Nitrogen Management for Corn Production
Timing and Rate

John E. Sawyer
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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 $\Leftrightarrow$ 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></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td></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>
</tr>
<tr>
<td>(Dry)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59</td>
</tr>
<tr>
<td>1990</td>
<td></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>
</tr>
<tr>
<td>(Wet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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
# 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></td>
<td></td>
<td>Average (SD*)</td>
<td>Average (SD*)</td>
</tr>
<tr>
<td><strong>Nitrogen Management</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Timing</strong></td>
<td>Moving from fall to spring pre-plant application</td>
<td>6 (25)</td>
<td>4 (16)</td>
</tr>
<tr>
<td></td>
<td>Spring pre-plant/sidedress 40-60 split Compared to fall-applied</td>
<td>5 (28)</td>
<td>10 (7)</td>
</tr>
<tr>
<td></td>
<td>Sidedress – Compared to pre-plant application</td>
<td>7 (37)</td>
<td>0 (3)</td>
</tr>
<tr>
<td></td>
<td>Sidedress – Soil test based compared to pre-plant</td>
<td>4 (20)</td>
<td>13 (22)$^{**}$</td>
</tr>
<tr>
<td><strong>Source</strong></td>
<td>Liquid swine manure compared to spring-applied fertilizer</td>
<td>4 (11)</td>
<td>0 (13)</td>
</tr>
<tr>
<td></td>
<td>Poultry manure compared to spring-applied fertilizer</td>
<td>-3 (20)</td>
<td>-2 (14)</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>Rye</td>
<td>31 (29)</td>
<td>-6 (7)</td>
</tr>
<tr>
<td></td>
<td>Oat</td>
<td>28 (2)</td>
<td>-5 (1)</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>
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 NO₃-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

J.E. Sawyer, ISU Agronomy Extension
## Fall Urea Application

### 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></td>
<td></td>
</tr>
<tr>
<td>Corn, sp urea</td>
<td></td>
</tr>
<tr>
<td>Corn, fall urea</td>
<td></td>
</tr>
</tbody>
</table>

Continuous corn.  
Mallarino and Rueber, 2010.
# Corn response to N timing in Iowa, Minnesota, and Wisconsin (1987-1992)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td>65</td>
<td>32</td>
<td>39</td>
</tr>
<tr>
<td>Responsive</td>
<td></td>
<td>25</td>
<td>28</td>
<td>20</td>
</tr>
<tr>
<td>PP = SD/Splt.</td>
<td></td>
<td>15</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>PP &gt; SD/Splt.</td>
<td></td>
<td>8</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>PP &lt; SD/Splt.</td>
<td></td>
<td>2</td>
<td>8</td>
<td>0</td>
</tr>
</tbody>
</table>

Killorn, IA; Randall, MN; Bundy, WI. 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.

Sawyer, Barker, Hanna, 2009
## 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>Sites</td>
<td>Pre</td>
<td>Split</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>Overall Mean</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.
<table>
<thead>
<tr>
<th>Soil Description</th>
<th>Fall</th>
<th>Preplant</th>
<th>Sidedress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium/Fine Texture, Well-Drained</td>
<td>OK*</td>
<td>Optimum</td>
<td>OK</td>
</tr>
<tr>
<td>Medium/Fine Texture, Poorly Drained</td>
<td>No</td>
<td>OK</td>
<td>Optimum</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 Use Efficiency Increased?

Data Source: USDA-NASS, TVA, AAPFCO

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Corn Grain Nitrogen Content Has Decreased Over Time

- Mid-1970’s – feed mill data
  - 0.82 lb N/bu
- Early 1990’s – feed mill data and various nitrogen research studies
  - 0.73 lb N/bu
- 2006-2007 – 14 nitrogen rate research sites in Iowa
  - 0.56 lb N/bu

