In-Season N Application Using Remote Sensing

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Outline

• Introduction
• Nitrogen Use Efficiency (NUE)
• In-season application of N for corn
• Research and application in the Corn Belt
• Regional algorithm project
• Minnesota N algorithm development
• Summary and what’s ahead
Introduction

• Nitrogen is the single most important nutrient in corn production.
  – Greater economic and production (yield) impact than any other applied nutrient.

• The price of N has increased dramatically in the last few months – years.
  – In 2000 N ranged from $0.15–0.20 per lb N
  – Fall of 2005 ($0.25–0.30 per lb N)
  – Spring of 2006 projected to be $0.30–0.40 per lb N.
Introduction cont.

• What can be done to increase profitability of N fertilizer?
  – Follow N BMP’s
    • Rate
    • Source
    • Time of application
    • Inhibitors
    • Take credits
As N costs rise

• Implementing N BMP’s will increase profitability, while reducing nitrogen loss from agricultural lands to ground and surface waters.
• Can more be done?

• Should more be done?
Nitrogen Use Efficiency

Research Highlights

**FACT:** Nitrogen use efficiency for cereal production in the world is 33%

**FACT:** 87,000,000 Mg of N fertilizer consumed each year in the world; 60% for cereal production

FACT: 20% increase in world cereal NUE would be worth > $10,000,000,000 annually ($835/Mt of actual N, or $757/2000 lbs of actual N, or $0.38/lb of N)

Nitrogen Deficiencies in Corn

Nitrogen Deficiency

>50% NUE? Our Approach

Sensor Based Nitrogen Rate Calculator

Calibration Stamp Technology

Nitrogen Use Efficiency Defined

Nitrogen Fertilizers

Nitrogen Deficiencies

Nitrogen Cycle

Nitrogen Uptake in Corn and Wheat

Nitrogen Fertilizer Consumption, World and by Country

NUE Science Network

NUE in Corn, Wheat, and Rice

World Wheat, Corn, and Rice

Nitrate (NO3-N) Critical Levels

Resolution for Precision Agriculture

In-Season Prediction, Wheat Yield

In-Season Prediction, Corn Yield

Response Index

Nitrogen Fertilization Algorithm

Benefits of Using this Technology
Nitrogen Use Efficiency (NUE)

• Defined
  – Nitrogen use efficiency or fertilizer recovery is a measure (ratio) of the amount of N taken up or removed in the crop to the amount of N applied.
  – FACTS (Raun and Johnson, 1999; Raun et al.)
    • NUE for cereal production in the world is 33%
    • A 1% increase in NUE in the WORLD would be worth $1,113,208,507 (2002)
What affects NUE in corn

- BMP’s – source, rate, timing, etc.
- Residual soil nitrate
- N mineralization from organic matter, crop residues and manure.
- N LOSS / WEATHER
- N uptake pattern of crop (CORN)
In-season application of N

• Let the crop tell us (show us) its N status
  – Helps us determine early season
    • N mineralization
    • N stress (N loss)
Regional research and applications
Raun et al.

$y = 4.917e^{3.2759x}$

$R^2 = 0.6616$

6 Site Years, 2003-2004, V8-V10
Sensor-Based Nitrogen Rate Calculator

Developed by Oklahoma State University, USDA-ARS, and CIMMYT

**Outputs**

- Response Index (RI):
- Yield Potential YP0, bu/acre: (1)
- Yield Potential YPN, bu/acre: (2)
- Yield Potential YPNRS, bu/acre: (3)
- Yield Potential CV, YPCV, bu/acre: (5)
- Critical CV, % (CrCV): (6)
- N Rate Recommendation, lb/acre:

**Inputs**

- Days from planting to sensing: (click to calculate)
- DVI Farmer Practice:
- DVI N-Rich-Strip:
- Coefficient of Variation (CV):
- Plant Population, Plants/acre:
- Maximum Yield for Region, bu/acre: (4)
Regional (MN) N Algorithm Project: Objective

- To develop an algorithm (a procedure for developing an N recommendation) for in-season sidedress application that would:
  - Maximize economic return to nitrogen
  - Increase fertilizer use efficiency, and
  - Incorporate recently refined N recs.
Developing an N Algorithm for Corn: Minnesota experiences

- Incorporate new N recommendations
- Chlorophyll meter
- GreenSeeker sensing
- Aerial photography and imaging
Minnesota - CC

Return to N, $/acre

N Rate, lb N/acre

0.05
0.10
0.15
0.20
2004 remote sensing for N on corn

- Previous crop: Corn removed for silage
- Soil: Nicollet-Webster complex
- N applied: 4/30 (PP), 6/28 (V8), 7/13 (V12)
- Sensing dates: 6/23 (V7), 6/28 (V8), 7/7 (V10), 7/12 (V12), and 7/26 (R1).
## Corn grain yield and N uptake as affected by rate and time of N application (corn after corn at Waseca)

