Nitrogen Fertility Management in Organic Production

Richard Smith, Farm Advisor
Monterey, Santa Cruz and San Benito Counties
Characteristics of the Organic Production System

• Nearly all N is provided by organic sources
• Mineralization needs to occur to produce nitrate and ammonium for plant growth
• There is a need to build up levels of soil organic matter which is used as source of N for crop growth
• Cover crops, crop residues and fertilizers also contribute N for crop growth
Nitrogen Cycle

Soil Organic Matter
Most soil N is in this form
(1000 – 3000 lbs N/A)

Mineralization*

NH$_4^+$

Nitrification

NO$_3^-$

Plants

CEC

Death

Microbes

Crop residue, Compost, Fertilizers

* Mineralization is a key step in making N available for plant growth.
It is dependent upon adequate soil temperatures (i.e. > 50 F)
Sources of Nitrogen for Crop Growth

1. Residual mineral N (NO$_3$-N and NH$_4$-N)
2. In season mineralization of N from soil organic matter
3. N availability from prior crops & cover crops
4. Organic Fertilizer
1. Residual Soil Mineral N (nitrate and ammonium pool)

- Can be measured with the Presidedress Nitrate Quick Test
Presidedress Nitrate Quick Test
Residual Soil Mineral N

- Nitrate is typically low in organic production systems.
- Organic systems differ from conventional systems in that N management cannot typically be based on measuring a large pool of mineral N in the soil.
- This can vary however, depending upon fertilization practices.
Comparison of Organic and Conventional Onions
Hollister, 1996

Soil ppm NO3-N

Conventional

Organic

May May Jun Jun Jul Jul Jul Aug
Soil Nitrate in Organic Vegetable Production 2001 - 2003

Jackson, 2005
2. In season mineralization of N from soil organic matter

- 2 to 5% of soil organic matter decomposes annually
- As the organic matter decomposes, NH$_4^+$ and nitrate NO$_3^-$ are released
In season mineralization of N from soil organic matter

- A rough estimate of mineralization from soil organic matter can be made based on the amount of organic N present in the soil and the percent of that N likely to mineralize over a given period of time.
In season mineralization of N from soil organic matter

For a soil with 1% organic matter:

• 2,800 lb organic N / acre x 0.02 (percent of organic N that mineralizes in 60 days) =

56 lb plant available N / acre over two months
Nitrogen Release Characteristics of N Soil Organic Matter

Available Nitrate (ppm)

Soil organic matter mineralization

Relative Rate of N Mineralization
3. N availability from cover crops

- Cover crops typically take up or fix between 100-200 lbs N/acre
- Cover crops are often tilled into the soil when the C:N ratio <20 to achieve a net release of N to the soil to feed subsequent vegetable crops
- Cover crops with a low N content such as mature cereals (i.e. C:N ratio > 20) temporarily tie up nitrogen*

* soil microbes utilize available soil N to break down the cover crop residue
# Nitrogen release from cover crop residue based on the N content

<table>
<thead>
<tr>
<th>Nitrogen Release</th>
<th>Percent N in Cover Crop</th>
<th>Examples of Cover Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Will Tie up N</td>
<td>0.5</td>
<td>Cereal Straw</td>
</tr>
<tr>
<td>Will Tie up N</td>
<td>1.0</td>
<td>Cereal Straw</td>
</tr>
<tr>
<td>Will Tie up N</td>
<td>1.5</td>
<td>Cereal at heading</td>
</tr>
<tr>
<td>May Tie up N*</td>
<td>2.0</td>
<td>Cereal pre heading</td>
</tr>
<tr>
<td>May Tie up N*</td>
<td>2.5</td>
<td>Mustards at heading and Imm. cereal</td>
</tr>
<tr>
<td>Will Release N</td>
<td>3.0</td>
<td>Mustards, legumes and juvenile cereal</td>
</tr>
<tr>
<td>Will Release N</td>
<td>3.5</td>
<td>Legumes and immature mustards</td>
</tr>
<tr>
<td>Will Release N</td>
<td>4.0</td>
<td>Legumes</td>
</tr>
</tbody>
</table>
Cover Crop Proteins

Microbes

Depends upon C:N; lignin and Polyphenols

Available Mineral Nitrogen

Typically <10-30% of cover crop N is taken up by the first subsequent Crop*

* A good deal of cover crop N remains in the system and can be taken up in later years (i.e. 73%)
N availability from cover crops

- The rate of mineralization of available N from a low C:N (<20) cover crop increases over a three- to six-week period following incorporation.
- Soil N levels return to pre-incorporation levels by week 6-10.
N Release Pattern from Cover Crops

