Cover crops as a Soil Management Practice to Improve Nitrogen Nutrition for Organic Vegetable Production

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Recent cost studies documenting fertilizer costs in organically produced broccoli and leaf lettuce

- Sample costs to produce organic broccoli
- Sample costs to produce organic leaf lettuce

http://www.agecon.ucdavis.edu/outreach/crops/cost.htm

- go to CEMonterey and go to the publication link
Comparison of Fertilizer Costs of Organic vs Conventional Leaf Lettuce

<table>
<thead>
<tr>
<th>System</th>
<th>Costs $/A</th>
<th>Percent of growing cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic¹</td>
<td>478</td>
<td>16</td>
</tr>
<tr>
<td>Conv.²</td>
<td>249</td>
<td>9</td>
</tr>
</tbody>
</table>

1 – Tourte and Smith, 2004; 2 – Tourte and Smith, 2001
## Comparison of Fertilizer Costs of Organic vs Conventional Broccoli

<table>
<thead>
<tr>
<th>System</th>
<th>Costs $/A</th>
<th>Percent of growing cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic¹</td>
<td>612</td>
<td>19</td>
</tr>
<tr>
<td>Conv.²</td>
<td>260</td>
<td>12</td>
</tr>
</tbody>
</table>

¹ – Tourte and Smith, 2004; ² – Smith et al. 2004
Background on Nitrogen Nutrition

• Prior to the development of the Haber-Bosch process in 1913, growers relied on a combination of nitrogen fixation from legumes, crop residues and scavenging of animal wastes to provide the nitrogen needs of their crops.

• Cover crops were a key source of nitrogen fertility
Background on Nitrogen Nutrition

- It is estimated that intensive farming operations were able to supply about 200 lbs/A of nitrogen from these sources.
- The only net input of nitrogen into the traditional farming system came from fixation of nitrogen from the air ($N_2$) by legumes was converted to reactive, plant-available forms of nitrogen: ammonium ($NH_4$) and nitrate ($NO_3$).
Background on Nitrogen Nutrition

• The sources of nitrogen for organic vegetable production has changed little from the pre Haber-Bosch era.

• However, we have improved our ability to process and transport nitrogen rich materials that are acceptable as organic fertilizers, such as meat, blood, fish and seed meals; guano from Peru; as well as manure and compostable materials.
Legumes

- Bell beans, vetches and peas

- They provide a net input of nitrogen into the crop production system by fixing atmospheric nitrogen (N2) into a form useable by crops

- Maximize N production by flowering

- Not as good as scavenging as cereals and mustards
Cereals

- Include rye, barley, oats, triticale, etc
- Good at scavenging and cycling nitrogen
- Absorb N up to the boot stage
- Typically lower N content and release N slower than legumes and mustards
Mustards

• White, Indian, Canola, and radishes

• Good at scavenging N and cycling it to subsequent crops

• May have biofumigation effects to reduce weeds and diseases
Cereal/legume Mix

• Provide the benefits of diverse species included [i.e. nutrient scavenging, net input of N (legume), weed control, etc.]
Nutrient Input and Cycling of Cover Crops

- Cereals and mustards are good at scavenging N from the soil. In the Salinas Valley, there is often high amounts of residual N in the soil left over from intensive crop production.

- Legumes have the ability to fix nitrogen. However, in high residual N soils, legume nodulation and N fixation are reduced.
# Nitrogen Content of Cover Crops

**Six year Average**

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>6 year mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>131.5</td>
</tr>
<tr>
<td>Legumes</td>
<td>145.7*</td>
</tr>
<tr>
<td>Cereal/Legume Mix</td>
<td>177.1</td>
</tr>
</tbody>
</table>

*How much is net fixation is not known*
## Scavenging of N - Three Cover Crops

*Chualar, 2003*

<table>
<thead>
<tr>
<th>Cover Crops</th>
<th>Biomass T/A</th>
<th>% N in Tops</th>
<th>lbs N/acre in Tops</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Mustard</td>
<td>2.5</td>
<td>3.9</td>
<td>194.8</td>
</tr>
<tr>
<td>Indian Mustard</td>
<td>2.2</td>
<td>4.5</td>
<td>199.7</td>
</tr>
<tr>
<td>Cereal Rye</td>
<td>3.1</td>
<td>3.3</td>
<td>203.7</td>
</tr>
</tbody>
</table>
## Cover Crop Mix Components

