Ammonia Volatilization: Process, Amounts, and Yield Effects

MABA/MGEA 2006 Convention

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MONTANA STATE UNIVERSITY EXTENSION

Why Important?

- Ammonium nitrate (34-0-0) has been discontinued by both Simplot and Agrium, affecting N source options for many growers.
- Some producers have historically used ammonium nitrate partially due to concerns with volatilization of alternatives, such as urea (46-0-0), and now will need information from you on understanding the volatilization process, and managing for it.

Presentation Outline

- Volatilization
  - Mechanism
  - Factors that affect it
  - Amounts
- N Source Comparisons in Montana
- Management
  - Inhibitors
  - Placement
  - Timing

Ammonia Volatilization

READY FOR SOME CHEMISTRY??

Ammonia Volatilization

$$NH_4^+ + OH^- \longrightarrow NH_{3\ (gas)} + H_2O$$

- **Can occur with urea and all ammonia or ammonium based fertilizers**
- **Losses vary with environment and are difficult to predict. Most research done in Kansas and Texas where climate is more conducive to volatilization.**

Looking at above equation, what is 1 factor that increases volatilization? **High pH**

N fertilizer can increase pH during 'hydrolysis'

Ex: Urea

Urease
Enzyme (found naturally in soil)

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH_4^+ + CO_3^{2-}$$

$$CO_3^{2-} + H_2O \rightarrow HCO_3^- + OH^-$$

Effect on pH? Increases *temporarily*. Why?

Good or bad? Bad: ↑pH, ↑volatilization

$$(NH_4^+ + OH^- \longrightarrow NH_{3\,(gas)} + H_2O)$$

Ammonium Sulfate Volatilization-Calcareous Soils

$$(NH_4)_2SO_4 + 3H_2O + CaCO_3 \rightarrow 2NH_4^+ + CaSO_4 \cdot 2H_2O + HCO_3^- + OH^-$$

(lime) **(gypsum)**

NOTE: Generation of OH^-, so pH rises.

In words: Sulfate dissolves some calcium carbonate releasing carbonate which increases pH. Increased pH increases volatilization.

Note: Ca-nitrate is generally too soluble to form so AN doesn’t dissolve $CaCO_3$, and thus no pH increase.

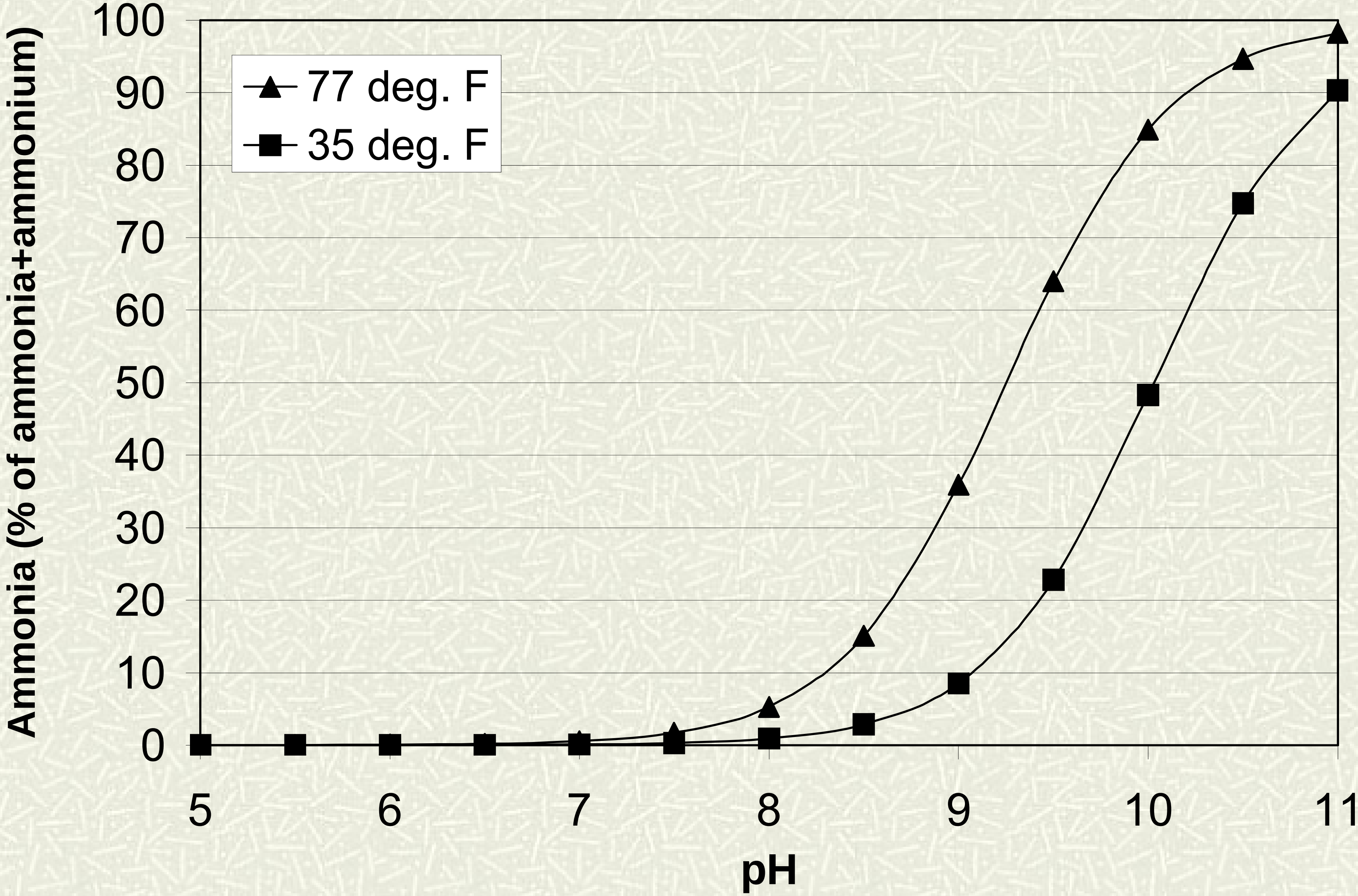
QUESTIONS?

