruit produced</th>
<th>Source</th>
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<tbody>
<tr>
<td>Apple</td>
<td>0.5-0.6</td>
<td>IFA, 1992; USDA, 1963</td>
</tr>
<tr>
<td>Citrus</td>
<td>1.1-1.6</td>
<td>Rocuzzo, 2013; Krueger/Arpaia 2010</td>
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<tr>
<td>Cherry (Sweet)</td>
<td>2-2.35</td>
<td>Huguet, 1980</td>
</tr>
<tr>
<td>Table Grape</td>
<td>1.3-1.9</td>
<td>Lohnertz, 1991; USDA 1963</td>
</tr>
<tr>
<td>Wine Grape</td>
<td>0.8-2</td>
<td>Coombe, 1992; Mullins, 1992</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>1.3-1.8</td>
<td>Smith et al., 1988; Pailly 1992</td>
</tr>
<tr>
<td>Walnut (In-shell)</td>
<td>14-20</td>
<td>Weinbaum 1991; Pope 2014</td>
</tr>
<tr>
<td>Peach</td>
<td>0.8-1.2</td>
<td>Maragoni and Rombola 1994; USDA 1963</td>
</tr>
<tr>
<td>French Prune</td>
<td>3 (1000 fresh), 9 (1000 Dry)</td>
<td>Weinbaum, et al., 1994, USDA, 1963</td>
</tr>
<tr>
<td>Olives</td>
<td>8</td>
<td>Angelo Rodrigues et al., 2012</td>
</tr>
<tr>
<td>Almond</td>
<td>68 (1000 lb kernel), ≈ 16 lb per 1000 lb whole fruit</td>
<td>Muhammad, Saa, Brown et al (2013)</td>
</tr>
</tbody>
</table>
Plant N Demand: Vegetative and Fruit Proportions

Nitrogen Demand in lbs per acre

0-1000 #
1001-2000 #
2001-3000 #
3001-4000 #

Yield Demand
Vegetative Demand

44 %
15 %
5 %
1.6 %
Plant Nutrient Demand: Effect of Excessive N Application

- Applying more N than needed does not result in greater N uptake by fruit, but does increase leaching potential.
- There is less vegetative growth when yield is high, even when N is applied in excess.
- Increasing N from 275 to 350 lbs N did not increase N removal by fruit.
- In plants receiving adequate N, 68 lbs of N is removed in 1000 lbs kernel yield.
- 80% of crop N is accumulated by 130 days after full bloom.
Right Rate
Sources of N Supply
The Right Rate Equation: Supply Function

Supply Function

- N mineralized in the soil
- N in the water
- N in the fertilization

Efficiency Factor

Demand Function

Plant Nutrient Demand
Crediting N in Soil: What Controls Decomposition and Mineralization Rates?

Generally:
- C:N ratio of 20:1 (2% N) is the dividing line between mineralization (immediate release) and immobilization (N binding and later release).
- Most N in added materials becomes available, though it may take several years.
- Long term efficiency of N use from high C:N organic materials in orchards is poorly understood.

<table>
<thead>
<tr>
<th>Organic material</th>
<th>% C</th>
<th>% N</th>
<th>C/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce sawdust</td>
<td>50</td>
<td>0.05</td>
<td>600</td>
</tr>
<tr>
<td>Newspaper</td>
<td>39</td>
<td>0.3</td>
<td>120</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>38</td>
<td>0.5</td>
<td>80</td>
</tr>
<tr>
<td>Corn stover</td>
<td>40</td>
<td>0.7</td>
<td>57</td>
</tr>
<tr>
<td>Maple leaf litter</td>
<td>48</td>
<td>1.4</td>
<td>34</td>
</tr>
<tr>
<td>Rotted barnyard manure</td>
<td>41</td>
<td>2.1</td>
<td>20</td>
</tr>
<tr>
<td>Bluegrass from fertilized lawn</td>
<td>42</td>
<td>2.2</td>
<td>20</td>
</tr>
<tr>
<td>Broccoli residues</td>
<td>35</td>
<td>1.9</td>
<td>18</td>
</tr>
<tr>
<td>Young alfalfa hay</td>
<td>40</td>
<td>3.0</td>
<td>13</td>
</tr>
<tr>
<td>Hairy vetch cover crop</td>
<td>40</td>
<td>3.5</td>
<td>11</td>
</tr>
<tr>
<td>Digested municipal sewage sludge</td>
<td>31</td>
<td>4.5</td>
<td>7</td>
</tr>
<tr>
<td>Soil microorganisms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacteria</td>
<td>50</td>
<td>10.0</td>
<td>5</td>
</tr>
<tr>
<td>Fungi</td>
<td>50</td>
<td>5.0</td>
<td>10</td>
</tr>
<tr>
<td>Soil organic matter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average forest O horizons</td>
<td>50</td>
<td>1.3</td>
<td>45</td>
</tr>
<tr>
<td>Average forest A horizons</td>
<td>50</td>
<td>2.8</td>
<td>20</td>
</tr>
<tr>
<td>Mollisol Ap horizon</td>
<td>56</td>
<td>4.9</td>
<td>11</td>
</tr>
<tr>
<td>Average B horizon</td>
<td>46</td>
<td>5.1</td>
<td>9</td>
</tr>
</tbody>
</table>
Crediting N in Soil: N from Solid Organic Fertilizers

