Products for Improving the Efficiency of N Fertilizers

Greg Binford
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THREE major forms of N?

1) Organic N (e.g., plant residues, manures)
2) Ammonium (\(\text{NH}_4^+\))
3) Nitrate (\(\text{NO}_3^-\))
NITRIFICATION

1) Conversion of Ammonium to Nitrate
2) $\text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + \text{H}_2\text{O} + 2\text{H}^+$
3) Biological Process
4) Nitrification is temperature dependent
5) Nitrification insignificant below 50 °F
6) How fast does the conversion occur?
Nitrification of Ammonium Sulfate

Rate of Fertilizer N Applied in Early April (lb N/acre)

Surface 0 to 6”

N Concentration in Late May (ppm N)

NH4+
NO3-
Nitrification Inhibitor Technology

1) Slows conversion of ammonium to nitrate
2) $\text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^- + \text{H}_2\text{O} + 2\text{H}^+$
3) Reduces N loss potential
4) Some studies have shown a benefit
5) Potential benefit greater in today’s fertilizer market
6) Potential value increases with length of time between application and plant demand
How is Nitrogen Lost?

THREE ways N is lost from soils:

1) LEACHING
2) DENITRIFICATION
3) VOLATILIZATION
1) Form of N lost this way? \( \text{NH}_4^+ \)

2) Ammonium in high pH environment

3) Soil pH is THE major influence

4) \( \text{NH}_4^+ \leftrightarrow \text{NH}_3(g) + \text{H}^+ \)

5) Other important factors: CEC, wind, and TEMPERATURE
1) Form of N lost this way? $\text{NH}_4^+$

2) Ammonium in high pH environment

3) Soil pH is THE major influence

4) $\text{NH}_4^+ \iff \text{NH}_3(g) + \text{H}^+$

5) Other important factors: CEC, wind, and TEMPERATURE

6) Prevent by incorporation of ammonium

7) Two big concerns: Surface applications of Manures and UREA containing fertilizers
Urea Prill Microsite pH

Hauck, 1984

Days After Application
Soil pH effects on percentages of N present as ammonia and ammonium

<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Ammonia</th>
<th>Ammonium</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.058</td>
<td>99.94</td>
</tr>
<tr>
<td>7</td>
<td>0.57</td>
<td>99.43</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>
Urease Inhibitors

1) Urease is the enzyme that breaks down urea
2) Urea (NH$_2$ – CO – NH$_2$) $\Rightarrow$ NH$_4$ Carbonate
3) NH$_4^+$ in a high pH environment goes to NH$_3$(g)
4) Urease inhibitors keeps N as urea until in soil
5) Rating the potential for response:
   1) UREA broadcast on soil surface
   2) UAN broadcast on soil surface
   3) UAN in a dribble band ??
6) If urea gets into the soil (rain or tillage), then there is no need for a urease inhibitor
New Products: Nitrogen

1) ESN = Polymer-Coated UREA fertilizer
2) Agrotain = Urease Inhibitor (urea/UAN)
3) Agrotain + = urease & nitrification inhibitor
4) Super U = urease & nitrification inhibitor
5) Nutrisphere-N (NSN) = urease & nitrification inhibitor
ESN STUDIES
ESN Release in Water

% N Released

Time (days)

Graph showing the release of N over time at different temperatures:
- 5°C (red circles)
- 10°C (green triangles)
- 23°C (blue triangles)

The graph illustrates an increase in the percentage of N released over time at all temperatures, with 23°C showing the highest rate of release.

University of Delaware
Field study; spring top-dress application on winter wheat
Source: R Koenig, Washington State Univ
N Source and N Leaching Losses
Winter Wheat, Ohio, 2003

Source: Dr. R. Islam, The Ohio State Univ, 2003.
Inorganic N in leachate from 100- x 30-foot lysimeters.
Calculated from total water volume and N concentration.
Delaware: Irrigated Corn in 2003

Statistically significant differences among all yields

150 lb N/ac applied total; sidedress = 40 preplant & 110 sidedress

All treatments incorporated; weather was wettest year in more than 100 yrs
Delaware: Dryland Corn in 2003

Statistically significant differences b/w PP & SD

Silt Loam Soil

150 lb N/ac applied total; sidedress = 40 preplant & 110 sidedress

No-tilled into wheat stubble, weather was wettest year in more than 100 yrs
Delaware: Irrigated Corn in 2005