Factors Affecting Volatilization

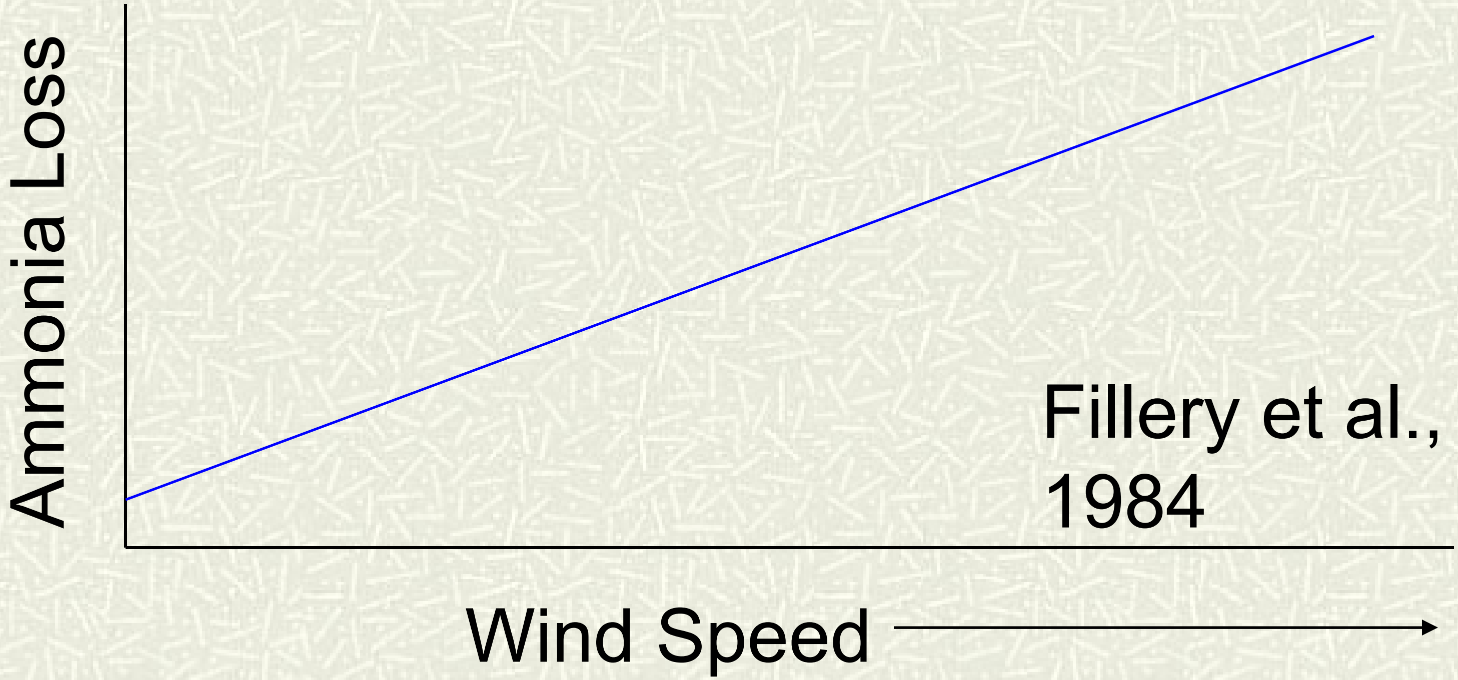
1. Soil pH and Temperature
2. Wind
3. Cation Exchange Capacity (CEC). WHY?
4. Buffering capacity (resistance to pH change)
5. Soil moisture/humidity
6. Rainfall/Irrigation following fertilization (depth in soil)
7. Ground cover/vegetation/residue. WHY?
8. Soluble and Exchangeable Calcium

