CONTROLLED-RELEASE NITROGEN FERTILIZERS
Why consider slow-release N?
Defining “slow-release”
Types of slow-release N products
When to use slow-release N

“How to choose an enhanced-efficiency fertilizer”, Dr. Tom Bruulsema, IPNI
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 preplant does not result in optimal use of N.
- N is subject to environmental losses.
- Yet, spoon-feeding N is not necessarily more efficient.
ENVIRONMENTAL LOSSES OF N

- Volatilization
- Denitrification
- Leaching
- Runoff

SOIL SYSTEM

NH₃ to atmosphere
N₂O to atmosphere
NO₃⁻ to groundwater
NH₄⁺ to surface waters

NO₃⁻ to surface water
- Slow-release fertilizer may be cost effective
- Consider slow-release N when attempting to reduce environmental losses
- Consider your soil system and cropping system and evaluate which N losses may be occurring and hindering your 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 increase in rate

(in each case more N is taken up per unit applied!)
Products mentioned in this presentation to 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
Three general categories:

- Uncoated, slow-release
- Coated, slow-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)
- **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
Urea-formaldehyde reaction products

1. Ureaform
   - 15% of N in an immediately available form

2. Methylene urea
   - 15 to 30% of N in immediately available form

Product releases N through microbial decomposition and hydrolysis (reaction with water)
Two methylene urea products available

- **Nitamin®** (Georgia Pacific, Atlanta, GA)
  - 30% N, 60% of which is slowly available
  - Methyl urea, urea, and triazone (liquid)

- **Nitamin Nfusion®** (Georgia Pacific, Atlanta, GA)
  - 22% N, 94% of which is slowly available
  - Methyl urea, urea, and triazone (liquid)
IBDU

- White crystalline solid
- 90 of N in an insoluble form
- Becomes plant available through hydrolysis (breakdown into urea through reaction with water)
- Availability controlled by granule size and soil moisture
- Will breakdown in low soil temperatures
- Used mostly in specialty agriculture
 OTHER PRODUCTS

- **Nzone**
  - Ca-heteropolysacharides
  - Ca-Aminoethylpiperazine

- **Nutrisphere**
  - 40% maleic-itaconic co-polymer
COATED, SLOW-RELEASE

- Sulfur-coated urea
- Polymer-coated (or Poly-coated) urea
Sulfur-coated urea

Releases N through:

- Biological oxidation of the S coating
- Fracture of the coating
- Diffusion through somewhat porous coating
Sulfur-coated

- Used for turf grass
- Evaluated on potatoes and corn in 1972-74 (Liegel and Walsh)
- Did not increase corn yield on irrigated sands
- Increased potato yields 1 of 3 years, when excessive rainfall leached out conventional N products
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)
- 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**
Worked well on sandy soils when fertilizer was applied preplant.

Late (4 wk, 6 wk) and split applications out performed ESN preplant.

Hancock, WI, July 8, 2004
## SUMMARY OF RESEARCH ON PREPLANT SLOW-RELEASE FERTILIZER

Adapted from Blaylock et al., 2005

Keep in mind, most studies were conducted in areas or conditions where a response would be expected.

<table>
<thead>
<tr>
<th>Yield increase of (bu/ac)</th>
<th>&lt;5</th>
<th>5 to 10</th>
<th>&gt;10</th>
<th>&gt;5</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of comparisons</td>
<td>47</td>
<td>23</td>
<td>30</td>
<td>53</td>
</tr>
<tr>
<td>Group average</td>
<td>-2.2</td>
<td>7.5</td>
<td>18.8</td>
<td>13.9</td>
</tr>
</tbody>
</table>
COATED UREA PRODUCTS

- Use different methods to delay entry of N into the environment
- Used to reduce leaching losses or denitrification losses
- Will have the greatest value on sandy (or somewhat sandy) soils or when soils are periodically saturated.
BIO-INHIBITORS

- Urease inhibitors
- Nitrification inhibitors
Soil enzyme urease

Urea $\rightarrow$ NH$_4^+$

NH$_3$ $\rightarrow$ Urea

NH$_4^+$ $\rightarrow$ NH$_3$
FACTORS FAVORING AMMONIA LOSS

- No rain of irrigation after application
- Crop residue on soil surface
- High temps
- High pH
- Low clay and organic matter (low CEC)
- Initially moist soil when urea was applied, followed by rapid drying
TEMPERATURE AFFECTS UREA BREAKDOWN