Dairy Manure Nutrient Content and Forms


OPTIMIZATION OF ORGANIC FERTILIZER SCHEDULES

Project Leaders:
David M. Crohn and Marsha Campbell Mathews

USING DAIRY MANURE AS A NITROGEN FERTILIZER FOR FORAGE CROPS

Marsha Campbell Mathews¹
David Crohn²


Crediting N in Soil: Nutrient Variation in Materials

C:N ratio

- Corral
- Mixed
- Settling & pond solids
- Mech screen solids
- Compost
- Almond shells

Manure Technical Guide Series
University of California Cooperative Extension

Dairy Manure Nutrient Content and Forms
Steps to Calculate the ‘Right Rate’

1. Know the tree nitrogen demand based on predicted yield
2. Calculate all the N credits
3. Calculate the amount of nitrogen still needed
4. Account for the fertilization efficiency
Supply Function: Crediting N in Irrigation Water

• Formula for Nitrate:
  – Nitrate concentration (ppm) x inches irrigation applied x 0.052

• Formula for Nitrate-N:
  – Nitrate-N concentration (ppm) x inches irrigation applied x 0.23

• Example: Lab reports 10 ppm Nitrate or 2.27 ppm Nitrate-N and you apply 48 inches of water
  Answer = 25 lbs N

  But currently we estimate that only 70% of the N in the water will be available, so:

  Answer = 17.5 lbs (25 x 0.7 = 17.5)
Steps to Calculate the ‘Right Rate’: Example

Example Calculating Remaining N Needed:

– Almond Demand Function: 3,000 kernel produced
  • 3.0 \times 68 = 204 \text{ lbs N}
– Sum of N credits from N in the water = 17 \text{ lbs N}

\begin{align*}
204 \text{ lbs N yield demand} \\
- 17 \text{ lbs N supply from irrigation} \\
= 187 \text{ lbs N needed by the crop}
\end{align*}
Nitrogen Use Efficiency

• Regulators will likely set N use efficiency standards at 70%.
  – Feasible in well managed orchards, but easier in some than others.
  – Example: \( \frac{187 \text{ lbs N}}{0.7} = 267 \text{ lbs N fertilizer should be applied} \)

• Efficiency can be reduced by:
  – Poor timing
  – Year to year yield variation (wrong rate)
  – Poor Irrigation uniformity (wrong place)
  – In field or between field variability (wrong rate, wrong place)
Improving Nitrogen Use Efficiency
Right Rate
N Use Efficiency: Pistachios

Tree NUE = N removed in harvested fruit / applied N

6 year Mean NUE = 0.72

- 42,000 lbs N applied for 6 years to 40 acres
- 26,880 lbs N exported in yield
- 6,000\text{ est} lbs N pruning, leaves, and growth
- 9,120 lbs N ‘lost’
- 38 lbs N/acre/year

- 24 yo Pistachio, 5 inch rainfall zone, no deep percolation.
- Silt loam, pH 6.7-7.0, OM 0.6%, 2 ppm NO$_3$N (100cm).
- Fertigated with five in-seasons split apps.
- 10 yr ave yield = 4,000 lb/acre = 112 lb N acre in exported fruit
- Mean N application 175 lb/acre.
Non-uniform Yield Within Field

Varying yields across 80 acres of Pistachio trees:

Managed as a single plot, large fields will always be non-uniform and less nutrient-efficient than smaller fields.
Non-uniform Yield Within Field: Solutions

Whole Field Average N demand = 150 lbs N

~5,000 lb yield

40 acre = 3,200 lb N

~2,000 lb yield

40 acre = 1,500 lb N

Difference in real N demand = 1,700 lb N

25% NUE increment

Pistachio Yield
Improved Nitrogen Use Efficiency

Nitrogen Use Efficiency 2008–2010 under optimum treatment (N 275) was >80%.

NUE = N Export in Fruit/N Applied  
70% of 275 = 82: 80% of 275 = 55 or a 40% reduction in lost N
Right Time
Nitrogen Use efficiency 2008 – 2010 under optimum treatment (N 275) was >80%.
Right Source
**Right Source: Blending Fertilizers**

Right Source: Forms of Fertilizer

- New technologies have been developed to improve nutrient stewardship
- Some of the important categories include:
  - Coated fertilizers
  - Slowly soluble fertilizers
  - Inhibitors of biological processes
  - Other nutrient enhancing materials

**Right Source: Enhanced Efficiency Fertilizer Forms**

- Synchronizing nutrient release with plant demand is a challenge with enhanced efficiency fertilizers.

- The same challenge is valid for organic fertilizers.

Right Source: Foliar Fertilizers

BIOLOGICAL RATIONALE:
1) Used to satisfy N needs when demand is extremely high (fruit growth), when application is difficult (wet soils) or risky (rainfall imminent), or when root growth is limited (cold soils, limited transpiration, poor roots post-harvest).