*Salinas, 2004*

<table>
<thead>
<tr>
<th></th>
<th>Biomass Tons/A</th>
<th>Percent N in tops</th>
<th>N in tops Lbs/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oat</td>
<td>2.5</td>
<td>2.2</td>
<td>104</td>
</tr>
<tr>
<td>Legume</td>
<td>1.5</td>
<td>2.8</td>
<td>86</td>
</tr>
<tr>
<td>Total</td>
<td>4.0</td>
<td>---</td>
<td>190</td>
</tr>
</tbody>
</table>
Release of N from Cover Crops

- When cover crops are incorporated into the soil, microbes begin to decompose the tissue and the complex forms of nitrogen that they contain (i.e. proteins).
- Plant available forms of nitrogen (ammonium and nitrate) are released to the soil through this process.
Release of N from Cover Crops

- The N content of the cover crop at incorporation is an important consideration whether the cover crop will release N or whether it will be tied up in the microbial biomass (immobilized).
- In general C:N ratios > 25 immobilize nitrogen (i.e. cereals at heading).
- Leaf tissue with higher N content mineralizes quickly, while the stem tissue may take longer to break down.
Cereal Residue
High C:N

Legume Residue
Lower C:N
**Nitrogen Content of the Cover Crop Tops, C:N Ratio and Potential N Mineralization**

<table>
<thead>
<tr>
<th>Percent N in CC</th>
<th>C:N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1:90</td>
</tr>
<tr>
<td>1.0</td>
<td>1:45</td>
</tr>
<tr>
<td>1.5</td>
<td>1:30</td>
</tr>
<tr>
<td>2.0</td>
<td>1:23</td>
</tr>
<tr>
<td>2.5</td>
<td>1:18</td>
</tr>
<tr>
<td>3.0</td>
<td>1:15</td>
</tr>
<tr>
<td>3.5</td>
<td>1:13</td>
</tr>
<tr>
<td>4.0</td>
<td>1:11</td>
</tr>
</tbody>
</table>
Release of N from Cover Crops

• The ideal scenario would be that the release of N from cover crop residue would match the N demand by crops (i.e. fast enough to match crop demand, but not so fast to leach)
Nitrate Release from Cover Crops
Salinas, 2003*

Salinas, 2003*

Legend:
- Legume Mix
- Mustard
- Oats
- Rye

* No crop present

Nitrate Release from Cover Crops

ppm Nitrate

0         11          25          39          53          67 days

Cover Crop Mineralization Comparison
Salinas, 2004

1x seeding rate

Rye
Legume
Mustard
Bare

9-Mar 16-Mar 24-Mar 6-Apr
How Much Cover Crop N is Made Available for Crop Growth

- Cover crops can contain 100 – 200 lbs N but typically less than half of this is made available to the subsequent crop.

Jackson, 2000

Cover Crop in Lettuce
Four months after incorporation

Lettuce Crop
Soil Organic N

Jackson, 2000
The synchronization of N release from cover crops with the demand by the subsequent cash crop are important for efficient use of cover crop N.

Release of N from cover crops depends upon the cover crop species, stage of growth and soil moisture/temperature conditions upon incorporation.
Nitrogen Release from Cover Crop Mix
Salinas, 2004
How Long is Cover Crop N Available for Crop Growth

- Following the initial burst of mineralization soil N levels return to background levels after 6 – 10 weeks
- The longevity of the release of N is a concern for crops that have a growth span of >6 weeks or so
- Cover crop N may be sufficient for short term crops (i.e. spinach, radishes), but longer season crops will need supplemental N applications
Nitrogen Release from Cover Crops

- The difficulty in matching the release characteristics of cover crops with the nitrogen demand of horticultural crops necessitates supplemental fertilization for many crops.
- The other difficulty is the nature of the crops: shallow rooted, high N demand and quality concerns.
Nitrate N in Pepper Petioles Following Cover Crop with and without Supplemental Application of Feather Meal
Nitrate Nitrogen in Soil of Sweet Corn Following Cover Crop and Four Fertilizer Rates, Salinas, 2004

7 14 22 36 43 53 78 92 106 121 days

0 lbs N/A 50 lbs N/A 100 lbs N/A 150 lbs N/A

1' tall tassel

* * *
Total Nitrogen in Corn Tissue

Two Growth Stages

15-Jun 11-Aug

Four Leaves Harvest

- 0 lbs N/A
- 50 lbs N/A
- 100 lbs N/A
- 150 lbs N/A
Yield of Sweet Corn
Fertilizer Rates Following Cover Crop

CC Yield   CC + Supplemental Fertilizer
0 50 100 150 lbs N/A
0 50 100 150

CC Yield   CC + Supplemental Fertilizer
0 50 100 150 lbs N/A
0 50 100 150
Cover Crop and Long-term Soil Fertility

• Cover crops are key for soil building as resistant forms of the plant biomass are converted to organic matter that then serves as a reservoir for slowly available nitrogen for future crops.

