Soil N Mineralization and the Value of Soil N Testing

Larry G. Bundy
Dept. of Soil Science
Univ. of Wisconsin
Overview

• Why is soil N mineralization important?

• Can N mineralization be measured?

• Is there potential for future improvement?

• What soil N tests are useful?
Nitrogen Mineralization

Temperature
Moisture
Climate
Cropping system
Soil properties
C & N inputs

Organic N
Mineralization
Immobilization

Inorganic N
Losses
## Contribution of Soil N to Yield

<table>
<thead>
<tr>
<th>State</th>
<th>CC</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>54</td>
<td>64</td>
</tr>
<tr>
<td>Iowa</td>
<td>45</td>
<td>75</td>
</tr>
<tr>
<td>Minnesota</td>
<td>60</td>
<td>76</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>71</td>
<td>77</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>56</td>
<td>70</td>
</tr>
</tbody>
</table>

1/ Yield with zero N as % of yield at EONR.

2/ Mean of 271 CC and 427 SC sites. Sawyer et al., 2005.
Contribution of soil N & fertilizer N to corn yield in WI

- Soil N contributes most of crop N need
- Reliable estimates of this contribution are needed
- Major effects on N efficiency and potential losses
Nitrogen Mineralization

- Temperature
- Moisture
- Climate
- Cropping system
- Soil properties
- C & N inputs

Organic N → Mineralization → Inorganic N

Mineralization

Immobilization → Organic N

Losses
Importance of N Mineralization Estimates

• Essential for improved N rate recommendations
• Many attempts to develop methods
• None have proven satisfactory
Current Status of N Mineralization Tests

- Chemical tests
  - Soil treated/extracted with chemical
  - Product of treatment measured
  - Correlation between product and N mineralization or crop response
Cropping System Effects – PBB N Availability Test †

**Corn – Corn**

Yield, bu/acre vs ppm N

- **Vanotti et al. (1995)**
- *r = 0.76***

**Soybean – Corn**

Rel. yield (%) vs ppm N

- **Schoessow (1996)**
- *r = 0.24NS*

† Gianello and Bremmer (1988)
Basis for the Illinois Soil N Test

• Amino sugar-N fraction related to corn N response (Mulvaney et al. 2001)

• Illinois soil N test (ISNT) proposed (Khan et al. 2001)
  - Measures amino sugar-N plus other soil N components
  - Related to amino sugar -N fraction
  - Related to corn N response
Results with the Illinois soil nitrogen test in Wisconsin

Critical value of 225 mg kg\(^{-1}\)

\(r^2 = 0.0013\)

\(n = 80\)
Relationship of ISNT to soil organic matter - Wisconsin

\[ y = 12.9715 + 62.5734x \]

\[ r^2 = 0.88 \]

\[ n = 80 \]
Regional ISNT vs. YONR
(Laboski et al., 2006)

R² = 0.22***
n = 96

*** Statistically significant at the 0.001 probability level
Regional ISNT vs. SOM (Laboski et al., 2006)

\[ y = -0.21 + 0.015x \]
\[ R^2 = 0.91^{***} \]
\[ n = 96 \]

*** Statistically significant at the 0.001 probability level
SUMMARY-ISNT

• The ISNT is not a reliable predictor of corn N response.
• The ISNT is measuring a constant fraction of the soil organic N rather than the readily mineralizable component.
Current Status of N Mineralization
Tests

• Biological tests
  - Usually soil incubation under fixed conditions
  - Inorganic N production measured
  - Correlation between mineralized N and crop response
  - Strength is that same processes are used as under field conditions
Regional Evaluation of N Mineralization Tests

• Seven states in NC region, 67 sites
  - (IL, KS, MI, MN, MO, NE, WI)
  - EONR for corn measured at each site
  - 16 chemical and biological tests
  - Relationship between test result and EONR determined

1/ NC-218 Regional Research Committee
Relationship between N availability tests and corn EONR at 67 sites in the NC region