ECONOMIC RATIONALE AND PRACTICAL CONSIDERATIONS:
1) Relative costs and benefits are difficult to assess.
2) Can the need for foliar fertilizers be predicted and the treatment implemented in time?
3) Can a meaningful amount of N be applied?
Right Place
### Right Place: Where does N uptake occur?

<table>
<thead>
<tr>
<th>Crop</th>
<th>Depth of Main Root Feeding Zone (inches)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almond</td>
<td>3-18</td>
<td>Olivos et al (2013)</td>
</tr>
<tr>
<td>Apricot</td>
<td>3-12</td>
<td>Ghena and Tercel 1962</td>
</tr>
<tr>
<td>Cherry</td>
<td>3-15</td>
<td>Tamasi 1975</td>
</tr>
<tr>
<td>Peach</td>
<td>0-25</td>
<td>Dziljanov and Penkov 1964b</td>
</tr>
<tr>
<td>Plum</td>
<td>1-20</td>
<td>Tamasi 1973</td>
</tr>
<tr>
<td>Walnut</td>
<td>0-20</td>
<td>Kairov et al. 1977</td>
</tr>
</tbody>
</table>

Leaf Sampling
Leaf Sampling

- July/August leaf sampling is useful to monitor general performance or identify deficiencies but is inadequate as a management strategy
  - Does not provide rate or timing information
  - Too late to respond for current year, too early for next year.

- UCD has developed new Early Leaf Sampling (UCD-ESP) methods for Almond and Pistachio, in Progress for Walnut
  - Useful as a means to determine if leaves will have adequate N for the season

- Several labs have adopted these methods
  - Ask your lab if they use the UCD-ESP program
Leaf Sampling: UCD Early Sampling Protocol

Leaf Collection Method:
• Collect from non-fruiting shoots of 18-28 trees in each mgmt. zone.
• Trees at least 30 yards apart.
• Collect at canopy from at least 20 well exposed leaves/leaflets, 5-7 ft. from the ground.

Timing:
• In April/May, collect samples at 35-45 days after full bloom.
  – Submit to a lab that uses UCD-ESP (almond) or PPM (Pistachio) program
• In July, collect samples using same method as April
  – Use Almond and Pistachio Production manuals to interpret July samples.
### Leaf Sampling: UCD Early Sampling Protocol

Fruit Growers Lab: Validation of UCD-Early Season Testing Protocol  
Location: Yolo/Colusa County  
Collected by: John Edstrom

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Lab Leaf N% 4/11/13</th>
<th>Lab Leaf N% 7/10/13</th>
<th>Leaf N in July</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (100+105)</td>
<td>3.64</td>
<td>2.55</td>
<td>2.53</td>
<td>-0.02</td>
</tr>
<tr>
<td>2 (145 E)</td>
<td>4.41</td>
<td>2.92</td>
<td>2.72</td>
<td>-0.2</td>
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<tr>
<td>3 (145 M)</td>
<td>4.19</td>
<td>2.76</td>
<td>2.66</td>
<td>-0.1</td>
</tr>
<tr>
<td>4 (145 W)</td>
<td>4.04</td>
<td>2.82</td>
<td>2.63</td>
<td>-0.19</td>
</tr>
<tr>
<td>5 (125)</td>
<td>3.46</td>
<td>2.34</td>
<td>2.48</td>
<td>0.14</td>
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<tr>
<td>6 (710+715)</td>
<td>3.99</td>
<td>2.55</td>
<td>2.61</td>
<td>0.06</td>
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<tr>
<td>7 (720)</td>
<td>3.84</td>
<td>2.67</td>
<td>2.58</td>
<td>-0.09</td>
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<tr>
<td>8 (740)</td>
<td>3.69</td>
<td>2.66</td>
<td>2.54</td>
<td>-0.12</td>
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<tr>
<td>9 (755)</td>
<td>3.99</td>
<td>2.53</td>
<td>2.61</td>
<td>0.08</td>
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<tr>
<td>10 (700+705)</td>
<td>3.96</td>
<td>2.49</td>
<td>2.61</td>
<td>0.12</td>
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<tr>
<td>11 (735)</td>
<td>3.73</td>
<td>2.61</td>
<td>2.55</td>
<td>-0.06</td>
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<tr>
<td>12 (725)</td>
<td>3.8</td>
<td>2.54</td>
<td>2.57</td>
<td>0.03</td>
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<td>13 (730)</td>
<td>3.79</td>
<td>2.73</td>
<td>2.56</td>
<td>-0.17</td>
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<td>14 (745)</td>
<td>3.97</td>
<td>2.77</td>
<td>2.61</td>
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<tr>
<td>15 (750)</td>
<td>4.09</td>
<td>2.43</td>
<td>2.64</td>
<td>0.21</td>
</tr>
</tbody>
</table>

**SUMMARY:**  
UCD-ESP model was within 0.15% in 93% of all samples  
UCD-ESP model was within 0.20% in 100% of all samples
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Course materials available at:

[Website Link]

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