• The nitrogen in organic matter is stored as amino acids and sugars that must be microbi ally processed to be made into plant available forms of N.
Types of Cover Crops to Build Soil Organic Matter

- Cereals and legumes have different impacts on building soil organic matter.
- Cereals contain phenolic compounds which are the building blocks of soil organic matter.
- Legumes are richer in nitrogen, but provide less of the building blocks for building organic matter.
## Phenolic Acids (PA) in Soils after Plant Residue Additions

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Day</th>
<th>Total PA (mg g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn</strong></td>
<td>0</td>
<td>729</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>433</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>345</td>
</tr>
<tr>
<td></td>
<td>84</td>
<td>220</td>
</tr>
<tr>
<td><strong>Soybean</strong></td>
<td>0</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>84</td>
<td>31</td>
</tr>
</tbody>
</table>

(Martens 2002)
Soil Organic Matter
Soil Mineralization

• In general, about 2% of the organic matter will mineralize over 60 days with soil temperatures at 77 F

• Soil containing 1-2% organic matter, approximately 30-60 lb N/acre would be expected to mineralize during a 60 day summer crop (0.5 to 1.0 lbs N/A/day)

• The higher the organic matter content, the more N that will be released
Comparison of Organic vs Conventional Soils
Salinas, 2003

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Management</th>
<th>Organic Matter Percent</th>
<th>Total Soil Nitrogen Percent</th>
<th>Stored Nitrogen Lbs/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay Loam</td>
<td>Organic</td>
<td>2.24</td>
<td>0.17</td>
<td>6,800</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>Conventional</td>
<td>1.78</td>
<td>0.14</td>
<td>5,600</td>
</tr>
<tr>
<td>Loam</td>
<td>Organic</td>
<td>1.74</td>
<td>0.14</td>
<td>5,600</td>
</tr>
<tr>
<td>Loam</td>
<td>Conventional</td>
<td>1.37</td>
<td>0.11</td>
<td>4,400</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>Organic</td>
<td>1.31</td>
<td>0.12</td>
<td>4,800</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>Conventional</td>
<td>0.66</td>
<td>0.06</td>
<td>2,400</td>
</tr>
</tbody>
</table>
## Ten Year Comparison of Management on Nitrogen in Soils (1989-1998) - UCD

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Organic Matter</th>
<th>Nitrogen Storage kg N/ha</th>
<th>Nitrogen Loss kg N/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Rotation Conventional (Low Biomass)</td>
<td>1.10</td>
<td>0</td>
<td>452</td>
</tr>
<tr>
<td>Organic (High Biomass)</td>
<td>1.46</td>
<td>901</td>
<td>90</td>
</tr>
</tbody>
</table>

Poudel et al. 2001
Soil Mineralization – Organic Soil Management

• However, the increased mineralization of N from cover crops and soil mineralization did not lead to comparable yields in the SAFS project at UC, Davis.

• This was partially attributable to the poor synchronization between the N release and crop demand.

• Necessitating careful supplemental fertilization.
Case example:
Other organic amendments
Summary of Nitrogen Impacts of Cover Crops on Crop Production

- Cover crops are a basic component in building up the organic matter levels in soils.
- On light soils, cereal based cover crops will be an important part of the soil building process.
- On heavier soils, higher proportions of legumes can be added to the cover crops to achieve the same level of organic matter.
Summary of Nitrogen Impacts of Cover Crops on Crop Production

- Cover crops mineralize useful amounts of nitrogen that can be an important source for subsequent crops.
- For high yield and quality, supplemental applications of N are needed for long-season crops.
- Over a period of years, as the soil organic matter levels build up from the use of cover crops and compost, the amounts of supplemental nitrogen fertilizer needed for high yields may decline.
Thank you for your attention