Gas in the Nitrogen (N) Cycle

- Volatilization: \( \text{NH}_3 \)
- Nitrification: \( \text{NH}_4^+ \rightarrow \text{NO}_3^- \)
- Fertilizer
- Denitrification: \( \text{N}_2\text{O}, \text{NO}, \text{NO}_2, \text{N}_2 \)
- Leaching
Ammonia Volatilization

• How it happens
• Factors increasing volatilization
• How we measure it
The Problem

• Up to 50% of ammonium ($\text{NH}_4^+$) based and urea fertilizer lost as ammonia ($\text{NH}_3$)

$$\text{Urea} + 2\text{H}_2\text{O} \xrightarrow{\text{urease}} \text{NH}_4^+ + \text{CO}_3^{2-}$$

Hydrolysis increases soil pH

$$\text{NH}_4^+ \rightarrow \text{NH}_3 \text{ gas} + \text{H}^+$$

Volatilization rate increases at high pH

• N fertilizer accounts for ~20% of NH$_3$ and ~ 70% of N$_2$O (anthropogenic, globally)
Why We Care About NH$_3$

- Reacts with SO$_x$ and NO$_x$ → aerosol particles

Columbia River Gorge
Why We Care About NH$_3$

- Reacts with SO$_x$ and NO$_x$ $\rightarrow$ aerosol particles
- Unintended deposition to N sensitive ecosystems
Why We Care About NH$_3$

- Reacts with SO$_x$ and NO$_x$ $\rightarrow$ aerosol particles
- Unintended deposition to N sensitive ecosystems
- Nitrogen loss is economically bad

$= $$$
Factors Increasing Volatilization

Environmental
- Moisture
- High Soil Temperature
- High wind speed
- Low CEC
- High Soil pH

Controllable… sometimes
- Irrigation
- Crop Residue
- Fertilizer Type
Factors Increasing Volatilization

Environmental
- Moisture
- High Soil Temperature
- High wind speed
- Low CEC
- High Soil pH

Controllable… sometimes
- Irrigation
- Crop Residue
- Fertilizer Type

So many products… Which ones work?
Choosing Fertilizer Additive to Limit Volatilization

- **Urease inhibitor, NBPT**
  - Active ingredient: (N-(n-butyl)thiophosphoric triamide)
  - In Agrotain® and others
  - >70% reduction of NH$_3$-N loss
Choosing Fertilizer Additive to Limit Volatilization

• Urease inhibitor, NBPT
• **Controlled/Slow release**
  – Degradable plastic coatings
    • Temperature
    • Moisture
  – Duration® & ESN ®
Choosing Fertilizer Additive to Limit Volatilization

- Urease inhibitor, NBPT
- Controlled/Slow release
- Ammonium sulfate (AS)
  - All of N is in NH$_4^+$ form
  - >60% reduction of NH$_3$-N loss
  - Results nearly as good as Agrotain®
Choosing Fertilizer Additive to Limit Volatilization

- Urease inhibitor, NBPT
- Controlled/Slow release
- Ammonium sulfate (AS)
- **Urea with AS**
  - Theory:
    
    
    acidifying effects of AS nitrification 
    +
    alkaline effects of urea hydrolysis 
    = no change in pH
  - Does it work?
Products

- (46-0-0) Urea
- (46-0-0) Urea + Agrotain®
- (21-0-0-24) AS
- (40-0-0-5) Urea + AS: separate
- (40-0-0-5) Urea + AS: fused
- (26-0-0-13) AS Nitrate (ASN)
- (39-0-0-12) Sulfur-coated urea (SCU)
Study Goals

- Find methods and products that limit $\text{NH}_3$ volatilization
- Estimate how much $\text{NH}_3$ is actually lost
Methods

- 10’ poles with wind vane
- Passive = no power, no influence on environment
- Tubes coated with oxalic acid: traps $\text{NH}_3 \rightarrow \text{NH}_4^+$
- Lab analysis of $[\text{NH}_4^+]$ translates into actual $\text{NH}_3$ loss estimate
Hermiston Agricultural Research and Extension Center
• Pre-applied 2” irrigation
• Average high temperature between 80 – 90 F
• Average high soil temperature between 80 – 90 F
• Sandy loam soil
• pH 7.3 – 7.9 overall
• pH 5.8 – 6.3 in top 3” of soil
• Applied to thick wheat stubble
• Study duration: Aug. 20 – Sept. 23
• Application rate: 150 lbs N per acre
Elevation

