Nitrogen Timing and Crop Uptake

Nitrogen Management Research

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Topics I will Cover

- Nutrient Management:
  - A very Complex System
  - It is much more than just putting on some fertilizer!
  - Must have an appreciation of the complexity of plant
  - Must have an appreciation of the complexity of the soil

- I will cover some basic plant physiology

- Nutrient Use Efficiency

- Touch on fertilizer management
Nitrogen, why is it important?

• It makes the crop grow and turn green………Right?
  – Growing and turning green are consequences of how the plant uses Nitrogen

• Nitrogen is a major component of ALL amino acids
  – Amino Acids are building blocks of proteins and enzymes
  – Life could not exist without the biochemical reactions mitigated by the proteins and enzymes.
Nitrogen, why is it important?

- 78% of the atmosphere is nitrogen (N$_2$)
  - Plants cannot use N$_2$

  - Nitrogen must be converted to a useable form
    - Requires a lot of energy input for conversion
      - Lightning
      - Symbiotic relationships
      - Electricity or Fossil fuel

  - Ammonium (NH$_4^+$) and nitrate (NO$_3^-$)
    - Primary N species used by agronomic crops
    - Absorption and assimilation are different
Nitrogen Absorption and Assimilation

- Root cells
  - Inside has negative charge compared to outside
    - Attracts cations (+ charged molecules…. \( \text{NH}_4^+ \))
    - Repels anions (- charged molecules……\( \text{NO}_3^- \))
  - Inside has higher concentration of nitrate compared to outside.
    - Nitrate tends to want to diffuse out and not in cell
  - Together: electrochemical potential gradient.
    - Down hill gradient for \( \text{NH}_4^+ \)
    - Up hill gradient for \( \text{NO}_3^- \)
Nitrogen Absorption and Assimilation

• Ammonium (NH$_4^+$) absorption and assimilation
  – Absorption is almost a passive uptake
    • Downhill electrochemical potential gradient
    • Very little energy input
  – Must maintain electrochemical potential gradient
    • Energy input to maintain the gradient
  – NH$_4^+$ is toxic to the plant at relatively low concentrations
    • Carbohydrates sent to roots to assimilate NH$_4^+$ immediately.
    • Assimilated NH$_4^+$ is transported throughout plant and converted
to amino acids, proteins, and enzymes
Nitrogen Absorption and Assimilation

• Nitrate (NO$_3^-$) absorption and assimilation
  – Absorption is an active uptake process
    • Uphill electrochemical potential gradient
    • Requires substantial energy
  – NO$_3^-$ can be transported and stored in the plant
    • not toxic
    • Stored in roots or above ground plant parts
  – NO$_3^-$ must be reduced to NH$_4^+$ before it can be assimilated
    • Requires substantial energy
    • NH$_4^+$ assimilated as before
Nitrogen Absorption and Assimilation

• Where does that energy come from?
  – Photosynthesis
    • Sun energy captured in chloroplasts
    • Converts CO₂ and H₂O to carbohydrates (energy captured in carbon bonds).
  – Respiration
    • Carbohydrates translocated to root (other plant parts)
    • Carbohydrate plus O₂ produces CO₂ and H₂O
      – Energy released as carbon bonds break
Nitrogen Management

• The soil complexity eliminates simplicity of nutrient management.

• For some, N management simply means how much fertilizer to apply, how to apply it, when to apply it, and where to apply it.
  – We could talk about this
    • This information is readily available
    • Extension, News articles, local fertilizer dealer etc.

• I want to take this talk to a little higher level
  – 10,000 ft level
Nitrogen Use Efficiency (NUE)

- The goal of most nutrient management specialists and researchers:
  - Maximize the effectiveness of the nitrogen that is available to the crop.
  - We call this, Nitrogen Use Efficiency (NUE)

- Maximize NUE!!!
  - Maximize returns for inputs
    - Dollars
    - Resource Use
  - Minimize risks to the environment
Nitrogen Use Efficiency (NUE)

- Many definitions of NUE
  - Depends on who is evaluating NUE
  - Overall NUE is composed of several different components.
  - Each component offers different pieces of information
    - Can be used for different interpretations and meanings.
    - Allows us to study different components of a complex system.
  - If someone uses this term, ask them to define it.
Nitrogen Use Efficiency (NUE)...as I am using it.

\[ \text{NUE} = \text{N Agronomic Eff.} \times \text{N Uptake Eff.} \]

N Agronomic Efficiency: lbs. grain produced / lbs. N uptake

N Uptake Efficiency: lbs N accumulated / lbs. N available

\[ \text{NUE} = \text{lbs. grain produced} / \text{lbs. N available} \]
Nitrogen Use Efficiency

• Agronomic Efficiency
  – Lb. of grain produced per lb. of N accumulated

• Combines elements of N accumulation and remobilization and their effects on dry matter accumulation and remobilization.

