Advantages and disadvantages of controlled-release fertilizers

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Outline

- Why consider slow-release N fertilizers?
- Defining “slow-release”
- Types of slow-release N products
  - Mechanisms
- Evaluating your need for slow-release
Why consider slow-release N

- There is a fundamental flaw in how we apply N fertilizer – we don’t apply N as the crop needs it.
- In some cases, applying all N at preplant does not result in optimal use of N
- N is subject to environmental losses
Environmental losses of N

- Volatilization
- Denitrification
- Leaching
- Runoff

NO₃⁻ → NH₃⁻ → N₂O → NO₃⁻

SOIL SYSTEM

atmosphere

surface waters
to groundwater
to surface water

NO₃⁻

NH₄⁺
Why consider slow-release N

- Consider slow-release N when attempting to reduce environmental losses
- Slow-release fertilizer is becoming more cost effective
- Consider your soil system and cropping system and evaluate which N losses may be occurring and hindering efficiency
The value of increasing efficiency

**Efficiency** = more N applied taken up by the crop

#1 – Increase in yield with same fertilizer rate
#2 – Maintain yield with reduction in rate
#3 – Increase in yield with decrease in rate
#4 – Large increase in yield with increase in rate

(in each case more N is taken up per unit applied!)
Disclaimer

- Products mentioned in this presentation do not reflect an endorsement of that product.
- Likewise, a lack of mention does not imply that a product is not recommended or available for use.
What does “controlled-release” mean?

Terms sometimes used synonymously

- Slow-release
- Controlled-release
- Delayed-release

Preferred term that encompasses all types of products: *Fertilizer technologies*
Fertilizer Technologies

Three general categories:

- **Uncoated, controlled-release**
- **Coated, controlled-release**
- **Bio-inhibitors**
  - Not really “slow-release” per se
  - Inhibit microbial processes that convert N into plant available forms (and thus making the N susceptible to environmental losses)

Slowly (or relatively slowly) parse N into soil environment
Uncoated, slow-release

- Urea-formaldehyde reaction products
  - Decompose in soil by chemical processes, biological processes, or a combination of both
- Isobutylidene diurea (IBDU)
  - Relies solely on soil chemical processes to breakdown product.
- Inorganic salts
  - Magnesium ammonium phosphate
Coated, slow-release

- Sulfur-coated urea
  - Releases N through oxidation of S coating
  - Used for turf fertilization
- Polymer-coated (or Poly-coated) urea
Coated, slow-release N

Polymer-coated

- Urea is coated with special polymer coating – special to each manufacturer.
- Water moves in through coating to dissolve urea
- N diffuses out through porous polymer membrane
Coated, slow-release

- Popular for conventional agriculture systems
- ESN ® (Environmentally Smart Nitrogen, Agrium, Calgary, AB)
- Polyon ® (Agrium, Calgary, AB)
- Nutricote ® (Chisso-Ashahi Fertilizer Co., Ltd., Tokyo, Japan)
Coated, slow release (PCU)

- Beneficial in reducing split applications in sand soils / potato (Wilson et al., 2009) MN
- Greater utilization of N in corn, barley, and potato (Shoji et al., 2001) CO
- Reduction in N leaching loss (Pack et al., 2006) on sandy soils. FL
- PCU increased corn yields on low-lying areas (subject to denitrification losses) (Noellsch et al., 2009) MO
- Good alternative to split application on corn in sandy soils (Bundy – 2004) WI
Bio-inhibitors

- Urease inhibitors
- Nitrification inhibitors
Urease Inhibitors – Volatilization

Soil enzyme urease

Urea $\xrightarrow{\text{NH}_3}$ $\xrightarrow{\text{NH}_4^+}$

$\xrightarrow{\text{NH}_3}$ $\xrightarrow{\text{NH}_4^+}$
Soil pH effects on percent N

<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Ammonia (NH₃)</th>
<th>Ammonium (NH₄⁺)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.06</td>
<td>99.94</td>
</tr>
<tr>
<td>7</td>
<td>0.6</td>
<td>99.4</td>
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<tr>
<td>8</td>
<td>5.4</td>
<td>94.6</td>
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<tr>
<td>9</td>
<td>36.5</td>
<td>63.5</td>
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</table>
Options for controlling volatilization

- Incorporate into soil
- Irrigate into soil
- Rainfall occurs with 2-3 days
- Apply urease inhibitor

- If not, volatilization losses can be 15-20% of the N applied.
- Maximum of 30% loss
Urease inhibitors

- N-(n-butyl) triophosphoric triamide (NBPT)
- Agrotain ® (Agrotain, Inc., LLC, Corydon, KY)
- Can be added to urea or mixed with UAN
Urease inhibitors

