Volatility losses of N from surface-applied urea: A micrometeorological study to quantify losses in Montana

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Winter wheat production in Montana

- large farms, no till has become norm
- seeded in September
- N fertilizer applications deferred to until fall, winter, and early spring (cold weather months)
- surface-applied urea - susceptible to volatility losses
- How much N are we losing?
Surface-applied urea & volatilization

\[ \text{urea} \xrightarrow{\text{urease}} (\text{NH}_4)_2\text{CO}_3 \]

\[ \text{pH}\uparrow \text{micro-site} \]
Factors affecting volatilization

1. Soil pH
2. Soil moisture and humidity
3. Wind
4. Precipitation following fertilization
5. Surface residue and vegetation
6. Soil texture (sandy more susceptible than clay soils)
7. Temperature

Bottom line → large number of soil & environmental factors make N losses variable and difficult to predict
Objectives

- How much N as NH$_3$ are we losing from surface-applied urea (fall, winter, and early spring)?

  *Do cold temperatures (< 5°C or 41°F) provide protection against volatility losses?*

- How do we mitigate losses (particularly when significant)?

  - *Enhanced efficiency N products (NBPT or Agrotain)*
  - *Incorporation & subsurface urea applications*
NBPT - urease inhibitor

\[ \text{urease} \]

\[
\begin{align*}
\text{CO(NH}_2\text{)}_2 + H^+ + 2H_2O & \rightarrow 2NH_4^+ + HCO_3^- \\
\end{align*}
\]
surface-applied urea prior to seeding
Integrated horizontal flux approach

- micrometeorological - mass balance (Ryden and McNeil, 1984)
- does not disturb the soil-atmosphere environment
- moderate size plots (~0.3 acre) > larger footprint than enclosures
- continuous measurement of gas loss over time

mast and shuttles
On-farm studies

- urea (90 lbs N/acre)
- urea + NBPT
  (Agrotain 4 qt/ton = $55)
Shuttles

- traps for collecting ammonia, idea & design developed in Australia (Leuning et al., 1985. Atmos. Environ)
Continuous measurements

- spent shuttles exchanged with recharged shuttles weekly over **6-10 week campaign** following fertilization
Field sites

- 3 dryland farms in northern Montana, no till mgnt
- Soils – range of soil textures
  - Telstad-Joplin loam: pH 5.5
  - Phillips-Elloam silt loam: pH 5.8-6.2
  - Scobey-Kevin clay loam: pH 6.0-6.5
## High NH₃ loss campaigns (>30%)

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Fertilization date</th>
<th>% urea-N volatilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 - north Havre</td>
<td>Nov. 14, 2008</td>
<td>31.5</td>
</tr>
<tr>
<td>4 - north Havre</td>
<td>March 25, 2009</td>
<td>35.6</td>
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<tr>
<td>5 - west Havre</td>
<td>March 26, 2009</td>
<td>39.9</td>
</tr>
</tbody>
</table>
High NH$_3$ losses – Campaign 4 (TJ loam)

Fertilized applied – March 25, 2009
“light snow & air-temp. 31°F”

soil surface frozen 18 °F
\( \Theta_v = 35\% \)
High NH₃ losses – Campaign 4 (TJ loam)

- Urea (35.6%)
- Urea + NBPT (18.0%)

Precipitation
0.01” = 0-2 wks
0.89” = 2-8 wks

Temperature
Soil = 30.7 °F
Air = 33.4 °F
High NH₃ losses – Campaign 4 (TJ loam)

Soil temp (1 cm) vs. time

Temperature, °C

March 25 March 27 March 29 March 31 April 2

diurnal variation mean = 30.7°F
High NH₃ losses – Campaign 4 (TJ loam)

Precipitation
0.25” = 0-2 wks
0.89” = 2-8 wks

Temperature
Soil = 38.0 °F
Air = 41.5 °F

% of applied N lost

<table>
<thead>
<tr>
<th>Weeks post-fertilization</th>
<th>Urea (35.6%)</th>
<th>Urea + NBPT (18.0%)</th>
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<tbody>
<tr>
<td>1</td>
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<td>2</td>
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<td>8</td>
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</table>

Urea > NBPT
Urea = NBPT
High NH₃ losses - Campaign 5 (PE silt loam)

Fertilized applied – March 26
“light snow on soil surface & air-temp. 21 °F”

soil surface with fertilizer prills beginning to dissolve 32 °F
High NH₃ losses - Campaign 5 (PE silt loam)