• Too complicated for a 30 minute general talk
  – Production efficiency
  – Remobilization/translocation efficiency
  – Accumulation efficiency before anthesis and after anthesis
Nitrogen Agronomic Efficiency in Corn

Adapted from Long-term continuous corn and nitrogen fertilizer effects on productivity and soil properties, Bundy, Andraski, Ruark, and Peterson. 2011. Agron. J. 103:1346-1351

Another source: Nitrogen use efficiency of corn increased from about 30 lbs. of grain per lbs. of nitrogen in 1960 to 60+ lbs. grain per lbs. of nitrogen in 2006.

Other sources indicate yields have increased about 2.2 bu. Ac$^{-1}$ yr$^{-1}$ will N rates have remained relatively static or perhaps decreased.
Nitrogen Agronomic Efficiency

Why is the Agronomic Efficiency increasing?

- At the field level
  - Better Hybrids/Varieties
  - Less stress from pests
    - Stacked traits
    - Better pesticides and pesticide management
  - Better agronomic cultural practices
  - Maybe some environmental issues?

- Appears to be happening in several crops
  - Corn
  - HRSW
  - Sugar Beets
Nitrogen Agronomic Efficiency

- Regardless of the reason, it seems to be happening
  - People are nervous about it.

  - **Question current N guidelines**
    - Want to increase N fertilizer applications

    - **We must maintain vigilance with continued Nitrogen research**
      - Things change over time
      - Principals probably remain the same
      - Their application to real world situations may change

    - **Vulnerable to sales pitches with no or shaky research data.**
      - A pitch with no data…..is an untested hypothesis!
Nitrogen Uptake Efficiency

• Most nutrient management specialist, regardless of specific role, work on this component of NUE.

• How do we maximize, or optimize, the uptake of nitrogen into the crop?
  – Crop gets it Nitrogen from:
    • Leaves…….foliar absorption
    • Roots…… this talk will focus on this part
  – Uptake Efficiency relates to uptake efficiency of available N
Nitrogen Uptake Efficiency

• Where does the crop get its nitrogen?
  – Residual soil nitrate
    • Estimated by a soil test
  – Mineralization of organic N to inorganic N
    • Very difficult to predict
    • Depends on:
      – Moisture, temperature, oxygen, amount and type of organic matter, time
  – Fertilizer
    • Manure (more difficult to estimate)
    • Commercial fertilizer (known N content and availability)
Nitrogen Uptake Efficiency

• Fertilizer management offers us the best opportunity to manage nitrogen
  – We can manage:
    • Rate
    • Timing
    • Placement
    • Source
  • Summarized into The 4 Rs:
    – Right Source, Right rate, Right Time, Right Place

• We want to maximize the Recovery of Fertilizer Nitrogen
Fertilizer Recovery Efficiency (FRE)

• The goal of Fertilizer management:
  – Maximize Fertilizer Recovery Efficiency (FRE)

• Two ways to study FRE

  1. $^{15}\text{N}$ (fertilizer with a chemical isotope of N)
     • Can apply fertilizer with enriched or depleted $^{15}\text{N}$ isotope relative to natural
     • Evaluate N in plant for enrichment or depletion of $^{15}\text{N}$.

  2. Difference Method
     • ($\text{lbs. N (fert)} - \text{lbs. N (check)})/\text{N applied}$
     • Apparent Fertilizer Recovery Efficiency
**Apparent Nitrogen Fertilizer Recovery in HRSW**

Combined data from 4 Hard Red Spring Wheat Varieties. Sims and Wiersma, 2011
Nitrogen Fertilizer Recovery

• World wide: 33% of fertilizer is recovered
• What happens to that not recovered?
  – Measured as residual nitrate-N in soil test
  – Immobilized: converted from inorganic N to organic N
    • Some will remain in the labile organic N pool
  – Unaccounted for
    • Many trials do N balance using either Difference or $^{15}$N
      – Frequently cannot account for 20 – 30% of fertilizer N
      – Leached below sampling zone?
      – Denitrification?
      – Volatilization (from soil surface and the plant)?
From Research to Recommendation