Statistically significant yield differences except for SD treatments

150 lb N/ac applied total; sidedress = 30 preplant & 120 sidedress

All treatments incorporated; rainfall was near-normal

Loamy Sand Soil
Delaware: Irrigated Corn 2005

LSD = 18 bu/ac

Grain Yield (bu/ac)

ESN/0  Urea/0  AN/UAN  ESN/ESN  ESN/UAN  Std

170 lb N/ac applied total; Split = 85 PP & 85 SD; Std = 30 PP/140 SD

ONLY preplant treatments incorporated.
Grain Yield (bu/ac)

- ESN/0
- Urea/0
- AN/UAN
- ESN/ESN
- ESN/UAN
- Std

170 lb N/ac applied total; Split = 85 PP & 85 SD; Std =30 PP/140 SD

ONLY preplant treatments incorporated.
Delaware: Corn in 2006

Yields with same letter within a site are not statistically different

Grain Yield (bu/ac)

120 lb N/ac Applied either Preplant, Sidedress, or as Even Split
Delaware: Winter Wheat in 2005

Yields with same letter within a site are not statistically different

<table>
<thead>
<tr>
<th></th>
<th>ESN70</th>
<th>ESN50</th>
<th>ESN30</th>
<th>UAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

75 lb N/ac applied at green-up as spring topdress
Delaware: Winter Wheat in 2006

Yields with same letter are not statistically different

- ESN50
- ESN30
- UAN

Grain Yield (bu/ac)

90 lb N/ac applied at green-up as spring topdress
1) FOUR N Rates as UAN
2) Agrotaín
3) Agrotaín Plus
4) Nutrisphere N
5) Polymer Coated Urea
6) Ammonium Nitrate and/or Urea
Winter Wheat in 2007: Sussex (Irrigated)

Yields with same letter are not statistically different

<table>
<thead>
<tr>
<th>Rate of N (lb/ac) applied at green-up as spring topdress</th>
<th>Grain Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>78</td>
</tr>
<tr>
<td>95</td>
<td>88</td>
</tr>
<tr>
<td>110</td>
<td>97</td>
</tr>
<tr>
<td>125</td>
<td>98</td>
</tr>
</tbody>
</table>

Rate of N (lb/ac) applied at green-up as spring topdress:
- 80 lb/ac: c
- 95 lb/ac: b, a
- 110 lb/ac: a
- 125 lb/ac: a

University of Delaware
Winter Wheat in 2007: Sussex (Irrigated)

Yields with same letter are not statistically different

LSD = 5.3
Winter Wheat in 2007: New Castle

Yields with same letter are not statistically different

Rate of N (lb/ac) applied at green-up as spring topdress

Grain Yield (bu/ac)

- 60
- 75
- 90
- 105

71 76 84 90
Winter Wheat in 2007: New Castle

Yields with same letter are not statistically different

Grain Yield (bu/ac)

LSD = 6.6
Winter Wheat in 2008: Sussex (Irrigated)

Yields with same letter are not statistically different

Grain Yield (bu/ac)

Rate of N (lb/ac) applied at green-up as spring topdress
Winter Wheat in 2008: Sussex (Irrigated)

Yields with same letter are not statistically different

LSD = 7
Winter Wheat in 2008: Sussex (Dryland)

Yields with same letter are not statistically different

Grain Yield (bu/ac)

Rate of N (lb/ac) applied at green-up as spring topdress

- 85 (b)
- 92 (ab)
- 99 (a)
- 102 (a)
Winter Wheat in 2008: Sussex (Dryland)

Yields with same letter are not statistically different

LSD = 9.9

Grain Yield (bu/ac)

urea
urea +at
Super U
urea +ns
esn30u
esn30an
an

UNIVERSITY OF DELAWARE
AGROTAI.N STUDIES
ESN/Agrotain Ammonia Losses

Source: Dr. W. Thornberry, Sturgis, KY; Dr. S. Ebelhar, Univ of Illinois
Laboratory incubation
PA Study (Fox & Piekieleks, 1993)

3-year study

Type of Nitrogen Treatment

UREA-  UREA+  34-0-0

PREPLANT UREA without (-) & with (+) Agrotain

CORN

Corn Grain Yield (bu/acre)

Avg. 100 + 150
N Sources for No-till Corn

Summary: Eight Site-years

Yield and Net $ Benefit compared to check treatment.