- Urease inhibitors kill or chemically inhibits the activity of the soil enzyme urease.
- This causes the urea to not breakdown as quickly, providing time for rainfall to move urea into the soil.
- Can inhibit for 2 weeks or more depending on conditions.
- Warm temps and wetter conditions cause urease to repopulate faster.
Urease inhibitors

Potential benefits:

- On no-till or reduced tillage systems with surface application of N
- Allows flexibility for application timing
- On soils that have factors that favor ammonia loss

However, when there are not conditions for volatilization, urease inhibitors have little to no value
Nitrification inhibitors

- Delay conversion of NH$_4^+$ to NO$_3^-$

Specific soil bacteria:
Nitrosomonas

Delays conversion 2-4 weeks depending on pH and temp
Nitrification inhibitors

Value occurs when NO$_3^-$ losses are high – from leaching or denitrification

- Tile drained soils (when leaching potential is high)
- Wet soils / poorly drained soils
- Fall applications
- Fertilizers containing NH$_4^+$
- No-till systems
<table>
<thead>
<tr>
<th>Location</th>
<th>Time of application</th>
<th>No. of experiments</th>
<th>No. of yield increases from $\text{NI}_2$</th>
<th>% Yield increase from $\text{NI}_3$</th>
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<tbody>
<tr>
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<td>Fall</td>
<td>24</td>
<td>17</td>
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<tr>
<td></td>
<td>Spring</td>
<td>51</td>
<td>29</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>Spring (no-till)</td>
<td>12</td>
<td>9</td>
<td>10.0</td>
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<tr>
<td>No. Illinois</td>
<td>Fall</td>
<td>12</td>
<td>5</td>
<td>5.0</td>
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<tr>
<td></td>
<td>Spring</td>
<td>14</td>
<td>2</td>
<td>-1.0</td>
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<tr>
<td>So. Illinois</td>
<td>Fall (NH$_3$)</td>
<td>7</td>
<td>7</td>
<td>4.6</td>
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<tr>
<td></td>
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<td>9</td>
<td>7</td>
<td>4.6</td>
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<td></td>
<td>Spring (no-till)</td>
<td>2</td>
<td>2</td>
<td>8.5</td>
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<td>Fall (N solution)</td>
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<td>1</td>
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<td>0</td>
<td>1.5</td>
</tr>
</tbody>
</table>


2 Significant at 95% probability level.

3 Average percent yield increase across all N rates and locations.
Nitrification products

- Nitrapyrin [2-chloro-6-(trichloromethyl)-piridine]]
  - N-Serve® (Dow AgroSciences LLC, Indianapolis, IN) – only labeled for corn, sorghum, and wheat.
  - Instinct™ (Dow AgroSciences)
- Dicyandiamide (DCD)
  - SuperU® (Agrotain) – contains Agrotain and DCD
Nitrification inhibitors

- Not necessary for above optimum levels of N
- Not necessary when applying sidedress
- Do not work well on coarse textured soils
- With the low CEC, NH$_4^+$ can leach out of zone containing inhibitor
Fertilizer technologies

- Uncoated, slow-release
  - specialty crops
- PCU
  - Sandy soils, prolonged saturated soils
- Urease inhibitor
  - Surface applied urea, no till systems
- Nitrification inhibitor
  - High potential for nitrate loss (leaching, denitrification), no till, fall applications
Some quick economics

- Based on data from mid-March, 2011
- Urea = $481 ton (46% N)
- Agrotaín = $78 gallon = $559 ton (46% N)
- SuperU = $620 ton (46% N)
- ESN = $650 ton (44% N)
How to choose an enhanced-efficiency fertilizer

- Dr. Tom Bruulsema, International Plant Nutrition Institute.
- IPNI Plant Nutrition Today, Winter 2009-2010, No. 1
How to choose an enhanced-efficiency fertilizer

#1 - Do you know the mode of action and is it relevant to your crop, soil and climate?
  – All the things we discussed here today

#2 - How as the product performed in your region/cropping system?
  – Look for regional data
  – University conducted research
How to choose an enhanced-efficiency fertilizer

#3 - How does the product perform in your fields?
   - On-farm tests, replicated strip trials

#4 - Does the product enhance your ability to plant at the optimum time?
   - Can this product allow for improvements to management?
How to choose an enhanced-efficiency fertilizer

#5 - Do you have the opportunity to improve?
   - How much N are you removing?
   - What the ratio of N removed from the system (in fruit or plant material) to the amount of N you apply?

#6 - What opportunities exist for innovation? (i.e. what haven’t we thought of yet?)
Questions? Thoughts? Concerns?