The N Cycle

- **Nitrogen Fixation**
  - $N_2(g)$
- **Plant Uptake**
- **Denitrification**
- **Leaching**
- **Exchange**
  - Clay or O.M.

**Intermediate Compounds**:
- $NO_3^-$
- $NO_2^-$
- $NH_4^+$

**Transformation Processes**:
- **Nitrification**
- **Hydrolysis**
- **Mineralization**
- **Immobilization**

**Gaseous Forms**:
- $NH_3(g)$
- $NH_3(aq)$

**Foliar Uptake**

**Volatilization**

**Urea** + Urease

**Organic Nitrogen**
Factors Increasing Volatilization

1. High Soil pH and Temperature
2. Windy
3. Low Cation Exchange Capacity (CEC). WHY?
4. Low buffering capacity (resistance to pH change)
5. High soil moisture/humidity
6. Little Rainfall/Irrigation following fertilization
7. High Ground cover/vegetation/residue. WHY?
8. Low Soluble and Exchangeable Calcium

Bottom line: Large number of factors make volatilization amounts VARIABLE and difficult to predict.
A first look at ammonia volatilization losses from surface-applied urea

Richard Engel, Clain Jones, Jeff Whitmus
Montana State University
Project Objectives

- How much N as ammonia are we losing from applications of surface urea (fall, winter, and early spring)?
- Is this a significant economic loss to Montana producer?
- If losses are significant, then how do we mitigate losses?
Research approach

- conduct on-farm trials – no till systems
- focus on Triangle Region
- diversity of soils (texture, pH)
- ammonia emissions quantified over 8-wk gas sampling campaign following fertilization (urea, NBPT-coated urea)
Integrated horizontal flux method

- preferred approach for quantifying gas loss
- moderate size plots (~0.3 acre)
- continuous measurement of ammonia loss over time

mast and shuttles
Circular plots (22 yard radius)

- urea (90 lbs N/acre)
- urea + NBPT (Agrotain @ 4 quarts/ton)
- large unfertilized buffer areas around plots
Shuttles

- traps for collecting ammonia, idea & design developed in Australia (Leuning et al., 1985. Atmos. Environ)
Two examples of field trial results from west Havre field site (Kaercher farm)

- Hill County
- Phillips-Elloam silt loam
- pH 6.0
- no till winter wheat
- Campaigns 2 and 5 - conducted in the identical field

Campaign 2: October 9, 2008.
Air temp = 45 F, Soil temp = 43 F

Campaign 5: March 26, 2009.
Air temp = 21 F, Soil temp = 34 F
Questions so far?
October 9, 2008 application, air-temp. 45 °F, dry soil surface

no rain for 24 days and then Nov. 2-5 field site received 0.98”ppt.

1 wk post-fertilization prills not dissolved
Campaign #2 - Kaercher farm

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

Mean Air Temp ~ 42 F
Mean Soil Temp ~ 41 F
Campaign #5 - Kaercher farm

Percentage of applied N lost

- urea (39.9%)
- urea + NBPT (18.1%)

Weeks post-fertilization

Conclusion: High losses observed even though temperatures were cold!
Peterson farm site - background

- 28 miles NW of Havre
- Telstad-Joplin loam
- pH 5.5
- no till winter wheat
- Campaigns 3, 4, and 8
Fertilized applied – March 25, 2009
“light snow & air-temp. 18 °F”

soil surface frozen, 30 °F
Campaign #4 – Peterson farm

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

- Percentage of applied N lost
  - Urea (35.6%)
  - Urea + Agrotain (18.0%)

- Weeks post-fertilization
  - Soil temp = 30 F
  - Air temp. = 18 F
Fertilizer applied - October 19, 2009
air-temperature = 43 °F
soil surface dry
Campaign #8 – Peterson farm

Precipitation
only 0.25” over 8 wks
(7-8 days post-fertilization)

<table>
<thead>
<tr>
<th>Weeks post-fertilization</th>
<th>Percentage of N lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5%</td>
</tr>
<tr>
<td>2</td>
<td>2.5%</td>
</tr>
<tr>
<td>3</td>
<td>1.0%</td>
</tr>
<tr>
<td>4</td>
<td>0.5%</td>
</tr>
<tr>
<td>5</td>
<td>0.5%</td>
</tr>
<tr>
<td>6</td>
<td>0.5%</td>
</tr>
<tr>
<td>7</td>
<td>0.5%</td>
</tr>
<tr>
<td>8</td>
<td>0.5%</td>
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</tbody>
</table>

- Urea (Total= 15.7%)
- Urea + NBPT (Total=3.4%)
Questions so far?
Campaign 9 & 10 – Willow Creek
Brocko silt loam