At 15.5% grain moisture
Corn Grain N Removal vs. N Application

- Iowa example
  - 1976-1980 vs. 2006-2010
  - 107 bu/acre vs. 171 bu/acre yield
  - 87 lb N/acre vs. 96 lb N/acre in grain harvest
  - 120 lb N/acre vs. 139 lb N/acre application
  - 0.73 ratio vs. 0.69 ratio (grain N to applied N ratio)
    - 0.82 lb N/bu vs. 0.56 lb N/bu
    - 85% N to planted corn acres per ground water protection act reporting method
    - USDA-NASS Iowa corn yield
Nitrogen Use Efficiency (NUE) and Yield With Increasing N Rate

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

J.E. Sawyer, ISU Agronomy Extension
Era Hybrid Yield and Response to N Application (2007-2008)

The graph shows the grain yield (bu/acre) over different eras from 1960 to 2000. The data includes:

- Yield at AONR
- Yield at 0 N rate
- Yield Response to N

The trend lines indicate an increase in grain yield over time, with the yield response to N showing the most significant increase.
Era Hybrid Yield and Response to N Application (2007-2008)

<table>
<thead>
<tr>
<th></th>
<th>Era 1960</th>
<th>Era 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>GY (bu/acre)</td>
<td>134b</td>
<td>224a</td>
</tr>
<tr>
<td>Total N uptake at R6 (lb/acre)</td>
<td>159b</td>
<td>190a</td>
</tr>
<tr>
<td>Grain N (lb/acre)</td>
<td>113b</td>
<td>138a</td>
</tr>
<tr>
<td>Grain (bu/lb N)</td>
<td>1.03b</td>
<td>1.42a</td>
</tr>
<tr>
<td>Grain N Concentration (%)</td>
<td>1.61a</td>
<td>1.23b</td>
</tr>
</tbody>
</table>

Woli et al.

J.E. Sawyer, ISU Agronomy Extension
Exploring a Regional Approach to Nitrogen Rate Guidelines (MRTN)

- 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 lower OM, less productive “southern area” soils
Yield Level Does Not Relate to Optimum N Rate

0.10 price ratio

J.E. Sawyer, ISU Agronomy Extension
### Economic Analysis of N Response Data

#### 43 Corn Following Soybean Sites in Iowa, 2001-2003

<table>
<thead>
<tr>
<th>Method</th>
<th>N Rate</th>
<th>Net Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>EONR - Mean Yield Eq.</td>
<td>104</td>
<td>145</td>
</tr>
<tr>
<td>Maximum RTN</td>
<td>104</td>
<td>138</td>
</tr>
<tr>
<td>Measured Yield†</td>
<td>174</td>
<td>110</td>
</tr>
</tbody>
</table>

† 1.2 lb N/bu factor, 50 lb soybean rotation “credit”

$0.60/lb N and $6.00/bu corn

Sawyer and Barker, ISU

---

$0.40/lb N:corn $4.00/bu (0.10 N:corn price ratio)
This website provides a process to calculate economic return to N application with different nitrogen and corn prices and to find profitable N rates directly from recent N rate research data. The method used follows a regional approach for determining corn N rate guidelines that is implemented in several Corn Belt states.

START HERE
Choose how you want to calculate N rates, using one set of prices or using multiple prices.

- SINGLE PRICE
- MULTIPLE PRICE

In association with these Universities:

- Iowa State University
- Purdue University
- Michigan State University
- Ilinois
- Wisconsin
- Ohio State University

For questions about the Corn Nitrogen Rate Calculator website, contact John Sawyer at sawyer@iastate.edu.

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http://cnrc.agron.iastate.edu/

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# Corn Nitrogen Rate Calculator

Main Iowa Area

## Rates and Charts

- **State:** Iowa
- **Region:** Main
- **Number of sites:** 204
- **Rotation:** Corn Following Soybean

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen Price ($/lb)</td>
<td>0.35</td>
</tr>
<tr>
<td>Corn Price ($/bu)</td>
<td>3.50</td>
</tr>
<tr>
<td>Price Ratio</td>
<td>0.10</td>
</tr>
<tr>
<td>MRTN Rate (lb N/acre)</td>
<td>134</td>
</tr>
<tr>
<td>Profitable N Rate Range (lb N/acre)</td>
<td>121 - 148</td>
</tr>
<tr>
<td>Net Return to N at MRTN Rate ($/acre)</td>
<td>$174.47</td>
</tr>
<tr>
<td>Percent of Maximum Yield at MRTN Rate</td>
<td>99%</td>
</tr>
<tr>
<td>Anhydrous Ammonia (82% N) at MRTN Rate (lb product/acre)</td>
<td>163</td>
</tr>
</tbody>
</table>
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/

