Managing Fertilizer is Complicated

- Crop requirements
- Soil and plant sample interpretation
- Crop prices
- Fertilizer prices
- Application logistics and costs
- Choice of Nitrogen fertilizer products
- When to apply
- Where to apply
- How much to apply

You want to end up doing as last year

https://www.fastweb.com
https://www.precisionag.com
https://www.online.colostate.edu
Confusion

https://masterful-marketing.com

https://www.stuff.co.nz
Not Silver Bullet
Useful Used Properly

Oh what to do, what to dooo?

https://crystalbastrology.com
Major Nitrogen Fertilizer Loss Pathways

- Ammonia Volatilization
- Nitrate Leaching
- $N_2O$ + Denitrification

- Complex
- Weather dependent
- Soil dependent
- Practice dependent
- Time of year dependent
Major Losses of Fertilizer Nitrogen
Ammonia Volatilization Loss of Fertilizer N Added

On average, 18% N added volatilized in North America

Pan et al. 2016
Leaching of Fertilizer N

% N Loss

- Incorporated
- Injected
- Surface applied

On average, 8% N added leached

Yield Mg/ha

- Incorporated
- Injected
- Surface applied

400 bu/ac
300 bu/ac
200 bu/ac

Why lowest yield with surface?
Additional losses with volatilization

Christianson and Harmel, 2015
# Denitrification Losses of Added Fertilizer N

<table>
<thead>
<tr>
<th>% Soil Organic Matter</th>
<th>Excessively Well Drained</th>
<th>Well Drained</th>
<th>Moderately Well Drained</th>
<th>Somewhat Poorly Drained</th>
<th>Poorly Drained</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>2-5</td>
<td>6</td>
<td>10</td>
<td>13</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>&gt;5</td>
<td>8</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Need warm soil temperatures to get this sort of losses*

Source: DuPont/Pioneer
4R Nutrient Stewardship

- Best use of crop nutrient additions
- Improve/maintain yields
- Improve profitability
- Limit losses
- Have co-benefits (water and air quality, GHG)
- Understandable and easy to follow
- Auditable, provide credits, use $incentive programs
- Applies “agronomic sense” of past, present and future advances
Enhanced Efficiency N Fertilizers

- **Stabilized N**
  - Urease inhibitor
  - Nitrification inhibitor
  - Double inhibitor

- **Controlled Release**
  - Polymer Coated Urea

- **Slow Release**
  - Sulfur-coated Urea, Methylene Urea, Isobuylidene Diurea, Urea Formaldehyde, Urea Triazone
Enhanced Efficiency Fertilizers

Mechanism of Action

Nitrification

1. Nitrification Inhibitors

2. Urease Inhibitors

3. Controlled and Slow Release Urea

Enhanced Efficiency Fertilizers

Lower Volatilization Losses

Lowers Appearance of $\text{NO}_3^-$

Denitrification

$\text{NO}_3^-$

$\text{N}_2$
Polymer Coated Urea

Release of urea to soil
Depends on
Soil moisture
Soil temperature
Soil contact (subsurface)
Ammonia

• Gaseous loss of fertilizer Nitrogen

• Prone to loss with
  • Anhydrous ammonia if injected shallow, slots not covered, especially sand soil
  • Ammonia producing sources such as urea granular and solution applied to soil surface
  • Ammonium and urea with basic reacting phosphate fertilizers applied to soil surface or shallow bands

• Losses more pronounced when warm, soil wet, air dry, lots of wind

• Losses more pronounce on soil that is basic (pH>7), low organic matter, sandy, low buffering ability
Ammonia Volatilization from Urea

Urease Enzyme

\[ \text{NH}_4^+ + \text{HCO}_3^- \rightarrow \text{CO}_2 + \text{OH}^- + \text{H}_2\text{O} \]

What Promotes Volatilization?
- Low organic matter
- Sand
- Low CEC
- High urea concentration
- Moisture
- Wind
- Temperature

Relative Concentration

pH

NH\text{3}^+

NH\text{4}^+
How Deep Placement Reduces Ammonia Volatilization from Urea

Deeper the incorporation more opportunity for acidity from organic acids and reserves on clay to neutralize bicarbonate and ammonia.
How Shallow Placement May Increase Ammonia Volatilization from Urea

For shallow banded, less volume of soil to buffer before ammonia gets to atmosphere
How Urease Inhibitor Reduces Ammonia Volatilization

Urease

\[ \text{NH}_4^+ + \text{HCO}_3^- \]

NH4+ increased chance to bind and move in soil

\[ \text{HCO}_3^- + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{OH}^- + \text{H}_2\text{O} \]

Less pH Increase

Less Volatilization

Slower release of \( \text{NH}_4^+ \) + \( \text{HCO}_3^- \)

High pH

BMPT

Urease Enzyme

BMPT

Urease Enzyme

BMPT

Urease Enzyme

BMPT

Urease Enzyme
Shallow Banding Ammonia Loss Concern For Northern Great Plains of Canada

• Standard recommendation is subsurface band to >3”
• Increasing use of shallow banding
  • Saves time
  • Saves fuel
• Some evidence in Eastern Canada that ammonia losses may be higher for shallow banding than surface placement of granular urea
Silty clay loam (27% clay)
125 lbs N/acre
20” band spacing
5 cm depth hand trenched band

Rochette et al. JEQ 2009
Ammonia Loss From Shallow Band Urea Increases with N Rate

Fig. 3. Maximum change in soil NH$_4$-N ($\Delta$NH$_4$) concentration and maximum change in soil pH ($\Delta$pH) during the monitoring period, and cumulative volatilization NH$_3$ losses following subsurface (5 cm) banding of urea at increasing application rates.