% of applied N lost vs Weeks post-fertilization:
- urea (39.9%)
- urea + NBPT (18.1%)

Precipitation:
- no rain 0-2 wks
- 1.54” 2-8 wks

Temperature:
- Soil = 34.3 °F
- Air = 33.1 °F
High NH₃ losses – Campaign 3 (TJ loam)

Surface damp from melting 2” snowfall event
November 14, 2008
High NH$_3$ losses - Campaign 3 - Summary

- **0-6 days post-fertilization**
  - N loss 12.3%
  - Soil temperature (1 cm) - 33.4 °F

- **6-21 days post-fertilization**
  - N loss 17.0%
  - Soil temperature (1 cm) - 28.9 °F

- precipitation – scattered events – often as snow
High NH$_3$ losses – Campaign 3 (TJ loam)

December 4, 2008
High NH$_3$ losses – Campaign 3 (TJ loam)

winter arrived December 7
## High NH₃ loss campaigns (>30%)

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<td>5- west Havre</td>
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</tr>
</tbody>
</table>
Moderate NH₃ loss campaigns (10-20%)

- urea applied to dry soil surface

Campaign 6
Oct. 6, 2009

Campaign 7
Oct. 13, 2009
Moderate NH$_3$ loss - Campaign 6 (clay loam)

% of applied N lost

- Urea (Total 11.6%)
- Urea + NBPT (Total 4.3%)

Days post-fertilization:
0 7 14 21 28 35 42 49 56

Rain, inch:
0.0 0.2 0.4 0.6 0.8 1.0

Events:
light ppt.

October 6

Weeks post-fertilization:
1 2 3 4 5 6 7 8

total = 0.83”

October 6
Moderate NH₃ loss – Campaign 7 (PE silt loam)

% of applied N lost

Weeks post-fertilization

October 13

Rain, inch

Days post-fertilization

Urea (Total = 10.4%)

Urea + NBPT (Total = 4.8%)

Light ppt. events total = 0.57”
Light ppt events (≤ 0.4”) are common along the Highline
What is meant by a precipitation event?

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<thead>
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<th>Day</th>
<th>November 2010</th>
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<td>8</td>
<td>0.01</td>
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<td>9</td>
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<td>10</td>
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<td>29</td>
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<tr>
<td>30</td>
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</tr>
</tbody>
</table>

0.32”

0.63”
Size and frequency of precipitation events
Havre Airport (last 5 years)

September 1 - May 31 (185 events)

91% of all events or 50% of precipitation

∑ 31.8” or 6.3”/yr

Size distribution of precipitation events, inch
October 9, 2008 application, air-temp. 45 °F, dry soil surface

no rain for 24 days & then Nov 2-5 received 1.0” ppt.

same field site as Campaign 5

1 wk post-fertilization prills not dissolved
Campaign 2 – low NH$_3$ losses

% of applied N lost

- Urea (3.1%)
- Urea + NBPT (1.4%)

Weeks post-fertilization
Campaign 9 - Willow Creek - Brocko silt loam

- calcareous soils, pH 8.3
What about urea on snow?
Campaign 9 – Willow Creek – Jan 27, 2010
Weeks post-fertilization

- **urea (total = 24.3%)**
- **urea + NBPT (total = 9.3%)**
Campaign 9 – Willow Creek – Feb. 17

- urea (total = 24.3%)
- urea + NBPT (total = 9.3%)

- no run off
Campaign 9 – Willow Creek – Feb. 17

- urea (total = 24.3%)
- urea + NBPT (total = 9.3%)

Weeks post-fertilization: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

% of applied N lost

No run off!
NBPT - prolonged activity
Campaign 9 – Soil temperature (1 cm)

- 12.3% applied N
- lost 0-5 wk
- soil temp. 30.0°F
## Campaign Summary (% N loss)