Graph showing the percentage of urea hydrolyzed over time after urea application at different temperatures: 79°, 62°, and 50°.
### Ammonia-based N

<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Ammonia (NH$_3$)</th>
<th>Ammonium (NH$_4^+$)</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>
</tr>
<tr>
<td>8</td>
<td>5.4</td>
<td>94.6</td>
</tr>
<tr>
<td>9</td>
<td>36.5</td>
<td>63.5</td>
</tr>
</tbody>
</table>
OPTIONS FOR CONTROLLING VOLATILIZATION

- Incorporate into soil
- Irrigate into soil
- Rainfall occurs with 2-3 days

- If not, volatilization losses can be 15-20% of the N applied.
- Maximum of 30% loss
Urease inhibitors kill or chemically inhibit 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 1-2 weeks or more depending on conditions. Warm temps and wetter conditions cause urease to repopulate faster.
UREASE INHIBITORS

- N-(n-butyl) triophosphoric triamide (NBPT)
- Agrotain ® (Agrotain, Inc., LLC, Corydon, KY)
- Can be added to urea or mixed with UAN
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$_3^-$

\[
\text{NH}_4^+ \quad \text{Nitrosonomonas} \quad \text{NO}_2^- \quad \text{NO}_3^- \\
\]

Specific soil bacteria:

- Denitrification
- Plant uptake
- Leaching loss
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
NITRIFICATION PRODUCTS

Nitrapyrin [2-chloro-6-(trichloromethyl)-piridine]]
- N-Serve® (Dow AgroSciences LLC, Indianapolis, IN)
  - Anhydrous Ammonia, dry ammonium fertilizers, urea
  - Labeled for corn, sorghum, wheat
- Instinct™ (Dow AgroSciences)
  - UAN, urea, liquid manure
  - Labeled for corn

Dicynandiamide (DCD)
- SuperU® (Agrotain) – contains Agrotain and DCD
NITRIFICATION INHIBITORS

- Delay conversion for 4 to 10 weeks
- Depending on soil pH and temperature
### Table 3. Effects on Grain Yields of Corn Grown with Conventional and No-Till Systems from Addition of Nitrification Inhibitors to Fall- and Spring-Applied Ammoniacal Fertilizers.

<table>
<thead>
<tr>
<th>Location</th>
<th>Time of application</th>
<th>No. of experiments</th>
<th>No. of yield increases from NI₂</th>
<th>% Yield increase from NI₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indiana</td>
<td>Fall</td>
<td>24</td>
<td>17</td>
<td>12.5</td>
</tr>
<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>
</tr>
<tr>
<td>No. Illinois</td>
<td>Fall</td>
<td>12</td>
<td>5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>14</td>
<td>2</td>
<td>-1.0</td>
</tr>
<tr>
<td>So. Illinois</td>
<td>Fall (NH₃)</td>
<td>7</td>
<td>7</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Spring (NH₃)</td>
<td>9</td>
<td>7</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>Spring (no-till)</td>
<td>2</td>
<td>2</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Fall (N solution)</td>
<td>5</td>
<td>4</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Spring (N solution)</td>
<td>5</td>
<td>2</td>
<td>-1.2</td>
</tr>
<tr>
<td>Kentucky</td>
<td>Spring (no-till)</td>
<td>8</td>
<td>7</td>
<td>14.3</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Fall</td>
<td>2</td>
<td>1</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>Spring</td>
<td>2</td>
<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 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
For the most part, the products work when there is an environmental disadvantage to applying conventional fertilizer.

Using such products can be viewed as a form of risk insurance (Rankin, UW-Extension).
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?

#2 - How as the product performed in fields like yours?
Cumulative NO₃-N Leachate Loading, 2010

- ON
- ASAN
- SuperU
- Agrotain
- ESN
- Rain and Irrigation

NO₃-N Loading (kg/ha)

Rainfall and Irrigation (mm)

Date

5/1/10  6/1/10  7/1/10  8/1/10  9/1/10  10/1/10
CURRENT RESEARCH

- Comparing products on corn, chisel plow vs. no till
  - Arlington
- Products on no-till corn
  - Arlington, Marshfield
- Products on sandy soils (Central Sands)
  - Corn, sweet corn, potato
- Single year evaluations are not as meaningful compared to multi-year
#3 - How does the product perform in your fields?

#4 - Does the product enhance your ability to plant at the optimum time?
#5 - Do you have the opportunity to improve?

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

THOUGHTS?

CONCERNS?
REFERENCES