Controlled Release Nitrogen Fertilizers for Agriculture

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Presentation Overview

• Fundamentals of Controlled Release Fertilizers (CRFs)
• How can they be used in CA/AZ?

How do they work?
What are the benefits?
How can we increase nitrogen use efficiency?

- Apply 4R nutrient stewardship
  - Apply the correct fertilizer source in the right amount as close as possible to when and where the crop needs it
  - Understand the relationship between irrigation management and nutrient management to control N losses
  - Use enhanced efficiency fertilizers as sources when/where appropriate

Objective is to satisfy crop demands for optimum growth while avoiding nitrogen losses to the environment
Why use enhanced efficiency fertilizers (EEFs)?

- Growers may have to reduce N rates
- Cannot use excess N as a form of insurance against N loss
- N inputs must be budgeted according to nutrient management plans (science)
- Under a tight N budget (working on the edge of sufficiency), N losses can have a significant impact on yield or quality
- EEFs help to extract the most from the N that is applied by helping to control N losses

EEFs are beneficial to growers and the environment
N Loss Mechanisms

1. Ammonia Volatilization

\[ \text{NH}_3 \rightarrow \text{NH}_4^+ \]

2. Nitrate Leaching

\[ \text{UAN} \rightarrow \text{NH}_4\text{NO}_3 \]

\[ \text{(NH}_4\text{)}_2\text{SO}_4 \]

3. Gaseous Loss

\[ \text{N}_2\text{O}, \text{N}_2, \text{NO} \]

Nitrification

Denitrification

Urea
Enhanced efficiency nitrogen products

- **Inhibitors (liquids and solids)**
  - Chemicals that are added to standard fertilizers
  - Examples: Agrotain, Agrotain Plus, N-serve, Instinct

- **Slow Release Fertilizers (SRFs)**
  - Urea reaction products (liquids and solids)
  - Sulfur coated urea

- **Controlled Release Fertilizers (CRFs)**
  - Polymer-coated granular fertilizers
# Commercially available EEFs

## Controlled Release (Polymer Coated) Fertilizers

<table>
<thead>
<tr>
<th>Brand</th>
<th>EEFs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrium Advanced Technologies</td>
<td>ESN, POLYON, DURATION</td>
</tr>
<tr>
<td>everris.</td>
<td>OSMOCOTE</td>
</tr>
<tr>
<td>Haloa</td>
<td>MULTICOTTE</td>
</tr>
<tr>
<td>CHISSO-ASAHI</td>
<td>NUTRICOTE, MEISTER</td>
</tr>
<tr>
<td>SHAW’S / KNOX</td>
<td>SURFKOTE, XRT</td>
</tr>
<tr>
<td>FLORIKAN</td>
<td>FLORIKOTE</td>
</tr>
</tbody>
</table>

## SLOW RELEASE (UREA FORMALDEHYDE, METHYLENE UREA)

<table>
<thead>
<tr>
<th>Brand</th>
<th>EEFs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrium Advanced Technologies</td>
<td>NITROFORM, NUTRALENE, BCMU</td>
</tr>
<tr>
<td>Lebanon Seaboard</td>
<td>METHEX, MESA</td>
</tr>
<tr>
<td>saepep chimlea</td>
<td>SAZOLENE</td>
</tr>
<tr>
<td>JOHN CLEVELAND</td>
<td>GENERIC METHYLENE UREA</td>
</tr>
</tbody>
</table>

## SLOW RELEASE (PC SULFUR COATED UREA)

<table>
<thead>
<tr>
<th>Brand</th>
<th>EEFs</th>
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</thead>
<tbody>
<tr>
<td>Agrium Advanced Technologies</td>
<td>XCU</td>
</tr>
<tr>
<td>TurfCare</td>
<td>POLY-PLUS, LESCO</td>
</tr>
<tr>
<td>everris.</td>
<td>POLY-S</td>
</tr>
</tbody>
</table>

## INHIBITORS (Not controlled or slow release)

<table>
<thead>
<tr>
<th>Brand</th>
<th>EEFs</th>
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<tbody>
<tr>
<td>KOCH</td>
<td>AGROTAIN, SUPER-U, UMAXX, UFLEXX</td>
</tr>
<tr>
<td>DOW AGROSCIENCE</td>
<td>N-SERVE, INSTINCT</td>
</tr>
<tr>
<td>COMPO</td>
<td>ENTEC (DMPP)</td>
</tr>
</tbody>
</table>
Manufacturing of Polymer-Coated Plant Nutrients