<table>
<thead>
<tr>
<th>Chemical test</th>
<th>Relationship (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate borate buff. (11.2) dist., 8 min</td>
<td>0.07</td>
</tr>
<tr>
<td>Dist. with 2M KCl + MgO, 8 min</td>
<td>-0.01</td>
</tr>
<tr>
<td>Incubation with hot 2M KCl, 20 hr.</td>
<td>0.08</td>
</tr>
<tr>
<td>Na borate buff. dist (11.5), 8 min.</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Na tetraphenylboron extraction, 5 min</td>
<td>-0.10</td>
</tr>
</tbody>
</table>
Relationship between N availability tests and corn EONR at 67 sites in the NC region

<table>
<thead>
<tr>
<th>Biological test</th>
<th>Relationship (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term (300 d) aerobic incub. ( N_0 )</td>
<td>-0.11</td>
</tr>
<tr>
<td>Aerobic incub. (14-d, 30°C), soil:sand</td>
<td>-0.41**</td>
</tr>
<tr>
<td>Anaerobic incub. (14-d, 30°C), moist</td>
<td>-0.12</td>
</tr>
<tr>
<td>Anaerobic incub. (14-d, 30°C), air dried</td>
<td>-0.03</td>
</tr>
<tr>
<td>Preplant soil nitrate test (0-3 ft)</td>
<td>-0.13</td>
</tr>
<tr>
<td>Presidedress soil nitrate test (0-1 ft)</td>
<td>-0.26</td>
</tr>
<tr>
<td>Presidedress soil nitrate test (0-2 ft)</td>
<td>-0.27</td>
</tr>
</tbody>
</table>
Site-specific Aerobic Soil Incubation

- Soil collected from no-N control plots in 10 rotations in 1996.
- Rotations ranged from cont. corn to corn following alfalfa
- Aerobic incubation for 16 wk at 25°C
Relationship between N mineralized during aerobic soil incubation and corn yield in crop rotations, Lancaster, WI

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.75</td>
<td>0.14</td>
<td>0.33</td>
</tr>
<tr>
<td>4</td>
<td>0.82</td>
<td>0.49</td>
<td>0.69</td>
</tr>
<tr>
<td>8</td>
<td>0.88</td>
<td>0.54</td>
<td>0.72</td>
</tr>
<tr>
<td>10</td>
<td>0.92</td>
<td>0.72</td>
<td>0.72</td>
</tr>
<tr>
<td>14</td>
<td>0.92</td>
<td>0.72</td>
<td>0.60</td>
</tr>
<tr>
<td>16</td>
<td>0.70</td>
<td>0.54</td>
<td>0.50</td>
</tr>
</tbody>
</table>

\( r^2 \)

\(^1/\) van Schaik (1998)
Aerobic Soil Incubation - Results

- Best relationships found at 10 wk.
- Suggests that site-specific N mineralization data from one year may be useful for predicting N needs in future years
Delta Yield

• A reasonable substitute for soil N supplying capability?
• Yield @ EONR - Yield w/ no N
• Reflects N mineralization plus site factors
Delta Yield ($\Delta Y$)

• Kachanoski et al. (1996)
  - 300 expts., 1962-1992
  - No yield vs. EONR relationship
  - $\Delta Y$ vs. EONR ($r^2 = 0.5$ to 0.75)
Delta Yield ($\Delta Y$)

- Lory and Scharf (2003)
  - 298 expts. (IL, MN, MO, PA, WI)
  - Yield vs. EONR ($r^2 = 0.02$)
  - $\Delta Y$ vs. EONR ($r^2 = 0.47$)
Soil-Based Measurements

- Preplant residual nitrate tests
  - A component of soil N supplying capability
  - Semi-arid and some humid regions
  - Generally under-utilized
Residual Nitrate Testing - Low Rainfall Areas

- Long history in low rainfall areas
- Recommended test for western Minnesota
- N rates adjusted according to equation:
  \[ NG = (N \text{ rec for } C-C) - (0.6 \times STN_{(0-24 \text{ in})}) \]
Residual Nitrate Testing - Humid Areas