Calcareous soil, pH 8.3
Campaign 9 – Willow Creek – Jan. 27

6 inches of snow
0.6 inches of moisture
Campaign 9 – Willow Creek – Feb. 10

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

% of applied N lost

Weeks post-fertilization

Results
Campaign 9 – Willow Creek – Feb. 17

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

- no runoff
Campaign 9 – Willow Creek – Feb. 17

- no runoff
- NBPT < urea (10 wks activity)

% of applied N lost

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

Weeks post-fertilization

Bar chart showing the percentage of applied N lost over 10 weeks post-fertilization.
Campaign 10 – Willow Creek

- Feb 26 application (no snow)
- ppt (0-9 wks) = 0.9 inches
- NBPT - 7 wks activity

Results

- % of applied N lost

[Bar chart showing urea (total=44.1%) and urea + NBPT (total=11.9%) over weeks post-fertilization]
## Campaign Summary (% N loss)

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Fertilization date</th>
<th>Urea</th>
<th>NBPT-urea</th>
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<tbody>
<tr>
<td>1</td>
<td>April 3, 2008</td>
<td>8.4</td>
<td>4.4</td>
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<tr>
<td>2</td>
<td>Oct 8, 2008</td>
<td>3.1</td>
<td>1.4</td>
</tr>
<tr>
<td>3</td>
<td>Nov 14, 2008</td>
<td>31.5</td>
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<td>4</td>
<td>March 25, 2009</td>
<td>35.6</td>
<td>18.0</td>
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<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>10.7</td>
<td>3.3</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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<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>20.4</td>
<td>6.8</td>
</tr>
</tbody>
</table>

*wide range in N loss amounts*
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 fertilize wheat 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 (in picture 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 presently being conducted at two farms in northern Montana, with a third farm site to be added in the fall 2009. I have constructed this web site to keep people up-to-date on the progress of this study.

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

Updated: 08/29/2009
Summary – take home messages

✓ Significant ammonia losses (30-40% of applied N) from surface-applied urea can occur even though soil temperatures are near freezing!

✓ Soil moisture conditions at surface that dissolve urea granules (i.e. prolonged damp) without rain promote high ammonia losses (more common to find these conditions in MT during late fall or early spring)

✓ NBPT (Agrotain) reduced losses 62% over untreated urea
Questions so far?
If ~20% of broadcast urea is lost, why didn’t MT research from the 1990s show large yield/protein losses compared to ammonium nitrate and/or subsurface banding? (Jones et al. 2007)

1. Adequate precipitation may have occurred after application.

2. Urea takes 2 - 5 weeks to become available whereas AN is immediately available for plants and for other losses-urea’s ‘slow release’ property may increase its efficiency, making up for loss.

3. About 50% of N uptake comes from fertilizer (rest from soil). So 20% of 50% is 10% difference in N availability-might not make a statistically SIGNIFICANT difference (though still a bottom line difference).

4. With longer term no-till could ‘urease’ enzyme concentrations have increased? It is known that residue contains more urease than bare soil.

5. With longer term no-till, some calcium has likely leached out of surface soil. Calcium is known to decrease volatilization and most source studies were conducted last decade.
Effect of Urea Placement on Hays Annual Forage Yield

![Bar chart showing forage yield (tons/acre) in 2009 and 2010 with subsurface band and broadcast treatments. The chart includes data from Angvick et al. unpublished data.]

- **Froid, MT**
- **Yield**
- 2009:
  - Subsurface band: 2.5 tons/acre
  - Broadcast: 2.0 tons/acre
- 2010:
  - Subsurface band: 2.5 tons/acre
  - Broadcast: 1.5 tons/acre

Note: The chart displays statistical significance with letters a and b indicating differences in yield.
2009 (apparent low volatilization)

2010 (apparent high volatilization)
Effect of irrigation rate on urea volatilization (Horneck, unpub data)

\[ y = 62.655e^{-3.9586x} \]

\[ R^2 = 0.9193 \]
Does ½ inch of rain also stop volatilization? (Horneck unpub data)

Not if spread out over 3 days
Effect of N source applied with the seed on dryland spring wheat yield

![Graph showing the effect of N source on grain yield](image)

- **Urea**
- **Urease inhibitor**
- **Polymer-coated**

Saskatchewan
Malhi et al. 2003

**Grain yield (bu/acre)**

**Application rate (lb N/acre)**

0 25 50 75 100 125
What should you do to minimize volatilization?

1. Do not apply urea on moist ground UNLESS a snow or rainstorm is forecast to drop at least ½ inch of rain in a day. Preferably more (unlikely unfortunately!).
2. If you irrigate, apply ½ inch of irrigation after urea application.
3. Apply urea below the surface – either in a midrow band, 2 inches from the seed or with the seed with a ‘protected’ product.
4. Consider seeding right after urea application to cover some urea; wider openers will help with this. (We’re currently testing effectiveness of this practice)
5. Consider using Agrotain or ammonium nitrate (if available) if can’t apply during a low risk time.
Other Resources

- Soil Fertility information: http://landresources.montana.edu/soilfertility
Questions?