Enhanced Efficiency Fertilizers: Why is Efficiency Important? How Do They Work? What Can We Expect?

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Today’s Approach

• Kratochvil’s webinar on enhanced efficiency fertilizers on March 9
  – www.anmp.umd.edu
    • workshop tools
      • top of list

• many misconceptions are afloat among our clients
  – “slow release N”
Why the Interest in N?
1) Ag Profitability

- nitrogen fertilizer prices have dramatically increased in recent years
  - cost of N fertilizer is closely linked to cost of natural gas
- increase in price is indicative of a long term trend
  - global increase in demand for energy & crop nutrients
Why the Increase in Price?

- N fertilizer production is an energy-intensive process
  - Haber-Bosch process
    - hydrogen (H₂) + nitrogen (N₂) = ammonia (NH₃)
    - hydrogen gas (H₂) from natural gas
    - nitrogen gas (N₂) from the atmosphere
  - natural gas is steam reformed to make hydrogen gas
  - nitrogen gas must be separated from air
  - nitrogen and hydrogen are combined at very high temperature (850 °F) and pressure (250 atm)
Energy Inputs for Big 3

- N - 45 GJ / ton (5% of the global consumption of natural gas)
- P - 20 GJ / ton
- K - 8 GJ / ton
Why the Interest in N?

2) Reactive Nitrogen ($N_r$)

• vulnerable to loss
  – leaching
  – denitrification
  – volatilization

• biologically, radiatively and photo-chemically active N compounds
  – $N_2O$ nitrous oxide (greenhouse gas and ozone destroyer)

• “cascades through the environment external to the agroecosystem” (Cassman)

• economic loss and environmental risk
Figure 3-2. The Nitrogen Cycle.

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Nitrogen Use Efficiency (NUE)

- $R_{\text{eN}}$ - N fertilizer recovery efficiency
  - fertilizer-N recovered in the above-ground biomass during the growing season
  - 37% in corn (USA Corn Belt, Cassman)

- worldwide in cereals – 33% (Raun)
  - developed countries - 42%; developing countries - 29%
Keys to Improving NUE
“The 4 Rs”

- right rate
- right source
- right time
- right place
“Maximize utilization of nitrogen fertilizer you’ve applied.”

- reduce rate of nutrient release (N) to the soil solution
- reduce transformations to mobile forms
  - slow down nitrification (ammonium to nitrate)
- reduce the transformation to gaseous forms (N)
  - reduce denitrification (nitrate to nitrogen gas) **
  - reduce ammonium volatilization (ammonium to ammonia)
Enhancing Synchrony: Minimize Vulnerable Nitrogen

- if the N is not yet applied, it can not be lost
- solution? split application (Penn State Agronomy 12)

Note: Arrows indicate when fertilizer is applied.
## DE Yield Data on Split Application of N on Corn (bu/ A)

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<thead>
<tr>
<th></th>
<th>150 lbs/A pre-plant</th>
<th>40-110 lbs/A pre-plant sidedress</th>
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<tbody>
<tr>
<td>2003*, irrigated loamy sand soil</td>
<td>48a</td>
<td>102b</td>
</tr>
<tr>
<td>2003*, dryland, loamy sand soil</td>
<td>102c</td>
<td>126d</td>
</tr>
<tr>
<td>2005, irrigated, loamy sand</td>
<td>98e</td>
<td>158f</td>
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So, why isn’t sidedressing a widespread nitrogen BMP?
Is there a product that can be applied pre-plant and not be vulnerable to loss?
Controlled Release Nitrogen

- protect nutrients with a semi-permeable membrane
  - ESN®, Environmentally Smart Nitrogen
  - a polymer-coated urea
  - diffusion of urea is temperature controlled

ESN™

• a controlled release urea product
• relies upon diffusion
• diffusion is temperature-dependent
• ESN was designed for the Mid-West corn belt
• may not function optimally in other climatic zones
# Corn Yield Data from DE (150 lbs/ A N)

<table>
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<tr>
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<th>all preplant UAN</th>
<th>all preplant ESN</th>
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Fertilizer Additives

• nitrification inhibitors
  – retard conversion of ammonium to nitrate
  – reduce conversion to a more mobile form

• urease inhibitors
  – ties up urease enzyme so to slow conversion of urea to ammonium
Reduce Transformations to Mobile Forms

- nitrification inhibitors $\text{NH}_4^+ \rightarrow \text{NO}_2^-$
  - $N$-Serve™ is a bactericide that kills targeted organisms, *Nitrosomonas*, works with anhydrous ammonia
  - *Instinct™* designed to work with surface-applied products
  - both are nitrapyrin
  - organic compound that itself is subject to microbial attack
Reduce the Transformation to Gaseous Forms

• aka minimizing ammonia volatilization

• affects broadcast, surface-applied urea, UAN, ammonium nitrate and manure

• ammonium in the presence of hydroxyl (OH⁻) can produce ammonia gas

\[ \text{NH}_4^+ + \text{OH}^- \rightarrow \text{H}_2\text{O} + \text{NH}_3 \]
So How Does Urea Relate to Ammonia Loss?

• urea is converted to ammonia by the enzyme, urease

• if urease activity is blocked, the rate of conversion is reduced

• urease is ubiquitous – in soil & on crop residue – 20 X more residue than soil

• enter … urease inhibitors, like NBPT or Agrotain™
Urease Inhibitors

- Urea: $\text{urea} \rightarrow \text{urease} \rightarrow \text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O}$

- $\text{NH}_3 \leftrightarrow \text{NH}_4^+ + \text{OH}^-$

- Urea is very soluble but hydrolysis of urea is rapid under warm temperatures.

- Urease inhibitors (UIs) temporarily block the action of urease.

- UIs are organic compounds, subject to microbial attack.
When Might It Be Effective?

• Ul's may block urea conversion up to 2 weeks
• If rainfall occurs, urea will move into the soil
• Effectiveness depends upon temperature and rainfall
• Most effective in warm weather when broadcasting urea
Long-term Phosphorus Issue

• “We’re running out!”
• US has reserves for 25 year
• Morocco has 75% of the world’s reserves
  – geographical imbalance could pose a geostrategic ticking time bomb
• US is importing P from Morocco
  – prolongs US reserves
“Maximize utilization of phosphorus fertilizer you’ve applied.”

- reduce reactions of phosphorus with soil
  - phosphorus fixation
  - **adsorption** onto surfaces of iron and aluminum oxides
  - **precipitation** as secondary P compounds
    - in acid soils P combines with iron (Fe) and aluminum (Al) to form insoluble compound
    - in neutral and calcareous soils P combines with (Ca) to form insoluble compounds
Fixation by hydrous oxides of Fe, Al and Mn
Reduce Reactions of Phosphorus with Soil

• protect phosphorus with a chemical shield
  – AVAIL® - “enhance P availability”
  – coated with a chemically-reactive material
  – protects P from reacting with Fe, Al or Ca in the soil solution

• Question?
  – Under what circumstances might it be useful?
EFFs

• engineer controlled release products

• design additives that slow down natural processes that lead to loss

• develop “shields” to protect nutrients from the reacting with soil components
Questions or Comments?

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