- Measures residual (carryover) nitrate
  - Corn after corn
  - Medium- and fine-textured soils
  - Normal or below normal rainfall
  - Available N exceeds crop need
- Not useful on sands, loamy sands
Residual Nitrate and Optimum Corn N Rate

- **Fayette**
- **Plano**

Optimum N Fertilizer Rate, lb/acre

Spring Residual Nitrate-N, lb/acre (0-3 ft)

\[ Y = 216 - 0.98X, \quad X < 220 \]

\[ Y = 0, \quad X > 220, \quad R^2 = 0.92 \]
## Residual N Credit for Spring Preplant Soil Nitrate (0-2 ft)

<table>
<thead>
<tr>
<th>Soil nitrate-N ppm</th>
<th>Residual N credit lb N/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-6</td>
<td>0</td>
</tr>
<tr>
<td>6.1-9</td>
<td>35</td>
</tr>
<tr>
<td>9.1-12</td>
<td>65</td>
</tr>
<tr>
<td>12.1-15</td>
<td>95</td>
</tr>
<tr>
<td>15.1-18</td>
<td>125</td>
</tr>
<tr>
<td>&gt; 18</td>
<td>155</td>
</tr>
</tbody>
</table>
Soil-Based Measurements

- Presidedress soil nitrate tests
  - Estimates N mineralization
  - Identifies nonresponsive sites
  - Temperature sensitivity underestimates N mineralization
Temperature effects on accuracy of PSNT-based N recommendations

Below (n=46)

<table>
<thead>
<tr>
<th>Correct</th>
<th>Over-applied</th>
<th>Under-applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>37</td>
<td>59</td>
<td>4</td>
</tr>
</tbody>
</table>

Average or above (n=55)

<table>
<thead>
<tr>
<th>Correct</th>
<th>Over-applied</th>
<th>Under-applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>76</td>
<td>16</td>
<td>7</td>
</tr>
</tbody>
</table>

May-June average temperature
May-June temperature effects on PSNT-based N recommendations

![Graph showing the relationship between excess N rate (kg/ha) and temperature departure (°C). The graph includes data points for Medium (n=45) and High (n=56) soil yield potential.](image-url)
Nitrogen rates based on yield response data

- When similar soils and cropping systems are grouped, the data base reflects the average soil N supplying capability.
## Nitrogen Rate Guidelines—Minnesota*

<table>
<thead>
<tr>
<th>N/corn value ratio</th>
<th>Corn/corn MRTN</th>
<th>Range (lb N/acre)</th>
<th>Corn/soybean MRTN</th>
<th>Range (lb N/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>155</td>
<td>130-180</td>
<td>120</td>
<td>100-140</td>
</tr>
<tr>
<td>0.10</td>
<td>140</td>
<td>120-165</td>
<td>110</td>
<td>90-125</td>
</tr>
<tr>
<td>0.15</td>
<td>130</td>
<td>110-150</td>
<td>100</td>
<td>80-115</td>
</tr>
<tr>
<td>0.20</td>
<td>120</td>
<td>100-140</td>
<td>85</td>
<td>70-100</td>
</tr>
</tbody>
</table>

* Highly productive soils
Potential for Future Improvements

• Compile field-specific N mineralization info. from aerobic incubations

• Consider delta yield ($\Delta Y$) as substitute for N mineralization measurements.
Potential for Future Improvements

- Tests or groups of tests must be related to crop N response in the field
- Use applied modeling approach to integrate factors contributing to soil N supplying capability
Potential for Future Improvements

• Integrate info. from individual procedures
• Employ under-utilized field-based tests
  – Soil nitrate testing
  – Crop sensing techniques
• N rate guidelines based on N response functions incorporate average soil N supplying capability
Potential for Future Improvements

- Improved estimates of N mineralization will:
  - Require higher level of management
  - Increase management costs
  - Higher N prices and environmental requirements may provide incentive