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MRTN/CNRC - Database Driven Approach
Direct Use of “BIG DATA”

- Corn response data from many recent research-based N rate trials
  - 1,500 trials ≈ 36,000 research plots
  - > 90% less than 15 years Old
  - Iowa: SC 244 trials and CC 127 trials

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

Current Data → N Rate Guidelines
Steps in MRTN Computation

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
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

$0.40/lb N:$4.00/bu

Iowa, CNRC
Effect of Prices on MRTN and Most Profitable N Rate Range

- $4.00/bu
- $0.20/lb N
- $0.40
- $0.60
- $0.80

Flat Payoff

Most Profitable Range
Within $1/acre MRTN

Iowa - SC

N Rate, lb N/acre

Return to N, $/acre

Iowa, CNRC

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Strengths of MRTN Approach

- Straightforward computation
- Based on N rate response 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”
  - Documents data used for guidelines

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MRTN and N Risk Management

- 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
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
Strengths of MRTN Approach

- Easy to add new response trials
  - Keeps rate guidelines current with production practices and climatic conditions
- Able to subdivide states into regions
SE Iowa Corn Nitrogen Rate Region

Iowa Soil Regions

Legend

Soil Regions
1 Leaves over glacial till - low rainfall
2 Northwest Iowa Loess
3 Tazewell Glacial Till
4 Loessy Wisconsin Glacial Till
5 Clayey Lake Deposits
6 Iowa Erosion Surface
7 Shallow to Bedrock
8 Loess with Bedrock Outcrops
9 Shallow Loess over Glacial Till
10 Lees Ridge and Sodic soils
11 Loess with exposures of Glacial Till
12 Very Deep Loess
13 Missouri River Shale
14 Missouri River Alluvium
15 Loessy Ridge/Glacial Till - SW Iowa
16 Lees, Shale, and Glacial Till
17 Loess Ridge/Glacial Till - SE Iowa
18 Eolian Sand
19 Loess - Timberland
20 Alluvium
21 Loess Ridge/Clay Till Sodic soils
22 Loess Ridge/Clay Palmer
23 Water

USDA NRCS
United States Department of Agriculture
Natural Resource Conservation Service

Iowa State University
Extension and Outreach

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# Nitrogen Rates for Corn in Iowa

Nitrogen rate guidelines for Iowa continuous corn and corn following soybean based on output of the Corn Nitrogen Rate Calculator (CNRC).

<table>
<thead>
<tr>
<th>Price Ratio $/lb N:$/bu</th>
<th>Corn Following Soybean Rate</th>
<th>Range</th>
<th>Corn Following Corn Rate</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Iowa Region</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>152</td>
<td>138 - 169</td>
<td>206</td>
<td>190 - 229</td>
</tr>
<tr>
<td>0.10</td>
<td>134</td>
<td>121 - 147</td>
<td>184</td>
<td>172 - 197</td>
</tr>
<tr>
<td>0.15</td>
<td>120</td>
<td>110 - 131</td>
<td>167</td>
<td>154 - 181</td>
</tr>
<tr>
<td>0.20</td>
<td>110</td>
<td>99 - 120</td>
<td>152</td>
<td>141 - 163</td>
</tr>
<tr>
<td>Southeast Iowa (Soil Regions 17, 21, 22)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.05</td>
<td>181</td>
<td>163 - 204</td>
<td>240</td>
<td>225 - 240</td>
</tr>
<tr>
<td>0.10</td>
<td>154</td>
<td>139 - 168</td>
<td>207</td>
<td>190 - 226</td>
</tr>
<tr>
<td>0.15</td>
<td>135</td>
<td>126 - 147</td>
<td>183</td>
<td>177 - 197</td>
</tr>
<tr>
<td>0.20</td>
<td>125</td>
<td>115 - 136</td>
<td>181</td>
<td>169 - 186</td>
</tr>
</tbody>
</table>