Nitrogen Management for Corn Production

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Soil Fertility Extension Specialist
Department of Agronomy
Four Factors Influencing Optimum Time of Application

- Crop to be grown
  - Timing of N uptake
- Climate: Temperature ↔ Precipitation
  - Excess water – Nitrate loss
- Soil texture -- drainage
  - Leaching / Saturation / Denitrification
- Nitrogen product - chemical formulation
  - Ammonium vs. Nitrate vs. Urea
Impact of Nitrogen Application Timing on Corn Yield

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>4/1</th>
<th>4/15</th>
<th>5/1</th>
<th>5/15</th>
<th>6/1</th>
<th>6/15</th>
<th>7/1</th>
<th>Split E.</th>
<th>Split L.</th>
<th>CK</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989 (Dry)</td>
<td>151</td>
<td>144</td>
<td>149</td>
<td>151</td>
<td>151</td>
<td>138</td>
<td>131</td>
<td>128</td>
<td>143</td>
<td>142</td>
<td>59</td>
</tr>
<tr>
<td>1990 (Wet)</td>
<td>114</td>
<td>126</td>
<td>128</td>
<td>128</td>
<td>140</td>
<td>145</td>
<td>143</td>
<td>137</td>
<td>130</td>
<td>136</td>
<td>68</td>
</tr>
</tbody>
</table>

N applied at 112 lb N/acre as liquid fertilizer. Split early was at first cultivation, split late was at second cultivation (half – half rate split). Continuous corn. Baker et al., 1995, Ames, IA.
Fall Nitrogen Application for Corn Production

- Relatively good in Corn Belt?
  - Medium - to fine textured soils
  - Soils not conducive to leaching/denitrification
  - On average -- 85 to 90% as effective as Spring applied N
  - Fall and late spring - early summer moisture

- Application after 4 inch soil temperature 50 ºF and cooling (colder the better)

- Only anhydrous ammonia

- Consider nitrification inhibitor

J.E. Sawyer, ISU Agronomy Extension
Effect of Time of N Application and N-Serve on Corn Yields after Soybean from 1987–2001 at Waseca, MN

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Time of N Application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall</td>
</tr>
<tr>
<td>15-Yr Avg. Yield (bu/A)</td>
<td>144</td>
</tr>
<tr>
<td>15-Yr Avg. FW NO$_3$-N Conc. (mg/L)</td>
<td>14.1</td>
</tr>
<tr>
<td>7-Yr Avg. Yield (bu/A) **</td>
<td>131</td>
</tr>
</tbody>
</table>

** Seven years when statistically significant differences occurred.

Gyles Randall, Univ. Minnesota
### Northern Research Farm, 2007-2010

<table>
<thead>
<tr>
<th>Crop</th>
<th>N rate applied to corn, lb N/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>80</td>
</tr>
<tr>
<td>160</td>
<td>240</td>
</tr>
<tr>
<td>Corn, sp urea</td>
<td>- - - - - - - bu/acre - - - - - -</td>
</tr>
<tr>
<td>Corn, fall urea</td>
<td>59</td>
</tr>
<tr>
<td>126</td>
<td>158</td>
</tr>
<tr>
<td>186</td>
<td></td>
</tr>
</tbody>
</table>
Corn response to N timing in Iowa, Minnesota, and Wisconsin (1987-1992)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sites</td>
<td>Total</td>
<td>Responsive</td>
<td>PP = SD/Splt.</td>
</tr>
<tr>
<td>Killorn, IA; Randall, MN; Bundy, WI</td>
<td>65</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>39</td>
<td>20</td>
<td>17</td>
</tr>
</tbody>
</table>

L.G. Bundy, Univ. of Wisconsin

J.E. Sawyer, ISU Agronomy Extension
Spring Preplant vs. Spring-Sidedress Three Application Split in Iowa

Across Five Years (1987-1991)

- Two of three dry springs: preplant > split
- One dry spring: no difference
- Two wet springs: split > preplant

____________________
From Baker et al., 1995. Iowa State University. Average of liquid N (0 to 180 lb N/acre) point injected with and without N-Serve, Ames IA. Continuous corn.
# Preplant or At-Planting and Split/Sidedress

<table>
<thead>
<tr>
<th>Category</th>
<th>Sites</th>
<th>Mean EONR</th>
<th>Mean YEONR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre</td>
<td>Split</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- - lb N/acre - -</td>
<td>- - bu/acre - -</td>
</tr>
<tr>
<td>Split EONR at least 10 lb N/acre lower than Preplant</td>
<td>4</td>
<td>167</td>
<td>138</td>
</tr>
<tr>
<td>Preplant EONR at least 10 lb N/acre lower than Split</td>
<td>3</td>
<td>108</td>
<td>126</td>
</tr>
<tr>
<td>Preplant and Split EONR within 10 lb N/acre</td>
<td>7</td>
<td>151</td>
<td>147</td>
</tr>
<tr>
<td><strong>Overall Mean</strong></td>
<td>14</td>
<td>146</td>
<td>140</td>
</tr>
<tr>
<td>Chariton (2015)</td>
<td>1</td>
<td>250*</td>
<td>250*</td>
</tr>
</tbody>
</table>