![Graph showing the release pattern of nitrogen from cover crops over 18 days after incorporation. The graph plots Total Mineral Nitrogen (ppm) against Days After Incorporation of Cover Crop. The data is for three types of cover crops: Legume Mix, Mustard, and Oats. The peak nitrogen release is observed between days 39 and 53 for all three cover crops.](image-url)
Nitrogen Release Characteristics of N From Cover Crop

Available Nitrate (ppm)

Cover Crop Incorporation

Cover Crop Mineralization

Soil organic matter mineralization

Relative Rate of N Mineralization
## 4. N Availability from Organic Fertilizers

<table>
<thead>
<tr>
<th>Material</th>
<th>Nitrogen</th>
<th>Material</th>
<th>Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chilean nitrate</td>
<td>16</td>
<td>Soybean meal</td>
<td>7</td>
</tr>
<tr>
<td>Blood meal</td>
<td>12</td>
<td>Processed liquid fish</td>
<td>4</td>
</tr>
<tr>
<td>Feather meal</td>
<td>12</td>
<td>Alfalfa meal</td>
<td>4</td>
</tr>
<tr>
<td>Seabird and bat guano</td>
<td>9-12</td>
<td>Pelleted chicken manure</td>
<td>2-4</td>
</tr>
<tr>
<td>Fish meal or powder</td>
<td>10-11</td>
<td>Bone Meal</td>
<td>2</td>
</tr>
<tr>
<td>Meat and bone meal</td>
<td>8</td>
<td>Kelp</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>
Pelleted Poultry Manure
Net N Mineralization

Incubation - Weeks

Hartz and Johnstone, 2006
Fish Powder
Net N Mineralization

Incubation - Weeks

Hartz and Johnstone, 2006
Feather Meal
Net N Mineralization

Incubation - Weeks

Hartz and Johnstone, 2006
Percent of Initial Organic N Mineralized – 4 Weeks Incubation

Hartz and Johnstone, 2006
Nitrogen Release Characteristics
of N From Fertilizer

Available Nitrate (ppm)

Fertilizer Mineralization

Soil organic matter mineralization

Relative Rate of N Mineralization
Integrating Sources of N for Organic Production
The cover crop plots produced 3.2 tons of biomass and contained 194.5 lbs N/A.
The cover crop was incorporated February 14.
12 inches of rain fell between incorporation of the cover crop and transplanting broccoli on April 20.
Rain Events Between Cover Crop Incorporation and Transplanting Broccoli

![Graph showing rainfall events and cumulative rainfall between 14-Feb and 18-Apr.](image)

- **Rainfall Events**: Vertical bars indicate rainfall events on specific dates.
- **Cumulative Rainfall**: Line graph shows the accumulation of rainfall over time.

Dates and Rainfall Amounts:
- 14-Feb: 0.0 in.
- 21-Feb: 0.1 in.
- 28-Feb: 0.2 in.
- 7-Mar: 0.3 in.
- 14-Mar: 0.4 in.
- 21-Mar: 0.5 in.
- 28-Mar: 0.6 in.
- 4-Apr: 0.7 in.
- 11-Apr: 0.8 in.
- 18-Apr: 0.9 in.
Soil Temperatures Between Cover Crop Incorporation and Transplanting Broccoli

![Graph showing soil temperatures between cover crop incorporation and transplanting broccoli from 14-Feb to 18-Apr. The graph shows a general increase in soil temperature over time, with some fluctuations.]
Total Mineral Nitrogen in Soil Between Cover Crop Incorporation and Transplanting Broccoli

Total Mineral Nitrogen, Hartnell Organic Plot 2006

- **CC**: Cover Crop
- **No CC**: No Cover Crop

- **Total Mineral N (mg/kg +/- SEM)**

- **Dates**:
  - 21-Feb
  - 1-Mar
  - 9-Mar
  - 16-Mar
  - 23-Mar
  - 31-Mar
  - 6-Apr
  - 13-Apr
  - 20-Apr
Harvest – Number of Heads

<table>
<thead>
<tr>
<th>Number of Heads</th>
<th>0</th>
<th>5000</th>
<th>10000</th>
<th>15000</th>
<th>20000</th>
<th>25000</th>
<th>30000</th>
<th>35000</th>
<th>40000</th>
<th>45000</th>
<th>50000</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Cover Crop</td>
<td>0</td>
<td>75</td>
<td>150</td>
<td>225</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cover Crop</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>

Pounds N/A
Harvest – Weight of Heads
Tons/A

<table>
<thead>
<tr>
<th>Pounds N/A</th>
<th>0</th>
<th>75</th>
<th>150</th>
<th>225</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Cover Crop</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Cover Crop</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>
N availability from cover crops