Ebelhar & Varsa, 2004
N Sources for No-till Corn
Summary: Eight Site-years

Ebelhar & Varsa, 2004

Net AgroteiN Benefit:
+$42 $1 -$2

Yield Benefit
Net $ Benefit

Urea Urea+NBPT UAN (Br) UAN (Br)+NBPT UAN(Dr) UAN(Dr)+NBPT Amm. Nitrate Anhydrous UAN Inj.

Yield and Net $ Benefit compared to check treatment.
N Sources for No-till Corn

Summary: Eight Site-years

Net AgrotaiN Benefit:

Yield Benefit  Net $ Benefit

+42       1     -2

Yield and Net $ Benefit compared to check treatment.

Ebelhar & Varsa, 2004
Summary: Eight Site-years in Illinois

Yield and Net $ Benefit compared to check treatment.

Net AgroMaiN Benefit:
+$42 $1 -$2
N Fertilizer Source and Rate Studies on Rice Yield and N Uptake
-Calloway silt loam, pH ~ 7.6-

- **N Sources**
  - Urea
  - Agrotain
  - Ammonium Sulfate
  - Urea/Ammonium Sulfate Blend

- **N Rates**
  - 0, 67, and 134 kg N/ha

- **Timing**
  - 1, 5, and 10 days prior to flooding

- **Experiment Design**
  - Factorial with 4 replications

- **Measurements**
  - Ammonia volatilization, grain yield and N uptake
Ammonia Volatilization Losses

LSD (0.05) between times = 1.66%; LSD (0.05) between N sources = 4.08%
## Preflood N Source X Time Prior to Flooding Effects on Total N Uptake

<table>
<thead>
<tr>
<th>N Fert Sources</th>
<th>N Rate (kg N/ha)</th>
<th>Application time Prior to Flooding (days)</th>
<th>1</th>
<th>5</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTC</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>194</td>
<td>158</td>
<td>145</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrotain</td>
<td>193</td>
<td>185</td>
<td>173</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>187</td>
<td>189</td>
<td>177</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea + AS</td>
<td>185</td>
<td>170</td>
<td>161</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† Beginning Heading  

Source: Rick Norman, University of Arkansas
## Preflood N Source X Time Prior to Flooding Effects on Rice Grain Yield

<table>
<thead>
<tr>
<th>N Fert Sources</th>
<th>N Rate (kg N/ha)</th>
<th>Application time Prior to Flooding (days)</th>
<th>Grain Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>UTC</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>134</td>
<td>9,424</td>
<td>8,061</td>
</tr>
<tr>
<td>Agrotain</td>
<td>134</td>
<td>9,482</td>
<td>9,173</td>
</tr>
<tr>
<td>AS</td>
<td></td>
<td>9,125</td>
<td>8,974</td>
</tr>
<tr>
<td>Urea + AS</td>
<td></td>
<td>9,226</td>
<td>8,473</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Rick Norman, University of Arkansas
Urea Compared To Nutrisphere Applied At Different Times Prior To Flooding Mississippi-2006

- **Locations**
  - DREC: Sharkey clay, pH=8.0

- **N Sources**
  - Urea
  - Nutrisphere (0.5%)
  - Nutrisphere (1.0%)

- **N Rates**
  - 101 and 168 kg N/ha

- **Timing**
  - 1 and 10 days prior to flooding

- **Experiment Design**
  - Factorial with 4 replications

- **Measurements**
  - Grain yield
### Nutrisphere Study
#### Mississippi

<table>
<thead>
<tr>
<th>N Rate kg N/ha</th>
<th>Grain yield, kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>7913</td>
</tr>
<tr>
<td>168</td>
<td>9173</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>353</td>
</tr>
</tbody>
</table>

Source: Rick Norman, University of Arkansas
### Nutrisphere Study
#### Mississippi

<table>
<thead>
<tr>
<th>N Applied Time(^\dagger)</th>
<th>DREC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain yield, kg/ha</td>
</tr>
<tr>
<td>1 dbf</td>
<td>8,770</td>
</tr>
<tr>
<td>10 dbf</td>
<td>8,316</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>353</td>
</tr>
</tbody>
</table>

\(^\dagger\) dbf = days before flooding.