650 – 680 ft

680 - 720 ft

720 - 750 ft
Results
Cumulative NH$_3$-N Loss by Treatment

NH$_3$-N Loss [% Applied] vs Days After Application [DAA]

- Urea
Cumulative NH$_3$-N Loss by Treatment

Days After Application [DAA]

NH$_3$-N Loss [% Applied]
Cumulative NH$_3$-N Loss by Treatment

- Urea
- Urea + Agrotain
- Urea + Ammonium Sulfate

Days After Application [DAA]

NH$_3$-N Loss [% Applied]
Cumulative NH$_3$-N Loss by Treatment

NH$_3$-N Loss [% Applied] vs Days After Application [DAA]

- Urea
- Urea + Agrotain
- Urea + Ammonium Sulfate
- Fused Urea Ammonium Sulfate
Cumulative $\text{NH}_3$-$\text{N}$ Loss by Treatment

- **Urea**
- **Urea + Agrotain**
- **Urea + Ammonium Sulfate**
- **Fused Urea Ammonium Sulfate**
- **Sulfur-Coated Urea**

Days After Application [DAA] vs. $\text{NH}_3$-$\text{N}$ Loss [% Applied]
Cumulative NH$_3$-N Loss by Treatment

- Urea
- Urea + Agrotain
- Urea + Ammonium Sulfate
- Fused Urea Ammonium Sulfate
- Sulfur-Coated Urea

**NH$_3$-N Loss [% Applied]**

**Days After Application [DAA]**

**Precipitation [in]**

0.05 0.10 0.15 0.20 0.25 0.30 0.35 0.40 0.45 0.50
Cumulative NH$_3$-N Loss by Treatment

- **Urea**
- **Urea + Agrotain**
- **Urea + Ammonium Sulfate**
- **Fused Urea Ammonium Sulfate**
- **Sulfur-Coated Urea**

The graph shows the cumulative NH$_3$-N loss as a percentage of applied nitrogen over time. The treatments include Urea, Urea + Agrotain, Urea + Ammonium Sulfate, Fused Urea Ammonium Sulfate, and Sulfur-Coated Urea. The y-axis represents the NH$_3$-N loss (% Applied), while the x-axis shows the days after application (DAA) ranging from 0 to 35 days.
Conclusions

• In a localized race between the hydrolysis reaction of urea and nitrification of AS, urea hydrolysis wins
Conclusions

• In a localized race between the hydrolysis reaction of urea and nitrification of AS, urea hydrolysis wins

• Hydrolysis occurs at a faster initial rate
Conclusions

• In a localized race between the hydrolysis reaction of urea and nitrification of AS, urea hydrolysis wins

• Hydrolysis occurs at a faster initial rate

• AS provides extra NH$_4^+$ to volatilize until urea hydrolysis slows down.
Ways to Reduce NH$_3$ Volatilization

- Incorporate fertilizer
  - Irrigation
  - Tillage
- Apply in favorable environmental conditions
  - Not 100% outside or after a mild rain
- Choose fertilizer type or additive that reduces loss depending on environmental conditions and loss mechanism
  - Inhibitors, controlled/slow release, NH$_4^+$, NO$_3^-$, or urea based fertilizer
Acknowledgements

• Yara International
• Koch Industries, Inc.
• J.R. Simplot Company
• Two Rivers Terminal, LLC
• The growers that make it possible
• My major professor, mentors from campus
• HAREC
Concurrent Research

- Fertigation studies using our mini-center pivots: 61 ft, irrigates ~1/5 acre
Concurrent Research

- Laser gas analyzers
- Allows measurement downwind, outside of fields
- Measures NH$_3$, SO$_x$, and NO$_x$
- Have studied effluent water, anhydrous, etc.
Questions?

Thank you!
Appendix Slides
2009 Product Study

NH₃-N loss (% of N applied) vs Days after application for Urea, Ammonium Sulfate, and Agrotain.
Effluent Results

- Effluent estimated to contain 100 ppm TKN
- Need to be cleaned up still
- Large amounts of data contains some noise
Effect of irrigation

Irrigation vs. Loss as ammonia

No water  30-80% N loss!

$y = 62.908e^{-0.16x}$
Agrotain vs. Urea

N Loss as NH$_3$ (% N applied) vs. Days after Application

- 0.00" Irrigation
- 0.05" Irrigation
- 0.30" Irrigation
- Agrotain + 0.0" Irrigation
- Agrotain + 0.05" Irrigation
- Agrotain + 0.30" Irrigation