- It is likely that a substantial portion of the nitrogen contained in the cover crop was lost to leaching prior to planting the broccoli.
- In spite of these conditions, there was an increase of 25 lbs of N/A in the biomass of broccoli in cover cropped plots vs non-cover cropped plots at the end of the growing season.
- Mark Gaskell has typically seen cover crops to contribute 100 lbs of N/A in studies on peppers and cabbage.
High Yielding Treatments Low Synchrony form Cover Crop but Good Synchrony of N Release from Fertilizer

Available Nitrate (ppm)

- - - Crop Demand

Cover Crop Incorporation

Fertilizer Mineralization

Cover Crop Mineralization

Soil organic matter mineralization

Relative Rate of N Mineralization
Low Yielding Treatments had Poor Synchrony between N Availability from Cover Crop and Fertilizer Rates that were too Low

![Graph showing the relationship between the relative rate of N mineralization and available nitrate levels compared to crop demand. The graph illustrates the synchronization issues between cover crop mineralization, fertilizer mineralization, and soil organic matter mineralization.]
Organic Fertilizer Form and Timing Trial
Watsonville, 2001

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Preplant May 8</th>
<th>Top dress May 31</th>
<th>Top dress June 7</th>
<th>Top dress June 14</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fert Treat No. 1</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>180</td>
</tr>
<tr>
<td>Fert Treat No. 2</td>
<td>90</td>
<td>0</td>
<td>45</td>
<td>45</td>
<td>180</td>
</tr>
<tr>
<td>Fert Treat No. 3</td>
<td>135</td>
<td>0</td>
<td>0</td>
<td>45</td>
<td>180</td>
</tr>
</tbody>
</table>

1) Meat Meal 8-5-1; 2) Feather Meal 12-0-0
3) Blood Meal 13-0-0; 4) Guano/Chicken 7-0-0
Nitrate-Nitrogen in the Soil of 135-45 Fertilizer Treatments

Organic Broccoli, Watsonville, 2001

Fertilizer Application
Total Number of Heads, Organic Broccoli
Watsonville, 2001

- Untreated
- Meat Meal
- Feather Meal
- Blood Meal
- Guano/Chicken

Graph showing the total number of heads with different organic fertilizers.
Total Weight of Heads, Organic Broccoli
Watsonville, 2001

- Untreated
- Meat Meal
- Feather Meal
- Blood Meal
- Guano/Chicken
Comparison of Materials and Timing
Organic Broccoli, Watsonville, 2001

<table>
<thead>
<tr>
<th></th>
<th>Blood Meal</th>
<th>Guano/Chicken</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>90-45</td>
<td>135</td>
</tr>
<tr>
<td>3</td>
<td>135</td>
<td>45</td>
</tr>
<tr>
<td>4</td>
<td>4x</td>
<td>2x</td>
</tr>
<tr>
<td>5</td>
<td>45</td>
<td>90-45</td>
</tr>
<tr>
<td>6</td>
<td>135</td>
<td>2x</td>
</tr>
</tbody>
</table>

Weight (lbs)
Chicken/Guano Rate and Timing in Good Synchrony with Crop Demand

![Graph showing nitrate concentration, fertilizer N availability, background nitrate availability without cover crop, and crop demand over 8 weeks.]

- Nitrate Concentration
- Weeks
- Background Nitrate Availability without Cover Crop
- Crop Demand
- Fertilizer N Availability
Fertilizers Rate is Adequate, but Timing and Mineralization Rate Out of Synch with Crop Demand (i.e. 4x rate of 45 lbs N/A)
Fertilizers Rate is Adequate, but Timing is Out of Synch with Crop Demand (i.e. 4x rate of 45 lbs N/A)
Integrating All Sources of Nitrogen

- Achieving effective synchrony between crop uptake and N supplied by mineralization from soil organic matter, cover crop residues and fertilizers is the challenge for managing N fertility of vegetables in organic systems.
Effective Synchrony Between Mineralization from the Various Sources and Crop Demand

Available Nitrate (ppm)

Cover Crop Incorporation

Fertilizer Mineralization

Cover Crop Mineralization

Soil organic matter mineralization

Relative Rate of N Mineralization

Crop Demand
Nitrogen fertilization in organic systems is trickier than in conventional systems where applications of readily available N can be applied in a timely manner.

There are typically large pools of organic N in soils, but the availability of this N and the synchrony of release and availability for crop production are difficult to predict.
Summary

• As a result, organic growers have to develop excellent skills and knowledge to work with this system
• There may be a tendency to over fertilize, especially in cold soils to make sure there is adequate material available for mineralization