Role of Cover Crops in Nutrient Cycling and Soil Health

Kristy Borrelli
Northeast SARE Pennsylvania State Coordinator Penn State Extension
Overview

• Soil organic matter role in nutrient cycling

• Pools of soil organic matter

• Cover crop role in nutrient cycling
  o Nitrogen retention
  o Nitrogen supply

• Nitrogen contributions from soil organic matter
Soil Organic Matter (SOM) improves soil health by directly influencing other soil components.
Healthy soil has structure and can support life

SOM Role in Nutrient Cycling

- Soil Particle Aggregation
  - Water Flow/Absorbance
  - Support Organisms
  - Root Growth
- Nutrients and Carbon Supply
- Chelates
- Cation Exchange Capacity
  - Clays = 50-150 meq/100 g
  - Humus ≥ 200 meq/100 g

Low SOM
Poor Structure

High SOM
Good Structure
Soil animal photos from bio@biois.com

Scanning electron micrographs from www.micropedology.uni-bremen.de
Soil Organic Matter Pools

- **Labile SOM** - 5-20% of SOM
  - Simple compounds
  - Principal energy source
  - Changes rapidly

- **Stable SOM** - 60-90% of SOM
  - Stable structure, adsorbed to clay, protected in aggregates
  - Changes slowly
Build Healthy Soil by diversifying SOM inputs

Photo: Edwin Remsberg and USDA-SARE
Soil Organic Matter and Cover Crops

Cover crops can add 1 to 5 tons organic matter/acre/yr. Leads to significant increases in %OM over time.

Equilibrium organic matter level is a balance between gains and losses to the soil.

- Roots
- Leaves
- Mulches
- Manures
- Composts

OM increase from CCs

- Harvest
- Decomposition
- Erosion
Plant certain types of cover crops based on your goals

**Grasses**
Annual ryegrass: nitrogen scavenger, erosion prevention, weed suppression

**Legumes**
Crimson clover: nitrogen source, erosion prevention

**Brassicas**
Forage radish: erosion prevention, weed suppression, soil compaction reduction

Photos: Edwin Remsberg
Legume Crops

- Fix and Supply Nitrogen
  - Root nodules
  - Plant available form
- Low C:N
  - ~3.5 to 4% N before flowering
  - ~3 to 3.5 % N after flowering
- Prior to N demanding crop
- Low biomass production
- Inoculate seeds
Brassica Crops (broadleaves)

- Deep taproots
  - Biodrilling

- Radish and Canola respond to high N soils

- Scavenge N
  - Produce less biomass

- Winterkilled or planted in early spring
  - NO$_3$ leaching
  - Good in mixes

Photo: Edwin Remsberg and USDA-SARE
Cereal Crops/Grasses

- Fibrous Roots
- High C:N
  - ~2 to 3 % N before flowering
  - ~1.5 to 2.5 % N after flowering
- Nitrogen Retention
  - Control NO$_3$ leaching
- A lot of above ground biomass
- Between Summer Annuals
  - Corn – Cover – Soybean
Species Characteristics Affect N Retention

Nitrate Leaching Below 12 Inches (lbs N/acre)

- No cover crop or slow growing legume
- Winterkilled and/or fast growing legume

Species:
- Fallow
- Clover
- Pea
- Oat
- Radish

Includes Winterhardy grass or brassica:
- Rye (20% seed rate)
- Rye (20%) + Canola (25%)
- Rye (20%) + Canola (50%)
- Rye (50%)

Comparison:
- Red Clover vs. Austrian Winter Pea
Cover crop species usually have a tradeoff between N supply and N retention.

**Legumes**
- Poor N retention
- Greater N Supply

**Non-Legumes**
- Good N retention
- Less N Supply

Cover crop biomass carbon:nitrogen ratio influences N supply.
C:N ratio of cover crop residues regulates N supply vs. N tie up

Carbon:Nitrogen Ratio

<table>
<thead>
<tr>
<th>5:1</th>
<th>10:1</th>
<th>15:1</th>
<th>20:1</th>
<th>30:1</th>
<th>40:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>N mineralization - Microbes release excess N to soil</td>
<td>Neutral mineralization/immobilization</td>
<td>N immobilization - Microbes tie up N from soil</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Clovers
- Peas
- Radish
- Canola
- Cereal Rye, Triticale
- Annual Ryegrass
- Oats
- Sorghum sudangrass
- Research Station Mixtures
- On-Farm Mixtures

High Nitrogen Concentration

Low Nitrogen Concentration

PennState Extension
Corn Yield Declined with Increasing C:N Ratio of Cover Crop

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>C:N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pea</td>
<td>10</td>
</tr>
<tr>
<td>Radish</td>
<td>12</td>
</tr>
<tr>
<td>Clover</td>
<td>27</td>
</tr>
<tr>
<td>Fallow</td>
<td>28</td>
</tr>
<tr>
<td>4Spp</td>
<td>27</td>
</tr>
<tr>
<td>3SppN</td>
<td>28</td>
</tr>
<tr>
<td>6Spp</td>
<td>27</td>
</tr>
<tr>
<td>Canola</td>
<td>28</td>
</tr>
<tr>
<td>Oat</td>
<td>3Spp</td>
</tr>
<tr>
<td>W</td>
<td>Rye (50%)</td>
</tr>
<tr>
<td>Rye</td>
<td>Rye (100%)</td>
</tr>
</tbody>
</table>

Corn Silage Yield (T/ac)
Across sites and cover crop treatments, N retention and supply were controlled by interrelated factors.