Based on N response equations and 0.10 N:corn price ratio.
Sawyer, Lundvall, Hall, and Barker, 2014-2016.
# Recommended Timing of Nitrogen Applications for Corn

<table>
<thead>
<tr>
<th>Soil Description</th>
<th>Fall</th>
<th>Preplant</th>
<th>Sidedress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium/Fine Texture</td>
<td>OK*</td>
<td>Optimum</td>
<td>OK</td>
</tr>
<tr>
<td>Well-Drained</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium/Fine Texture</td>
<td>No</td>
<td>OK</td>
<td>Optimum</td>
</tr>
<tr>
<td>Poorly Drained</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse texture</td>
<td>No</td>
<td>No</td>
<td>Optimum</td>
</tr>
</tbody>
</table>

*Includes use of BMPs for fall-applied N.

L.G. Bundy, Univ. of Wisconsin
Has Nitrogen Fertilization Requirement Increased Like Corn Yield?

Annual Corn Yield in Iowa

- 1866-1939
- 1940-2016

\[ y = 1.9x - 3624 \]

\[ R^2 = 0.90 \]

Data Source: USDA-NASS

J.E. Sawyer, ISU Agronomy Extension
Why Are Nitrogen Rate Guidelines Similar Across Many Years and Corn Yield Gains?

<table>
<thead>
<tr>
<th>Reference (year)</th>
<th>Rotation</th>
<th>Suggested N Rate Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM-905 (1979)</td>
<td>Soybean-Corn</td>
<td>100 – 150 Ib N/acre</td>
</tr>
<tr>
<td></td>
<td>Corn-Corn</td>
<td>150 – 200</td>
</tr>
<tr>
<td>CNRC (2018)</td>
<td>Soybean-Corn</td>
<td>126 – 152</td>
</tr>
<tr>
<td></td>
<td>Corn-Corn</td>
<td>175 – 203</td>
</tr>
</tbody>
</table>

PM-905 Crop Rotations, Effect on Yields and Response to Nitrogen, 1979
Corn Nitrogen Rate Calculator (CNRC), 2018

J.E. Sawyer, ISU Agronomy Extension
## Corn Era Comparison: 1960 vs. 2000

### What’s Changed?

<table>
<thead>
<tr>
<th>Era</th>
<th>For 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Yield (bu/acre)</td>
<td>134b 224a +67%</td>
</tr>
<tr>
<td>Total Plant N (lb/acre)</td>
<td>159b 190a +19%</td>
</tr>
<tr>
<td>Grain N (lb/acre)</td>
<td>113b 138a +22%</td>
</tr>
<tr>
<td>Grain N Harvest Index</td>
<td>0.71a 0.73a</td>
</tr>
<tr>
<td>Harvest Index (%)</td>
<td>49a 53a</td>
</tr>
<tr>
<td>Grain (bu/lb total plant N) (IE)</td>
<td>0.84b 1.18a +40%</td>
</tr>
<tr>
<td>Grain N Concentration (%DM)</td>
<td>1.61a 1.23b -24%</td>
</tr>
<tr>
<td>Grain N (lb N/bu) at 15%</td>
<td>0.77a 0.59b -24%</td>
</tr>
</tbody>
</table>

Inverse of Internal Efficiency (IE) gives the per bushel N factor times yield: 1.2 (1960) and 0.8 (2000).  

Woli et al.
Corn Era Plant Components
Nitrogen Concentration

J.E. Sawyer, ISU Agronomy Extension

Woli et al.
Corn Era Plant Components
Nitrogen Content

J.E. Sawyer, ISU Agronomy Extension

Woli et al.
Corn Era Comparison: 1960 vs. 2000
Nitrogen Uptake Timing has Not Changed

Woli et al.
Nitrogen Use Efficiency (NUE) and Yield With Increasing N Rate

2006-2007 - 14 Iowa Sites. Yield/Agronomic Efficiency. Sawyer and Barker, ISU.
Corn Nitrogen

- Corn plant N uptake timing by silking (R1) is still around 70%
- Corn plant total N is around 1 lb N/bu
- Corn grain N concentration is near 0.53 lb N/bu at 15.5% moisture (1.12% N in DM)
  - Example for 240 bu/acre yield
    - 127 lb N/acre in corn grain
- Grain N removal is less than suggested MRTN rates or most profitable N rate ranges
Nitrogen Use and Water Quality
Corn Grain N Removal vs. N Application