<table>
<thead>
<tr>
<th>Total N Rate</th>
<th>Application Time</th>
<th>Corn Grain Yield</th>
<th>N Uptake</th>
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</table>
Corn grain yield vs relative chlorophyll

12/1/2005

Relative chlorophyll, %
Nebraska Approach

Y = 0.798150429 + (0.002112939 * Nrate) - (0.00000584568 * (Nrate^2))

Nrate (kg/ha)

Relative SPAD
Relative chlorophyll vs N rate at V8
Relative chlorophyll vs N rate at V10

![Graph showing the relationship between relative chlorophyll and N rate at V10. The x-axis represents N Rate in lb/A, ranging from 0 to 250. The y-axis represents Rel. Chlorophyll in %, ranging from 70 to 100. The graph includes a curve indicating the increase in chlorophyll as N rate increases, peaking around the 50-100 lb/A range, and then remaining relatively flat.](image-url)
Relative chlorophyll vs N rate at V12

N Rate, lb/A

Rel. Chlorophyll, %

70 75 80 85 90 95 100

0 50 100 150 200 250

N Rate, lb/A
Relative chlorophyll vs N rate at R1

N Rate, lb/A

Rel. Chlorophyll, %

0 50 100 150 200

70 75 80 85 90 95 100

N Rate, lb/A
## Predicted N credits based on MN algorithm

<table>
<thead>
<tr>
<th>N Credit (lb/A)</th>
<th>V8</th>
<th>V10</th>
<th>V12</th>
<th>R1</th>
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</table>
Sidedress N rates: MN algorithm

$$120^1 - \text{N rate credit}^2 = \text{sidedress rate}$$

1. Based on 2004 yield data, where a total of 120 lb N/A split applied yielded as well as 160 lb applied PP.
2. Based on relative chlorophyll content and response curve at respective growth stage.
### Application rates for the 2005 regional N project Minnesota treatments

<table>
<thead>
<tr>
<th>Plot</th>
<th>Trt</th>
<th>PP N rate</th>
<th>Chlorophyll SPAD</th>
<th>Rel.</th>
<th>MN Algorithm N Rate Credit</th>
<th>Applied</th>
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</table>

1. Relative calculated using 200 lb rate as reference (non limiting).
### Application rates and yields for other treatments

<table>
<thead>
<tr>
<th>N Trt.</th>
<th>PP N rate</th>
<th>SD* N rate</th>
<th>Total N N rate</th>
<th>Grain Yield</th>
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<td>12 MN</td>
<td>40</td>
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<td>170</td>
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* Sidedressed N applied at V6 for trts 1 & 3–6; at V9-10 for trts 7–10 and at V10 for trts 11 & 12.
MN “Norwegian” algorithm: First-year experiences

• Advantages
  – Simple intuitive / similar to Nebraska approach.
  – SPAD very good predictor of grain yield at V10-12.
  – Fits well with our new approach to N recommendations.

• Disadvantages / concerns
  – SPAD meter and V10 or later sensing not very practical.
    Need to adapt it to on-the-go sensing / application.
  – Not sure if it will work for other soils / crop rotations.
  – Still need a timely rain and cooperative weather.

INSEY = NDVI / Days after planting

Preplant N Rate, lb/acre

INSEY (V8)

Delta yield = (Max yield (ref) – ind. plot yield)

Delta yield, bu/a vs. Delta NDVI at V8

12/1/2005
The GreenSeeker Sensor (2005)

Delta NDVI at V7-8

Delta yield, bu/a

12/1/2005
Summary

• On-the-go sensing and N application have the potential to increase NUE and improve profitability.
• However, sensor-based N application research on corn is still in its infancy.
• The chlorophyll meter used at V10–R1 is well correlated with grain yield and N response, but in non irrigated corn in MN it’s practicality is limited.
Future

• 2006 in Minnesota
  – Several corn research sites across southern MN
  – Continued data interpretation and evaluation in MN and with regional partners for development of N algorithm.
  – Delineating crop rotation differences (corn after corn vs corn following soybean etc.).
THANKS

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Growing season precipitation at Waseca in 2005

![Graph showing precipitation data for Waseca in 2005](image-url)
Application rates and yields for the 2005 regional N project - Minnesota treatments

<table>
<thead>
<tr>
<th>Rel. Chl. %</th>
<th>PP N rate</th>
<th>N Algorithm Credit</th>
<th>Applied* lb N/a</th>
<th>Total N rate</th>
<th>Grain Yield bu/a</th>
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* Sidedressed N applied at V10 on July 7, 2005