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Fertilization date</th>
<th>Urea</th>
<th>NBPT-urea</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>April 3, 2008</td>
<td>8.4</td>
<td>4.4</td>
</tr>
<tr>
<td>2</td>
<td>Oct 8, 2008</td>
<td>3.1</td>
<td>1.4</td>
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<td>Nov 14, 2008</td>
<td>31.5</td>
<td>4.0</td>
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<tr>
<td>4</td>
<td>March 25, 2009</td>
<td>35.6</td>
<td>18.0</td>
</tr>
<tr>
<td>5</td>
<td>March 26, 2009</td>
<td>39.9</td>
<td>18.1</td>
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<tr>
<td>6</td>
<td>Oct 6, 2009</td>
<td>11.6</td>
<td>4.3</td>
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<td>7</td>
<td>Oct 13, 2009</td>
<td>10.4</td>
<td>4.8</td>
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<td>8</td>
<td>Oct 19, 2009</td>
<td>15.7</td>
<td>3.4</td>
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<tr>
<td>9</td>
<td>Jan 27, 2010</td>
<td>24.3</td>
<td>9.3</td>
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<tr>
<td>10</td>
<td>Feb 26, 2010</td>
<td>44.1</td>
<td>11.9</td>
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<tr>
<td>11</td>
<td>March 29, 2010</td>
<td>6.3</td>
<td>1.7</td>
</tr>
<tr>
<td>12</td>
<td>April 20, 2010</td>
<td>14.7</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td><strong>20.4</strong></td>
<td><strong>6.8</strong></td>
</tr>
</tbody>
</table>

*wide range in N loss amounts*
What about applying urea in front of seeder?

### Three Campaigns this Fall

<table>
<thead>
<tr>
<th>Fertilization date</th>
<th>Cooperator</th>
<th>Pre-seeding</th>
<th>Post-seeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 15</td>
<td>McIntosh- north Havre</td>
<td>18.7%</td>
<td>13.8%</td>
</tr>
<tr>
<td>September 27</td>
<td>McCormick - Kremlin</td>
<td>20.4%</td>
<td>24.4%</td>
</tr>
<tr>
<td>October 7</td>
<td>Peterson – north Havre</td>
<td>4.1%</td>
<td>5.2%</td>
</tr>
</tbody>
</table>
McIntosh site
McCormick site
Campaign 15 (in progress) – low N loss

0-4 wks characterized by light precipitation events

October 7, 2010

Weeks post-fertilization

% of applied N lost

- urea-postplant (5.2%)
- urea-preplant (4.1%)
Summary comments

• significant N losses as NH\textsubscript{3} can happen in Montana when urea is surface-applied

• wet surface soil conditions w/o accompanying ppt → high risk for appreciable NH\textsubscript{3} loss, even if soil temperatures 28 to 41°F
✓ greater potential for these conditions in Montana during late fall, winter (thaw), early spring
✓ throw urea prills on the ground. Do they dissolve?

• surface-applying urea to a dry soil surface is best, then hope for rain and wet snow that infiltrates into soil; some loss of N (10-20%) appears likely based on results to date
Summary Comments

• mid-winter urea on snow – 1 campaign on soil pH 8.3 (24.3% N loss) - may be problematic from NH₃ loss standpoint  but we need to investigate further ??

• NPBT or Agrotain may have a role under the high loss potential conditions - longevity may be greater in calcareous soils

• surface-applying urea in front of air-seeder so far has not shown to be effective in suppressing volatility
Future Plans – evaluation form

- Winter applications
- Preplant N
- Goose Shooter – Kurt Kamberzell (Chester, MT)
- How are wheat yields and protein affected by N loss?
Support

- WSARE
- MT Fertilizer Advisory Committee
- MT Wheat and Barley Committee
- NRCS-CIG program
- International Plant Nutrition Institute
- Agrotain International
Ammonia volatilization and urea fertilizer

A micrometeorological study to quantify volatilization losses of ammonia from surface urea applications to no-till wheat

In Montana, farmers often broadcast urea by applying urea to the soil surface during the fall, winter, or early spring. The question of how much nitrogen is lost from this application strategy seems to be raised by growers and fertilizer dealers every season. Surface urea applications are known to be susceptible to nitrogen losses as a result of ammonia volatilization (lost to the air). However, the importance of this process in cold soils is not known and is the focus of an investigation I am currently leading. To answer this question, I am using a micrometeorological system referred to as the integrated horizontal flux (picture in photograph below) method to quantify ammonia losses from the soil. Micrometeorological are widely recognized as providing the most accurate measures of gas losses from soils. This method is not disruptive of the soil environment and provides for continuous collection of ammonia gas over time. This is a first of its kind study in Montana. Field studies are currently being conducted at two farms in northern Montana, with a third farm site to be added in the fall 2009. I have constructed this website to keep people up to date on the progress of this study.

Recent presentations
August 6, 2009 - CCA and Dealer Training, Huntley, Montana

Updated: 08/26/2009