- Reactive Layers Coating (RLC)
- Thin polymer coatings
- Continuous throughput
- Economy of scale
Polymer-Coated Urea
Difference between standard and controlled release nitrogen fertilizers

- **Standard** nitrogen fertilizers become 100% exposed to soil processes when applied
  - Examples include urea (46-0-0), ammonium sulfate (21-0-0), ammonium nitrate (34-0-0), and calcium nitrate (15.5-0-0)

- **Controlled release** nitrogen fertilizers are standard granular fertilizers encased in a polymer coating
  - Nutrients held inside polymer coating are protected from soil processes until released
Standard fertilizer dissolving in water

Urea (46-0-0)  Water added  5 minutes later (dissolved)
Polymer-coated urea (PCU) is protected from soil processes

Several weeks after adding water:
- Dissolved urea is inside coating
- Some of the urea inside is not completely dissolved

Hours after adding water
How Do Polymer-Coated Fertilizers Work?

- Urea completely dissolved
- Empty ‘capsules’
- Urea still solid
- Urea partially dissolved; some solid urea remains
- Urea still solid
Factors that control nutrient release from CRF

• Temperature
  – Solutes such as urea move through the coating by diffusion which is dependent on temperature

• Coating weight or thickness (for a given coating chemistry)
  – As coating thickness increases, the diffusion time through the coating increases

• Moisture is required but is a non-factor for irrigated crops

• Unaffected by pH, salinity, aeration, and microbial activity

• Coatings do not “break down” to release nutrients
Effect of temperature on release

T-Dependence of Release from "120-Day" PCU

- 50°F
- 68°F
- 86°F

Percentage of urea released vs. Days following application.
Effect of coating weight on release

Dependence of Release Time on Coating Thickness

- 45-Day PCU
- 80-Day PCU
- 120-Day PCU

<table>
<thead>
<tr>
<th>PCU</th>
<th>% Nitrogen</th>
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<tbody>
<tr>
<td>45-Day</td>
<td>44.5</td>
</tr>
<tr>
<td>80-Day</td>
<td>44.0</td>
</tr>
<tr>
<td>120-Day</td>
<td>43.0</td>
</tr>
</tbody>
</table>

Percentage of urea released vs. Days following application.
Benefits from using CRFs

• **Increases N use efficiency**
  – Helps maintain/increase productivity at reduced N rates
  – Reduces N loss to environment

• **Improves nutrient delivery to the plant**
  – Releases nutrients in small increments over time

• **Reduces the number of fertilizer applications**
  – Allows for front-loading of fertilizer N at pre-plant timings
  – Provides flexibility and cost savings in applications
Durability of Coated Fertilizer

- Coatings can be damaged by excessive handling
- Damage occurs from abrasion and impact
- Damage shortens release time and can reduce value
- Application equipment should be in good repair and properly adjusted
- Handle similar to seed
- Follow manufacturer guidelines for handling

When handled properly, CRFs can be used effectively for production agriculture
Market Potential for CRF

- Controlled release fertilizers (CRFs) currently are a negligible percent of worldwide consumption
- Given population and environmental pressures, CRFs will gain significance

World demand for fertilizer nitrogen is increasing and so is demand for nitrogen use efficiency
How can CRFs be used in CA/AZ?

• **Crops**
  – Corn, wheat, rice, cotton
  – Vegetable and melon
  – Leafy Greens
  – Tree & Vine

• **Advantages over standard fertilizers include**
  – Improved performance
  – Increased productivity at reduced N rates
  – Reduced number of applications
California Wheat

- Spring varieties
- Fall/winter plantings
- Split N applications
- Top-dress and fertigate N
- 3 lb N/100 lb grain
- 4 ton/A crop: 240 lb N/A
## Durum Trial (Dr. Tom Thompson, U. Arizona)

<table>
<thead>
<tr>
<th>Trt No.</th>
<th>Pre-plant</th>
<th>5-leaf</th>
<th>Joint</th>
<th>2-node</th>
<th>Heading</th>
<th>Late flowering</th>
<th>Total N (lb N/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25 (urea)</td>
<td>55</td>
<td>54</td>
<td>50</td>
<td>40</td>
<td>25</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>30 (MAP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>249 (PCU)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>30 (MAP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>187 (PCU)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>217</td>
</tr>
<tr>
<td></td>
<td>30 (MAP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>125 (PCU)</td>
<td>0</td>
<td>0</td>
<td>59</td>
<td>40</td>
<td>25</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>30 (MAP)</td>
<td></td>
<td></td>
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</table>
Figure 2-1. The Feekes scale of wheat development.