Silty loam (19% clay)
146 lbs N/acre
20” band spacing
5 cm hand trenched band

Rochette et al. CJSS 2013
Deeper Band Placement Reduces Ammonia Loss

Ammonia losses are nil if placement below 3”

Data from 15 published studies

Fig. 4. Summary of literature data on ammonia volatilization response to urea incorporation depth. Volatilization losses were expressed as proportion (%) of applied N (a) and proportion (%) of losses for a surface-application (b). Open squares are observations from this study. One datapoint (“x”) from Bouwmeester et al. (1985), for which water accumulation over the band artificially reduced volatilization, was not included in the analysis.
Canola Yield in Manitoba Trials with Placement N Rate Not Optimum (70% of Recommended)

*no effect of N source or ‘placement x source’ interaction*
Canola Yield in Manitoba Trials
N Rate Optimum
(100% of Recommended)

No difference in placement when N rate is optimum, Means loss of ammonia with surface placement is covered Up by extra Nitrogen addition

*when N rate optimum, no effect of placement
*no effect of product or ‘product x placement’ interaction
Assessing Ammonia Loss with Dosimeters

Agrotain Urea

Surface Granular Urea
Ammonia Loss Domain, Manitoba 2016
Clay Soil with Very High SOM

Site year with least ammonia loss

Low volatilization potential and no benefit to inhibitors
Summary of EEFs on Volatilization

### a. Urease inhibitor

<table>
<thead>
<tr>
<th>Compound</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydroquinone</td>
<td>(7)</td>
</tr>
<tr>
<td>ATS</td>
<td>(4)</td>
</tr>
<tr>
<td>CTS</td>
<td>(4)</td>
</tr>
<tr>
<td>PPDA</td>
<td>(4)</td>
</tr>
<tr>
<td>CHTPT</td>
<td>(2)</td>
</tr>
<tr>
<td>NBPT</td>
<td>(2)</td>
</tr>
<tr>
<td>Ammonium lignosulfonate</td>
<td>(2)</td>
</tr>
<tr>
<td>CHPT</td>
<td>(4)</td>
</tr>
</tbody>
</table>

### b. Controlled release fertilizer

<table>
<thead>
<tr>
<th>Compound</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>polymer-coated urea</td>
<td>(16)</td>
</tr>
<tr>
<td>polyefin-coated urea</td>
<td>(3)</td>
</tr>
<tr>
<td>sulphur-coated urea</td>
<td>(14)</td>
</tr>
<tr>
<td>thermoplastic resin-coated urea</td>
<td>(3)</td>
</tr>
<tr>
<td>methylene</td>
<td>(2)</td>
</tr>
</tbody>
</table>

### c. Nitrification inhibitor

<table>
<thead>
<tr>
<th>Compound</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>overall</td>
<td>(51)</td>
</tr>
<tr>
<td>DMPP</td>
<td>(4)</td>
</tr>
<tr>
<td>phenylacetylene</td>
<td>(3)</td>
</tr>
<tr>
<td>DCD</td>
<td>(31)</td>
</tr>
<tr>
<td>N-serve</td>
<td>(5)</td>
</tr>
<tr>
<td>CL-1580</td>
<td>(3)</td>
</tr>
<tr>
<td>AM</td>
<td>(3)</td>
</tr>
<tr>
<td>ATC</td>
<td>(3)</td>
</tr>
</tbody>
</table>

Fig. 3. Effect of (a) urease inhibitors, (b) controlled release fertilizers and (c) nitrification inhibitors on NH₃ volatilization. Means and 95% confidence intervals are depicted. Numbers of experimental observations are in parentheses. CHPT: cyclobexyl phosphoric triamide, CHTPT: cyclobexyl thiophosphoric triamide, ATS: ammonium thiosulphate, CTS: calcium thiosulphate, PPDA: phenyl phosphorodiamide, NBPT: N-(n-butyl) thiophosphoric triamide, PPD: phenyl phosphorodiamide, DMPP: 3,4-dimethylpyrazole phosphate, AM: 2-amino-4-chloro-6-methyl pyrimidine, ATC: 4-amino-1, 2,4-triazole, N-serve: 2-Chloro-6-trichloromethyl pyridine, DCD: dicyandiamide.
Don’t waste time and money buying urease inhibitor alone and apply subsurface to soil

http://wondergressive.com
Nitrous Oxide (N₂O)