**Source:** Rick Norman, University of Arkansas
## Nutrisphere Study
### Mississippi

<table>
<thead>
<tr>
<th>N Source</th>
<th>DREC</th>
<th>Grain yield, kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>8,518</td>
<td></td>
</tr>
<tr>
<td>Nutrisphere (0.5%)</td>
<td>8,417</td>
<td></td>
</tr>
<tr>
<td>Nutrisphere (1.0%)</td>
<td>8,669</td>
<td></td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

Source: Rick Norman, University of Arkansas
Urea Compared To Nutrisphere Applied At Different Times Prior To Flooding

Arkansas-2007

- **Locations**
  - LHRF: Hilleman silt loam, pH=6.1
  - RREC: Dewitt silt loam, pH=6.3

- **N Sources**
  - Urea
  - Nutrisphere

- **N Rates**
  - 0, 67, and 134 kg N/ha

- **Timing**
  - 1, 5, and 10 days prior to flooding

- **Experiment Design**
  - Factorial with 4 replications

- **Measurements**
  - Grain yield
## Nutrisphere Study
### Arkansas

<table>
<thead>
<tr>
<th>N Rate kg N/ha</th>
<th>LHRF Grain yield, kg/ha</th>
<th>RREC Grain yield, kg/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>7,006</td>
<td>2,822</td>
</tr>
<tr>
<td>67</td>
<td>8,114</td>
<td>6,149</td>
</tr>
<tr>
<td>134</td>
<td>8,468</td>
<td>8,014</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>403</td>
<td>504</td>
</tr>
</tbody>
</table>

Source: Rick Norman, University of Arkansas
# Nutrisphere Study

**Arkansas**

<table>
<thead>
<tr>
<th>N Applied Time(^\dagger)</th>
<th>LHRF</th>
<th>RREC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 dbf</td>
<td>8,921</td>
<td>8,266</td>
</tr>
<tr>
<td>5 dbf</td>
<td>8,215</td>
<td>7,258</td>
</tr>
<tr>
<td>10 dbf</td>
<td>7,862</td>
<td>5,746</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>403</td>
<td>504</td>
</tr>
</tbody>
</table>

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**Grain yield, kg/ha**

\(^\dagger\) dbf = days before flooding.

**Source:** Rick Norman, University of Arkansas
# Nutrisphere Study
## Arkansas

<table>
<thead>
<tr>
<th>N Source</th>
<th>LHRF</th>
<th>RREC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>8,417</td>
<td>7,157</td>
</tr>
<tr>
<td>Nutrisphere</td>
<td>8,266</td>
<td>7,006</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

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**Source:** Rick Norman, University of Arkansas
Laboratory-Incubation Study
Ammonia volatilization of urea, ammonium sulfate, Agrotain, and Nutrisphere applied to a Dewitt silt loam soil in an lab-incubation study at 25°C
Ammonia volatilization of urea, UAN and UAN + Nutrisphere applied to a Dewitt silt loam soil in an lab-incubation study at 25°C
SUMMARY: ESN

1) ESN does provide a slow release of N
2) Volatilization is of little concern
3) For preplant N in corn, ESN appears to have value compared to UAN or Urea applied preplant
4) Applying ESN preplant should NOT replace the standard practice of applying sidedress N
5) ESN should NOT be applied to bare soils and left on the soil surface without incorporation
6) Spring topdressings on wheat should contain no more than 30 to 50% ESN (@ green-up)
SUMMARY: Agrotain

1) Agrotain does reduce urea volatilization
2) Broadcasting urea on warm soils would provide the greatest potential value from Agrotain
3) Rainfall or irrigation (0.5”) eliminates the need for using urease inhibitors
4) Broadcasting UAN on warm soils would provide the second greatest potential value from Agrotain
5) Dribbling UAN on warm soils appears of questionable value...most data suggests little value
6) PLUS in Agrotain still not proven benefit
SUMMARY: Nutrisphere-N

1) NSN appears to have little effect on volatilization
2) Several studies with positive results are reported on Specialty Fertilizer’s web site
3) Research database is limited in this region
4) DE work has shown no benefit (started in 2006)
5) Effect on Nitrification has not been proven
QUESTIONS???

Greg Binford @302-831-2146 or binfordg@udel.edu
Winter Wheat in 2008; Fall N Rate Study

Yields with same letter are not statistically different

<table>
<thead>
<tr>
<th>Fall N Rate (bu/ac)</th>
<th>Spring N Rate (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,135</td>
<td>112</td>
</tr>
<tr>
<td>0,95</td>
<td>103</td>
</tr>
<tr>
<td>20,95</td>
<td>107</td>
</tr>
<tr>
<td>40,95</td>
<td>103.447</td>
</tr>
</tbody>
</table>

First Number is Fall N Rate; Second is Spring N Rate at Green-up

University of Delaware