<table>
<thead>
<tr>
<th>Tillering</th>
<th>Stem Extension</th>
<th>Heading</th>
<th>Ripening</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  one shoot</td>
<td>2  tillering begins</td>
<td>3  tillers formed</td>
<td>4  leaf sheaths lengthen</td>
</tr>
<tr>
<td>↑</td>
<td>↑</td>
<td>↑</td>
<td>↑</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trt.</th>
<th>1 55</th>
<th>55</th>
<th>54</th>
<th>50</th>
<th>40</th>
<th>25</th>
<th>lb</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>249/30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>lb</td>
</tr>
<tr>
<td>3</td>
<td>187/30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>lb</td>
</tr>
<tr>
<td>4</td>
<td>125/30</td>
<td>0</td>
<td>0</td>
<td>59</td>
<td>40</td>
<td>25</td>
<td>lb</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Durum (Maricopa, AZ)

<table>
<thead>
<tr>
<th>Nitrogen Source</th>
<th>TRT 1 Standard Split 279</th>
<th>TRT 2 pp(ESN+MAP) 279</th>
<th>TRT 3 pp(ESN+MAP) 217</th>
<th>TRT 4 pp(ESN+MAP) 155 + split 124</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield (ton/A)</td>
<td>3.5</td>
<td>14.0</td>
<td>14.0</td>
<td>13.5</td>
</tr>
<tr>
<td>Grain Protein Percentage</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
Durum Trial Summary

• Yield and protein differences were not significant
• Results suggest for 4.0-4.5 ton crop:
  – 220 lb N/A as 85/15 PCU-N/Urea-N pre-plant
    • May need extra N (50 lb/A) in pre-plant application for stubble decomposition
  – 50 lb N/A as standard fertilizer at flowering
• Ballpark economics (+$0.20-0.30/lb N over cost of urea)
  – $37-56/A increase over urea (187 lb PCU-N/A)
  – 4-6 bu/A (240 lb/A) increase to cover upcharge ($9 wheat)
  – Eliminates expense and inefficiency of fertigation
Predicted ESN Release Curves (Degree-Day Model)

Average Soil Temperature (6-in)

ESN Release Curve

Soil Temperature (°F)

Percent Urea Released

Date (month/day) 2010-2011

Five Points  Lodi  Porterville  Meloland

Five Points  Lodi  Porterville  Meloland
PCU for Vegetables and Leafy Greens (CA/AZ)

- Vegetable, melon, and head lettuce under furrow irrigation
  - Dr. Charles Sanchez (Yuma, AZ)
- Spinach under sprinkler irrigation
  - Richard Smith (Salinas, CA)
- Romaine lettuce under drip irrigation
  - Richard Smith (Salinas, CA)
Cauliflower (Yuma, AZ) Application Timeline and Soil Temperatures

Yuma, AZ, Fall Soil Temperatures
Average T = 59°F
Cauliflower Yield vs N Rate

Cauliflower Yield by Fertilizer Source and N Rate (Yuma, AZ)

- **UAN sidedress**
- **ESN**
- **50/50 ESN/D120**

<table>
<thead>
<tr>
<th>Nitrogen Application Rate (lb/ac)</th>
<th>Check</th>
<th>107</th>
<th>174</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7</td>
<td>4.9</td>
<td>5.5</td>
<td>5.2</td>
</tr>
<tr>
<td>5.5</td>
<td></td>
<td>6.0</td>
<td>6.4</td>
</tr>
<tr>
<td>5.2</td>
<td></td>
<td></td>
<td>5.5</td>
</tr>
</tbody>
</table>

Marketable Yield / ton/ac
Seedless Watermelon (Yuma, AZ) Application Timeline and Soil Temperatures

Yuma Spring Soil Temperatures
Average T = 73°F
Total Watermelon Yield vs N Rate

Seedless Watermelon Yield (LSD = 7.4)

- Urea Split
- D120
- 75/25 D120/ESN

Yield / tons/ac

- Check: 11.1
- 174: 20.0, 23.5, 25.3
- 307: 27.3, 30.3, 28.3

Nitrogen Application Rate (lb/acre)

- Nitrogen Application Rate (lb/acre)