The Role of Soil Testing in Precision Agriculture

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Soil Testing

- Soil testing **IS** a useful tool
- Soil testing is **NOT** perfect
  - Don’t overvalue its worth
  - Natural processes and management practices can make it difficult to translate test results into fertilizer recommendations/guidelines
Field Soil Test Calibration

• Soil test values **only** indicate the **available** nutrient in the soil, **not** the **fertilizer required** to grow a crop

• Field soil test calibration **gives meaning** to a soil-test value in terms of nutrient sufficiency and fertilizer need
  • Units of measurement for test results are **meaningless** without proper field calibration with yield response

• Follow your state recommendations/guidelines
Nutrient Management
Dark Colored “Prairie Soils”
Corn-Soybean Rotation

Same yield
Same rate

Yield
N rate
How Much Yield Can We Get Through Mineralization in MN? Percent of Corn Yield at EONR Obtained from the 0-N Check 53% C-C, 71% C-S

218 bu/a  
244 lb N/a

Ave:116 bu/a  
130 lb N/a

52 bu/a  
58 lb N/a
• Nitrogen management is risk management
  – So many unpredictable variables can make it a “game of chance”
• Need to manage based on probability

MRTN Rate
108 (120) 133
Adding N in D increase Nmin  Yes
Adding N in UD decrease Nmin  Yes
Soybean less Nmin than corn  Yes
D greater Nmin than UD  Yes

Marna silty clay loam and Nicollet silty clay loam; 5.3% OM
21% greater TOC and 12% greater TN in the undrained soil
Adding N in D increase N<sub>min</sub>  Yes
Adding N in UD decrease N<sub>min</sub>  No
Soybean less N<sub>min</sub> than corn  Yes
D greater N<sub>min</sub> than UD  No
Nutrient Management

Adding N in D increase Nmin  Yes
Adding N in UD decrease Nmin  Yes
Soybean less Nmin than corn  Yes
D greater Nmin than UD  Yes for fert. trt only

2015

Adding N in D increase Nmin  Yes
Adding N in UD decrease Nmin  Yes
Soybean less Nmin than corn  Yes
D greater Nmin than UD  Yes for fert. trt only
400 samples
0-12” deep
Every 6” distance
½ acre linear transect
TIN Spatial Variability

180 samples (0-6”, 6-12”, 12-24”)
10-core composite
Each dot is a 10x10’ area
Overall, 20 samples per 2.5 acres are needed to achieve a TIN estimate with 10% error margin at 0.05 significance level.
Can a shallow sample estimate a deeper sample?

0-6” soil samples can be good predictors of 0-12” soils, but the predicting power for 6-12”, 12-24”, and 0-24” soils is limited.
End of Season Soil N

![Graph showing corn yield and soil N content vs. N rate (lb N/ac)].

- Corn yield (bu/ac)
- Soil N 0-36" (lb/ac)

Points:
- (127, 72)
- (127, 187)

Equations:
- \( \Delta = 0.17 \text{ lb TIN/lb of fertilizer} \)
- \( \Delta = 0.91 \text{ lb TIN/lb of fertilizer} \)
Lamberton, Yield

Ves loam soil

PP: EONR 124 lb N/a, 142 bu/a

\[ y = -0.0014x^2 + 0.5448x + 92.832 \]

R² = 0.9202
Soil N with Pre-plant Applications

Soil with 4% OM, CEC 24 meq/100g

Ves loam soil
Becker, Yield

Hubbard loamy sand

\[ y = 0.2192x + 36.89 \]
\[ R^2 = 0.9129 \]
Soil N with Pre-plant Applications

Soil with 1.6% OM, CEC 8 meq/100g

Hubbard loamy sand
Coarse-Textured Soils, 3 site-yrs

N rate (kg ha\(^{-1}\))

Corn grain yield (Mg ha\(^{-1}\))

V4 TIN 0-1', Coarse-Textured Soils, 3-site-yrs

Grain Yield (Mg ha\(^{-1}\))

Soil N (kg N ha\(^{-1}\))

\[ y = 2.1274 + 0.0455x - 0.00009x^2 \]

\[ r^2 = 0.40 \]

Plateau = 253 kg N ha\(^{-1}\) (226 lb/a)
Nutrient Management
Becker 2014; 2015a,b
Clara City 2014; Waseca 2014 a,b; Waseca 2015 a,b
Lamberton 2014; Theilman 2014
Lamberton 2014
Nutrient Management

V4 NO3-N 0-1', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y=3.5278+0.1287x-0.00048x^2 \]
\[ r^2=0.6902 \]
Plateau 139 kg N ha⁻¹

V4 NO3-N 0-2', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y=2.9163+0.0848x-0.00021x^2 \]
\[ r^2=0.692 \]
Plateau 214 kg N ha⁻¹