- Example for state of Iowa
  - 107 bu/acre vs. 194 bu/acre state corn yield
  - 87 lb N/acre vs. 103 lb N/acre in grain harvest
  - 120 lb N/acre vs. 158 lb N/acre fertilizer use
  - 0.73 ratio vs. 0.65 ratio
    (grain N removal divided by applied N)

- 0.82 lb N/bu vs. 0.56 lb N/bu
- 85% N to planted corn acres per Iowa ground water protection act reporting method
- USDA-NASS Iowa corn yield

J.E. Sawyer, ISU Agronomy Extension
Increasing N rates in reaction to high corn yields will reduce profitability and worsen environmental issues like nitrous oxide emission and nitrate-N in water systems.

- A baseline nitrate-N
- Reasons why in-field 4R N practices have limits for water quality improvement
# Iowa Nutrient Reduction Practices

<table>
<thead>
<tr>
<th>Practice</th>
<th>Comments</th>
<th>% Nitrate-N Reduction†</th>
<th>% Corn Yield Change++</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moving from fall to spring pre-plant application</td>
<td>6 (25)</td>
<td>4 (16)</td>
<td></td>
</tr>
<tr>
<td>Spring pre-plant/sidedress 40-60 split Compared to fall-applied</td>
<td>5 (28)</td>
<td>10 (7)</td>
<td></td>
</tr>
<tr>
<td>Sidedress – Compared to pre-plant application</td>
<td>7 (37)</td>
<td>0 (3)</td>
<td></td>
</tr>
<tr>
<td>Sidedress – Soil test based compared to pre-plant</td>
<td>4 (20)</td>
<td>13 (22)**</td>
<td></td>
</tr>
<tr>
<td><strong>Source</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid swine manure compared to spring-applied fertilizer</td>
<td>4 (11)</td>
<td>0 (13)</td>
<td></td>
</tr>
<tr>
<td>Poultry manure compared to spring-applied fertilizer</td>
<td>-3 (20)</td>
<td>-2 (14)</td>
<td></td>
</tr>
<tr>
<td><strong>Nitrogen Application Rate</strong></td>
<td>Nitrogen rate at the MRTN (0.10 N:corn price ratio) compared to current estimated application rate. (ISU Corn Nitrogen Rate Calculator – <a href="http://extension.agron.iastate.edu/soilfertility/nrate.aspx">http://extension.agron.iastate.edu/soilfertility/nrate.aspx</a> can be used to estimate MRTN but this would change Nitrate-N concentration reduction)</td>
<td>10</td>
<td>-1</td>
</tr>
<tr>
<td><strong>Nitrification Inhibitor</strong></td>
<td>Nitrapyrin in fall – Compared to fall-applied without Nitrapyrin</td>
<td>9 (19)</td>
<td>6 (22)</td>
</tr>
<tr>
<td><strong>Cover Crops</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td>31 (29)</td>
<td>-6 (7)</td>
<td></td>
</tr>
<tr>
<td>Oat</td>
<td>28 (2)</td>
<td>-5 (1)</td>
<td></td>
</tr>
<tr>
<td><strong>Living Mulches</strong></td>
<td>e.g. Kura clover – Nitrate-N reduction from one site</td>
<td>41 (16)</td>
<td>-9 (32)</td>
</tr>
</tbody>
</table>
Corn Nitrogen Rate Determination

- Setting an N application rate by starting with corn yield goal is a poor system
  - Yield does not equate to N rate need

<table>
<thead>
<tr>
<th>High Yield Environments in Iowa</th>
<th>Rotation</th>
<th>No.</th>
<th>EONR</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lb N/acre</td>
</tr>
<tr>
<td>SC</td>
<td>40</td>
<td>150</td>
<td>233</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>13</td>
<td>183</td>
<td>232</td>
<td></td>
</tr>
</tbody>
</table>

EONR at 0.10 N:Corn price ratio.
J. Sawyer and D. Barker. ISU.
Exploring a Regional Approach to Nitrogen Rate Guidelines (MRTN and CNRC)

- Diverse N rate guideline systems across states in the Midwest USA
- Cross-state programs
- Volatile N fertilizer and corn prices
- Lack of optimum N rate relationship with yield
  - Yield-based N rates greater than economic optimum with high yields and too low rates on less productive soils
MRTN Development Timeline

- Discussions in 2004
- Initial N response trial database completion in 2005
- Web based Corn N Rate Calculator (CNRC) in 2005
- Regional extension publication in 2006

Corn Nitrogen Rate Calculator

http://cnrc.agron.iastate.edu/
MRTN/CNRC - Database Driven Approach

- Corn response data from many recent research-based N rate trials
  - 2,008 trials
  - > 90% less than 15 years old
  - Iowa: 411 trials