Cover crop mixtures should be tailored to site-specific soil conditions.

- **Soil Variables**
  - Soil Organic Matter
  - Fall Soil NO$_3^-$-N

- **N Supply to Corn**

- **NO$_3^-$ Leaching**
  - $+$
  - $-$

- **Cover Crop Variables**
  - Spring Biomass N
  - Spring Biomass C:N
  - Fall Biomass C:N
  - Non-Legume Seeding Rate
Key Takeaways for Nitrogen Management with Cover Crop Mixtures

To prevent nitrate leaching:
- For every 3 ppm soil nitrate-N at cover crop planting, add 10 %pts to the seeding rate of winter-hardy grasses.
- Fill in remaining seeding rate to 100% with legumes or other species of interest.

To maintaining N supply to next crop:
- Non-legumes decrease N supply, but this can be offset by high soil organic matter.
- To achieve high levels of both N retention and N supply, maintain low fall soil nitrate levels and/or increase SOM levels.

Example:
12 ppm nitrate-N = 40% winter-hardy grass seeding rate.
Graphical Decision Support Tool: CC & SOM Credited N-Recommendation

• Developed a tool based on trials through PA
• Calculates:
  o N contribution from CCs and SOM based on site-specific measurements
  o Adjusted fertilizer recommendation to achieve yield potential
• Fall GDD at cover crop planting
• Spring GDD at cover crop termination
Calculating CC-credited N-rates

• 35 lbs N applied as manure
  o Determined from testing and availability factors
• 69 lbs N/ac minus 35 lbs manure-N = 34 lbs N/ac

Yield Potential | Relative Yield | Supplemental Nitrogen Requirement
---|---|---
22 | 0.65 | 69 lbs N/ac
Nitrogen Rate Comparisons

In Corn Silage (following Rye CC)

• 22 T/ac Yield Potential
  o Agronomy Guide 100 lbs N / ac
  o CC Tool 34 lbs N / ac
  o PSNT 83, 54, & 0 lbs N / ac

In Corn Grain

• 160 Bu/ac Yield Potential
  • CC Tool 0 lbs N / ac
  • PSNT 90 lbs N / ac
  • All N applied as 30% UAN on July 6th
Evaluation

• To evaluate corn N sufficiency throughout the season:
  o Ear leaves were sampled at tasseling (VT) to determine N concentrations.
  o Late-season corn-stalk nitrate testing was conducted at ½ milk-line stage.
  o Corn silage and grain yields were measured.

• Means comparisons using PROC Mixed
  o Treatment as fixed effect, Block as Random Effect
Corn Silage Results

**Yield @ 65% moisture (Ton/Ac)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield @ 65% moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgroGuide</td>
<td>16.0</td>
</tr>
<tr>
<td>CCTool</td>
<td>18.0</td>
</tr>
<tr>
<td>PSNT</td>
<td>19.0</td>
</tr>
</tbody>
</table>

**Historical Yield Potential**

- NSD
- \( P=0.15 \)
Corn Silage Results

Ear Leaf-N Concentration at VT

Sufficiency Range

- NSD
- P > 0.5

Ear Leaf-N (%)

Treatment

AgroGuide
CCTool
PSNT

PennState Extension
Corn Silage Results

Late Season Corn Stalk Nitrate

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<th>AgroGuide</th>
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<th>PSNT</th>
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<tr>
<td>Optimal Range</td>
<td>NSD</td>
<td>P=0.15</td>
<td></td>
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</table>
Corn Grain Results

Corn Grain Yield

Grain Yield @ 15.5% Moisture (Bu/ac)

Treatment

Historical Yield Potential

- NSD
- P > 0.5
Corn Grain Results

Ear Leaf-N Concentration at VT

- Sufficiency Range

- CCTool
- PSNT

- NSD
- P=0.11
Corn Grain Results

Late Season Corn Stalk Nitrate

Nitrate-N (mg/kg)

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<th>PSNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Range</td>
<td>P&lt;0.05</td>
<td></td>
</tr>
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Conclusions

• CC Tool recommended N fertilizer rate was sufficient to meet the needs of a no-till corn silage and corn grain crops

• The CC Tool recommended N rate was lower than both the Agronomy Guide recommendation and the PSNT recommendation,
  o Highlights need/opportunity to credit the N contribution of cover crops and soil organic matter.
Summary

- SOM is important in improving both physical and biochemical aspects of nutrient cycling.

- Cover crop management strategies depend on goals and should be tailored to site specific conditions.

- N retention and supply determined largely by cover crop C:N, soil fall NO$_3$- supply, and SOM.

- SOM and cover crop residue contributions need to be considered for effective nutrient management.
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Kristy Borrelli
kab617@psu.edu

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