V4 TIN 0-1', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y=2.3847+0.1109x-0.00032x^2 \]
\[ r^2=0.6317 \]
Plateau 173 kg N ha⁻¹

V4 TIN 0-2', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y=1.462+0.078x-0.00015x^2 \]
\[ r^2=0.6631 \]
Plateau 282 kg N ha⁻¹
Nitrate

V8 NO3-N 0-1', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y = 5.3308 + 0.1683x - 0.00139x^2 \]
\[ r^2 = 0.251 \]
\[ Plateau = 61 \text{ kg N ha}^{-1} \]

V8 TIN 0-1', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y = 4.5823 + 0.0991x - 0.00043x^2 \]
\[ r^2 = 0.1648 \]
\[ Plateau = 115 \text{ kg N ha}^{-1} \]

V8 NO3-N 0-2', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y = 3.7807 + 0.121x - 0.00054x^2 \]
\[ r^2 = 0.3975 \]
\[ Plateau = 112 \text{ kg N ha}^{-1} \]

V8 TIN 0-2', Fine-Textured Soils, 5 site-yrs

Grain Yield (Mg ha⁻¹)

Soil N (kg N ha⁻¹)

\[ y = 3.0811 + 0.0775x - 0.0002x^2 \]
\[ r^2 = 0.2711 \]
\[ Plateau = 194 \text{ kg N ha}^{-1} \]
### V4 soil N (lb ac⁻¹) corn yield prediction

<table>
<thead>
<tr>
<th>Soil</th>
<th>Grouping</th>
<th>NO₃ 0-1'</th>
<th>NO₃ 0-2'</th>
<th>TIN 0-1'</th>
<th>TIN 0-2'</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>R²</td>
<td>Plateau</td>
<td>R²</td>
<td>Plateau</td>
</tr>
<tr>
<td>Coarse-Textured</td>
<td>3 Site-yrs</td>
<td>0.31</td>
<td>113</td>
<td>0.38</td>
<td>269</td>
</tr>
<tr>
<td>Fine-Textured</td>
<td>5 Site-yrs</td>
<td>0.69</td>
<td>124</td>
<td>0.69</td>
<td>191</td>
</tr>
<tr>
<td></td>
<td>3 Site-yrs</td>
<td>0.27</td>
<td>109</td>
<td>0.33</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>1 Site-yrs</td>
<td>0.06</td>
<td>74</td>
<td>0.15</td>
<td>120</td>
</tr>
</tbody>
</table>

### V8 soil N (lb ac⁻¹) corn yield prediction

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</tr>
<tr>
<td>Coarse-Textured</td>
<td>3 Site-yrs</td>
<td>0.32</td>
<td>58</td>
<td>0.42</td>
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<tr>
<td>Fine-Textured</td>
<td>5 Site-yrs</td>
<td>0.25</td>
<td>54</td>
<td>0.40</td>
<td>100</td>
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<tr>
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<td>3 Site-yrs</td>
<td>0.20</td>
<td>62</td>
<td>0.25</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>1 Site-yrs</td>
<td>0.12</td>
<td>---</td>
<td>0.13</td>
<td>---</td>
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</tbody>
</table>
Nutrient Management
Waseca, MN; clay loam soil
Becker, MN; sandy soil

- Split N (40 + V9)
- Split N (80 + V9)
- Single N (Pre-plant)

Grain Yield (bu/ac) vs. Total Nitrogen Rate (lbs/ac)

University of Minnesota Extension
Driven to Discover
Lamberton, C-C at 120 lb N/a
Nutrient Management

V4, Lamberton @ 120 lb N/a

V8, Lamberton @ 120 lb N/a

V12, Lamberton @ 120 lb N/a

R1, Lamberton @ 120 lb N/a
Becker, C-C at 120 lb N/a

Hubbard loamy sand
Can We Use Crop Sensors To Improve N Management?

Application Timing

Spatial Variability

Temporal Variability
V4 Stage <10% of N needs

- V3: 10 lb N/acre
- V6: 22 lb N/acre
- V12: 68 lb N/acre
- Silking: 135 lb N/acre
- Milk: 180 lb N/acre
- R3: 225 lb N/acre
- R6: 100%

- May
- Jun
- Jul
- Aug
- Sep

- 4%
Grain Yield Prediction – Sensor only – V4

GreenSeeker Field of View

61 cm
1.5 cm

Adapted from Barmeier and Schmidhalter, (2016)
Relative Sensor Reading (RSR) vs. Nitrogen Deficiency (kg N ha$^{-1}$)