- Analytical/predictive method to determine economic response and most profitable N rates directly from research trials

Current Data → N Rate Guidelines
Diminishing Return to N Application

Corn Following Sobyean

- Yield Without N
- Accumulated Response to N
- Response to Each 20-lb N Increment

Corn Yield (bu/acre)

Nitrogen Fertilizer Rate (lb N/acre)

0.10 price ratio

Iowa, CNRC

J.E. Sawyer, ISU Agronomy Extension
1. Collect N response trial site data
2. Observe shape of N response data
3. Fit regression equation to each trial data
4. Compile database of site response equations for CC and SC
Steps in MRTN Computation

- Corn N rate response trial example

![Graph showing the relationship between nitrogen rate and corn yield.](image)

\[ \text{Yield} = 117.7 + 0.8219N - 0.00263N^2 \]

Yield Plateau
Steps in MRTN/CNRC Computation

5. Calculate by 1-lb N rate increments: gross yield return, fertilizer cost, net return to N (RTN) using the regression equations

6. For user specified dataset (CC, SC, state, or substate), N and corn prices -- average across the RTN for selected response trials

7. The N rate with largest average RTN is the MRTN rate, with the most profitable range being the N rates within $1.00/acre of the maximum RTN
Net Return Determines MRTN Rate and Profitable Range

Most Profitable Range Within $1/acre MRTN

MRTN

Flat Payoff

Nitrogen Rate, lb N/acre

$0.40/lb N; $4.00/bu

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Effect of Prices on MRTN and Most Profitable N Rate Range

Iowa SC Main - Corn Price $4.00/bu

- 0.05 $0.20/lb N
- 0.10 $0.40
- 0.15 $0.60
- 0.20 $0.80

Return to N, $/acre

N Rate, lb N/acre
Nitrogen Rates for Corn in Iowa

Maximum Return to Nitrogen (MRTN) rate and Most Profitable Rate Range from the Corn Nitrogen Rate Calculator (CNRC).

<table>
<thead>
<tr>
<th>Price Ratio$/lb N:$/bu</th>
<th>Corn Following Soybean</th>
<th>Corn Following Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rate</td>
<td>Range</td>
</tr>
<tr>
<td><strong>MAIN Iowa Region</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td>140</td>
<td>126 - 153</td>
</tr>
<tr>
<td><strong>SEIA (Soil Regions 17, 21, 22)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td>153</td>
<td>138 - 168</td>
</tr>
</tbody>
</table>

1 Price per lb N divided by the expected corn price. For example, N at $0.40/lb N and corn at $4.00/bu is a 0.10 price ratio. Corn held at $4.00/bu for all price ratios.
Strengths of MRTN Approach

- Straightforward computation
- Based directly on N rate research
- Can use a variety of N rate trials
- Based on economic profitability
  - Not derived from yield level, but actual yield response which pays for the N applied
- Directly provides CC and SC rate guidelines
  - No reliance on inconsistent “soybean credit”
- Incorporates temporal and spatial variability
- Documents data used for guidelines
Strengths of MRTN Approach

- Easy to add new response trials
  - Keeps rate guidelines current with production practices and climatic conditions

![Graph showing MRTN Rate Over Time - Iowa - Entire State](image)

- Linear regression for CC: $y = 1.1x + 177\quad R^2 = 0.66$
- Linear regression for SC: $y = 1.5x + 120\quad R^2 = 0.95$
Strengths of MRTN Approach

- Provides opportunity for user input and N rate adjustment
  - Rotation
  - Fertilizer and corn price
  - Profitable N rate range
    - LOW ↔ MRTN ↔ HIGH
      - Farmer experience and attitude toward risk
      - Capitol allocation
      - Water and air quality
      - Local research information
      - Seasonal expectation

J.E. Sawyer, ISU Agronomy Extension
Although you may want to be 100% certain of N sufficiency, being that certain is not most profitable.

- The risk with lower N rates is decreased profitability due to lost yield.
- The risk with higher N rates is decreased profitability and environmental concerns due to unneeded N.
- Most profitable N rate range helps “protect” these risks.
MRTN and N Risk Management

$0.40/lb N:$4.00/bu

Crossover Point

Under-Application

Over-Application

Nitrogen Rate, lb N/acre

Net Loss for Sites with EONR's > Specific N Rate

Net Loss for Sites with EONR's < Specific N Rate

Iowa SC - MAIN
MRTN and N Risk Management

Iowa CC - MAIN

$0.40/lb N:$4.00/bu

Nitrogen Rate, lb N/acre

Net Loss for Sites with EONR's > Specific N Rate

Net Loss for Sites with EONR's < Specific N Rate

Crossover Point

Under-Application

Over-Application

J.E. Sawyer, ISU Agronomy Extension
Questions?