Sources:
- http://www.sedationdentistry4u.com/nitrous-oxide
- http://s1168.photobucket.com/user/alc0nzy/media/IPD_VOL_V0_C30_NOS_TANKS.jpg.html

IPCC AR5, 2013
1772 Joseph Priestley
www.niwa.co.nz
Whenever Ammonia, Ammonium and Urea Fertilizers added Nitrous Oxide Emissions Occur

F = fertilizer addition
T = Thaw emission

\[ F = \text{fertilizer addition} \]
\[ T = \text{Thaw emission} \]

\[ F = \text{fertilizer emission} \]

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Year</th>
<th>Crop</th>
<th>Year</th>
<th>Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006-07</td>
<td>Corn</td>
<td>2007-08</td>
<td>Fababean</td>
<td>2008-09</td>
<td>Spring Wheat</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
<td>2009-10</td>
<td>Rapeseed</td>
<td>2010-11</td>
<td>Barley</td>
</tr>
<tr>
<td></td>
<td>Barley</td>
<td>2011-12</td>
<td>Spring Wheat</td>
<td>2012-13</td>
<td>Corn</td>
</tr>
<tr>
<td></td>
<td>Alfalfa</td>
<td>2013-14</td>
<td>Soybean</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ FN = \text{Fertilizer N (g N ha}^{-1} \text{d}^{-1}) \]
What EEFs Do to Limit N$_2$O Losses?

- N$_2$O emissions occur
  - After fertilizer application following rains
  - Over the winter when soil is wet and crop growth is low
  - Where soil freezes, when soil thaws
- EEFs can only be expected to reduce emissions following fertilizer addition
- Other reductions need to be managed by other practices such as minimize residual soil nitrate after harvest, reduce soil moisture
Placement $N_2O$ emissions-2011 Wheat Manitoba

**Carman - sand soil**

- More Rains After Application
- Cumulative emissions $N_2ON_2O$ (kg $N_2O-N$ ha$^{-1}$)

**Oak Bluff - clay soil**

- Less Rains After Application
- Placement $N_2O$ emissions

### Table: N treatment vs $\Sigma N_2O$ (kg $N_2O-N$ ha$^{-1}$)

<table>
<thead>
<tr>
<th>N treatment</th>
<th>$\Sigma N_2O$ (kg $N_2O-N$ ha$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.55 d</td>
</tr>
<tr>
<td>Urea$_I$</td>
<td>1.82 a</td>
</tr>
<tr>
<td>Urea$_S$</td>
<td>1.55 a</td>
</tr>
<tr>
<td>Urea$_M$</td>
<td>1.31 ab</td>
</tr>
<tr>
<td>ESN$_M$</td>
<td>0.97 c</td>
</tr>
<tr>
<td>SuperU$_M$</td>
<td>0.98 c</td>
</tr>
</tbody>
</table>

Banding tends to reduce EEF 26% less than urea when banded

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Gao et al. 2014. Agron J
Irrigated Potato
Carberry Manitoba

Gao et al. 2016
Leaching Prevention

https://courses.lumenlearning.com
Leaching is Primarily Issue of Excess N Added

Fig. 2. (a and b) Dissolved N load and (c and d) corn yield versus N application rate for continuous corn (black line) or corn in a corn-soybean rotation (gray line) for dry (dashed line; a and c) and wet years (solid line; b and d); three outliers at a 448 kg N/ha application rate were removed; dry: precipitation < 820 mm, wet: precipitation > 850 mm.
Little Impact of Timing of N Application on Leaching

<table>
<thead>
<tr>
<th>N Timing</th>
<th>N rate</th>
<th>Corn Yield</th>
<th>Dissolved N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kg N ha^{-1}</td>
<td>Mg ha^{-1}</td>
<td>Kg N ha^{-1}</td>
</tr>
<tr>
<td>Well before planting</td>
<td>168</td>
<td>8.7</td>
<td>30</td>
</tr>
<tr>
<td>Before planting</td>
<td>200</td>
<td>9.4</td>
<td>31</td>
</tr>
<tr>
<td>At planting</td>
<td>152</td>
<td>7.5</td>
<td>27</td>
</tr>
<tr>
<td>Dress after planting</td>
<td>160</td>
<td>8.4</td>
<td>28</td>
</tr>
</tbody>
</table>
EEFs be Useful to Prevent Leaching in Some Circumstances

• Early season when nitrification as converted N to nitrate but crop growth hasn’t kicked in full gear

• Stabilized nitrogen and controlled release nitrogen can reduce the appearance of early nitrate and thus leaching in early growth season
Wrapping It Up

- You have lots of considerations to optimize nitrogen fertilizer use.
- Enhanced efficiency fertilizers are a tool to help out.
- Not a tool that always works or that you need.
- But a tool to go along with other management options.
- Know your soil and how it loses nitrogen.
- Know how much your crop doesn’t take up nitrogen.
- Know your main loss of nitrogen.
  - Can EEF Nitrogen fertilizers reduce those main loses?
- Is there a 4R practice that can reduce your loss without EEF?
  - If not, will EEF work for your situation?
- Pay attention to the economics, EEFs cost more, need a return.
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