- **ND = -84 lb N ac$^{-1}$**
  - RSR = 1.0
- **ND = -29 lb N ac$^{-1}$**
  - RSR = 1.01
- **ND = -41 lb N ac$^{-1}$**
  - RSR = 0.99

Graph showing the relationship between Relative Sensor Reading (RSR) and Nitrogen Deficiency (kg N ha$^{-1}$) for different sensors: SPAD, RS-NDVI, and RS-NDRE.
N Deficiency Determination – Sensor only – QPLoc – V12

Relative Sensor Reading vs. Nitrogen Deficiency (kg N ha\(^{-1}\))

- **ND** = 27 lb N ac\(^{-1}\)
  - RSR = 1.01

- **ND** = -2 lb N ac\(^{-1}\)
  - RSR = 0.99

- **ND** = -52 lb N ac\(^{-1}\)
  - RSR = 1.0

**Relative Sensor Readings:**
- **SPAD**
- **RS-NDVI**
- **RS-NDRE**

**Legend:**
- Orange line: SPAD
- Blue line: RS-NDVI
- Green line: RS-NDRE

**Nitrogen Deficiency (kg N ha\(^{-1}\)):**
- -200 to 50
N Deficiency Determination – Sensor only – QPLoc

Prescribed N Rate Variability (kg N ha\(^{-1}\))

Relative Sensor Reading (RSR)

RS-NDRE V12
RS-NDRE V8
# N Deficiency Determination – Sensor only – LINLoc

<table>
<thead>
<tr>
<th>Stage</th>
<th>SPAD</th>
<th>GS-NDVI</th>
<th>RS-NDVI</th>
<th>RS-NDRE</th>
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</thead>
<tbody>
<tr>
<td>V4</td>
<td>Linear</td>
<td>Q-P</td>
<td>Linear</td>
<td>Linear</td>
</tr>
<tr>
<td>V8</td>
<td>Q-P</td>
<td>Q-P</td>
<td>Linear</td>
<td>Linear</td>
</tr>
<tr>
<td>V12</td>
<td>Linear</td>
<td>ns</td>
<td>Linear</td>
<td>Linear</td>
</tr>
<tr>
<td>R1</td>
<td>Linear</td>
<td>ns</td>
<td>Linear</td>
<td>Linear</td>
</tr>
</tbody>
</table>

\[ R^2 = 0.65 \] \[ R^2 = 0.64 \]
Soil N sampling timing to improve sensor predictions of N deficiency
Improving Sensor Measurements

- Sensor only
- Sensor + Stepwise
- Sensor + V4 Soil N

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<thead>
<tr>
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<td>V8</td>
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$R^2$ values for different sensors and models.
## Sampling Depth and Nitrogen Measurement

<table>
<thead>
<tr>
<th>Predictive Tool</th>
<th>AIC*</th>
<th>R²</th>
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<tbody>
<tr>
<td>Sensor only</td>
<td>784</td>
<td>0.34</td>
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<tr>
<td>Sensor + 0-24” TIN</td>
<td>729</td>
<td>0.78</td>
</tr>
<tr>
<td>Sensor + 0-12” TIN</td>
<td>735</td>
<td>0.74</td>
</tr>
<tr>
<td>Sensor + 0-24” NO₃⁻</td>
<td>731</td>
<td>0.79</td>
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<tr>
<td>Sensor + 0-12” NO₃⁻</td>
<td>741</td>
<td>0.76</td>
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* Lower AIC means better fit

**V4 Soil NO₃⁻ @ 0-12” is the best approach to improve predictive power**
Utility of Soil Nitrogen to Improve Predictive Power of N Deficiency

- Sensor only
- Sensor + Soil Nitrate
- Soil Nitrate only

RMSE (Kg N ha⁻¹)

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<td>V8</td>
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<td>V12</td>
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<tr>
<td>R1</td>
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Nutrient Management
Take Home Messages

• Soil N is variable but it is an important tool

• Canopy sensors can help us manage N:
  – The earlier the sensing the greater the flexibility to apply nitrogen, **BUT**
  – The earlier the sensing the lesser the predictive power
  – The later the sensing the greater the predictive power, **BUT**
  – The later the sensing the lesser the flexibility to apply nitrogen and greater potential for yield loss

• Canopy sensor adjustments with soil N show promise

• In-season N application is **A** tool
NINTH ANNUAL NUTRIENT MANAGEMENT CONFERENCE

FEBRUARY 7, 2017

RIVER'S EDGE CONFERENCE CENTER
ST. CLOUD, MN

http://mawrc.org/events

THIRD Annual NITROGEN: MINNESOTA'S GRAND CHALLENGE & COMPPELLING OPPORTUNITY CONFERENCE

February 16, 2017
Verizon Wireless Center, Mankato, MN
Questions?

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