• Intensive research efforts on many subcomponents of:
  – Agronomic Efficiency
  – Uptake Efficiency

• Recommendations
  – Apply smaller pieces from the intensive research
  – Expand them to the broader picture
  – Nitrogen Utilization Efficiency
    • Managed Nitrogen to produced the greatest amount of product
    • Optimize Profit and Resource Utilization
    • Minimize Risk to the Environment
  – Develop Best Management Practices (BMPs)
Nitrogen uptake and Distribution in Corn

230 bushel Ac\(^{-1}\) corn crop

Adapted from Ross Bender, Corn Nutrient uptake and partitioning, Illinois Crop Physiology, University of Illinois. [http://cropphysiology.Cropsci.illinois.edu/research/Nutrient_uptake.html](http://cropphysiology.Cropsci.illinois.edu/research/Nutrient_uptake.html)
Applied N vs N uptake

- The longer nitrate/ammonium is in the soil, the more vulnerable it is to loss.
- Manage N fertilizer to reduce its exposure to potential losses.

Adapted from Nitrogen Fertilization Of Corn, Penn State Extension Agronomy Facts 12.
http://extension.psu.edu/cmeg/facts/agronomy-facts-12
• How do we protect the N during that vulnerable period?

• What are the risks?
  • Leaching
  • Denitrification
  • Volatilization
  • Immobilization

• Use BMPs in terms of source, rate, and timing of applications
  • Consider your soil, location and climate
  • Soil Test
  • Adequate soil incorporation
  • Spring N applications
  • Fall applications:
    • < 50°F temps
    • Ammonical Fertilizers
    • Urease or Nitrification inhibitors
  • Split applications
    • Applies N at beginning of rapid uptake phase
## In-Season N in HRSW

<table>
<thead>
<tr>
<th>N timing</th>
<th>Grain yld</th>
<th>Test Wt.</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bu/ac</td>
<td>Lbs/bu</td>
<td>%</td>
</tr>
<tr>
<td>Preplant</td>
<td>59.8</td>
<td>60.5</td>
<td>15.6</td>
</tr>
<tr>
<td>Preplant+Postplant</td>
<td>57.4</td>
<td>60.7</td>
<td>15.3</td>
</tr>
<tr>
<td>Postplant</td>
<td>59.1</td>
<td>60.7</td>
<td>15.1</td>
</tr>
<tr>
<td>Lsd (0.05)</td>
<td>NS</td>
<td>NS</td>
<td>0.4</td>
</tr>
</tbody>
</table>

- 100 lbs. N: all preplant was urea incorporated prior to plant; all postplant was 28% through stream nozzles. Preplant + Post plant: 50:50
- Consistent with earlier work in NW Minnesota (Lamb and Rehm)
- In-season N application: Must have moisture in the application zone for N to be effective

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Endres, Schatz, and Maine. 2005. HRS wheat variety response to N application timing and seeding rate. www.ag.ndsu.edu/archive/carringt/05data
## In-Season N in Corn

<table>
<thead>
<tr>
<th>Time of Application</th>
<th>Year/Site</th>
<th>1991</th>
<th>1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preplant N</td>
<td>Waseca Co.</td>
<td>84</td>
<td>77107.0</td>
</tr>
<tr>
<td>--- N rate (lbs N /Ac)</td>
<td>Blue Earth Co.</td>
<td>143</td>
<td>144</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>30</td>
<td>161</td>
</tr>
<tr>
<td>60</td>
<td>0</td>
<td>90</td>
<td>158</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
<td>165</td>
<td>157</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>182</td>
<td>153</td>
</tr>
<tr>
<td>120</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advantage of Split-N</td>
<td>+11</td>
<td></td>
<td>-11</td>
</tr>
</tbody>
</table>

Rainfall was 56% above normal in 1991

Adapted from Randall et al., 2008. Best management practices for nitrogen use in South-Central Minnesota. Univ. of Minn. Extension #08554
Summary

• Allot of work has been done on nitrogen
  – Current BMPs reflect our current state of knowledge

• Still more to do.
  – Ever changing dynamic of our crop production system

• Must always be thinking about:
  – Grower profitability
  – Resource utilization
  – Environmental preservation/protection