Bottom line: Large number of factors make volatilization amounts VARIABLE and difficult to predict.

1. Soil pH and Temperature Effects on Relative Amount of Ammonia in Soil Solution



2. Wind



- SO, don't apply on windy day or with high winds in short term forecast.

3. Cation Exchange Capacity

- As CEC increases, volatilization rates generally decrease (Fenn and Kissel, 1976). Why?

  1. Less NH_4^+ in solution to volatilize
  2. Increased pH buffering capacity (next slide)

4. Buffering Capacity

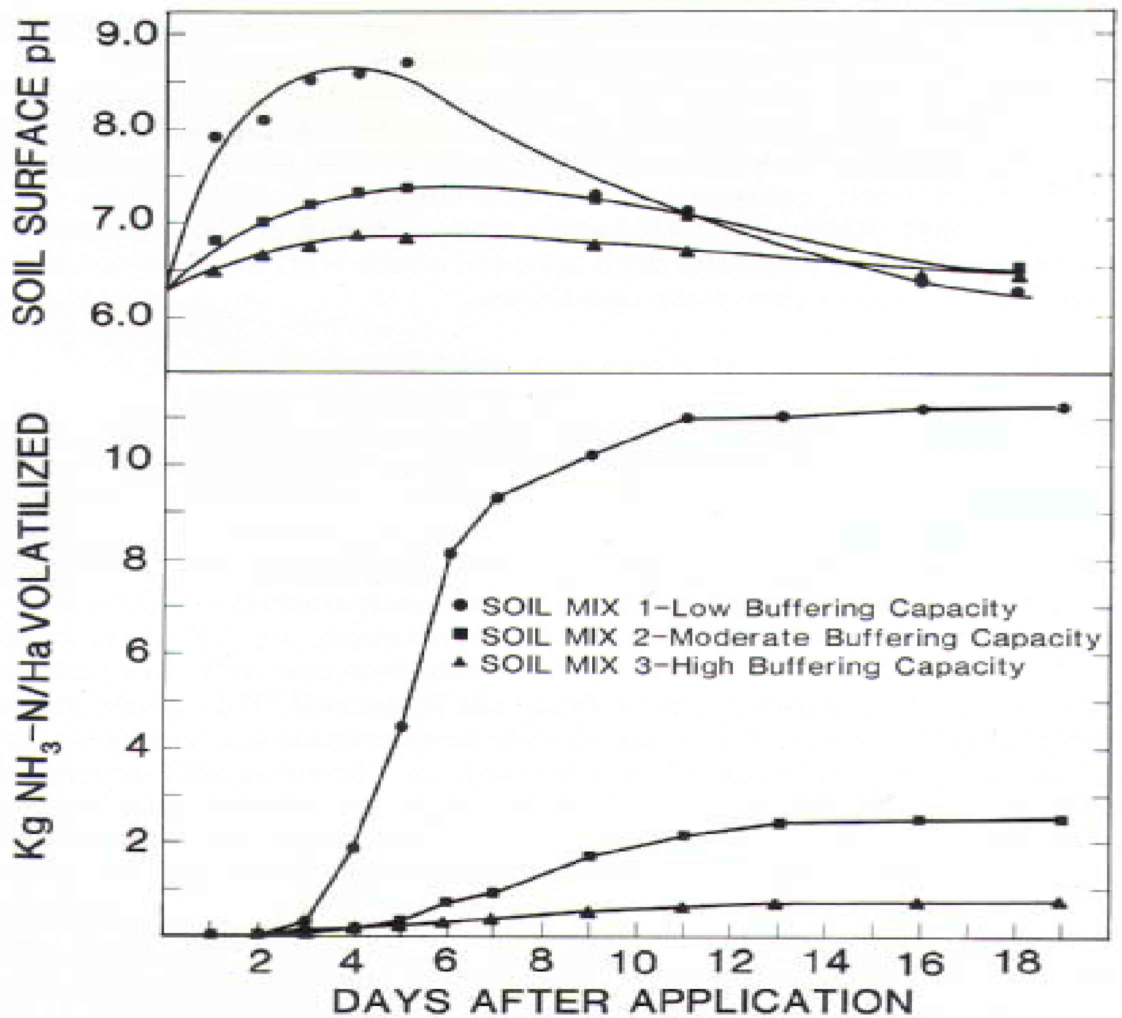
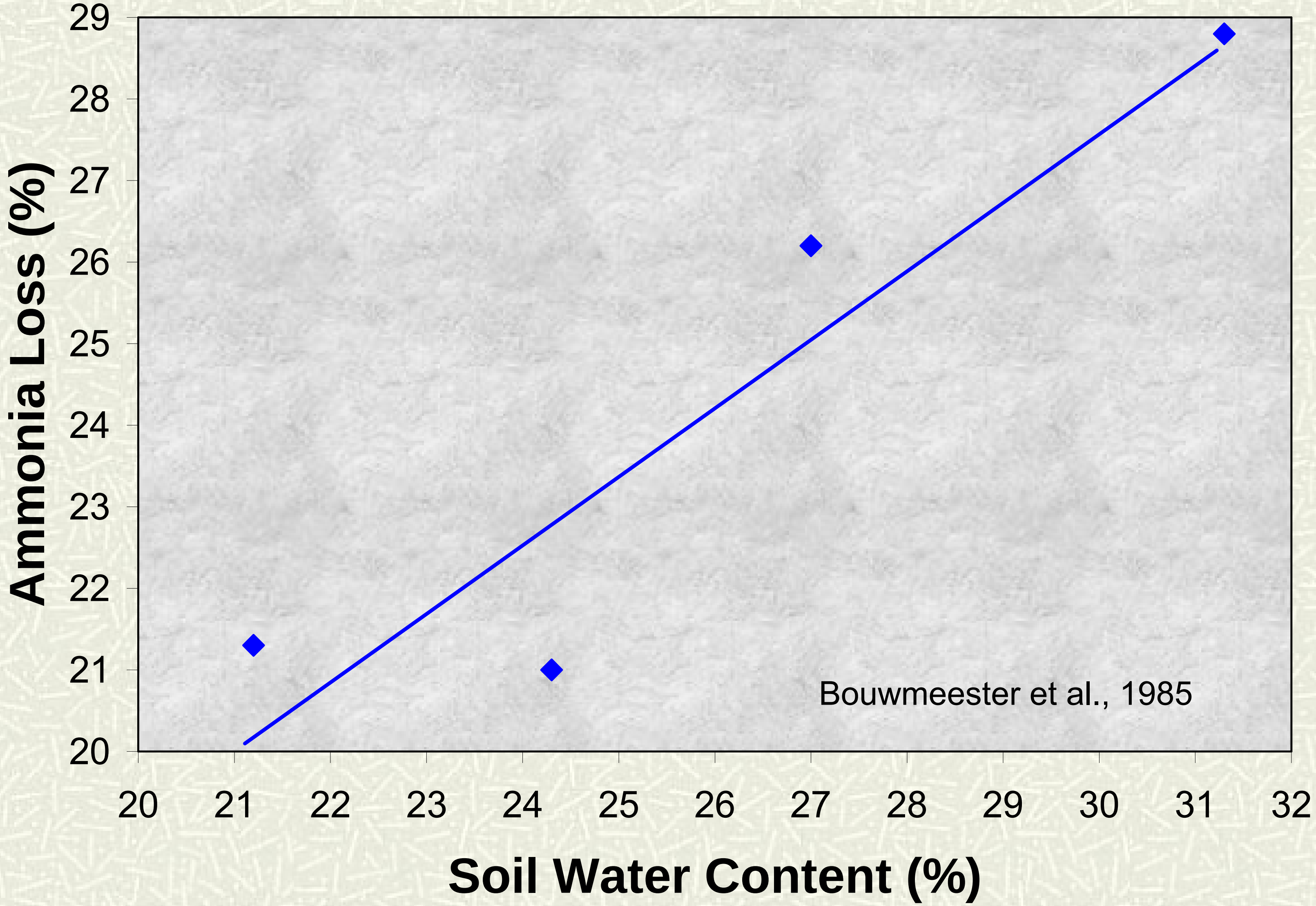


Figure 1. Soil surface pH and cumulative NH_3 loss as influenced by pH buffering capacity. (from Ferguson et al., 1984).

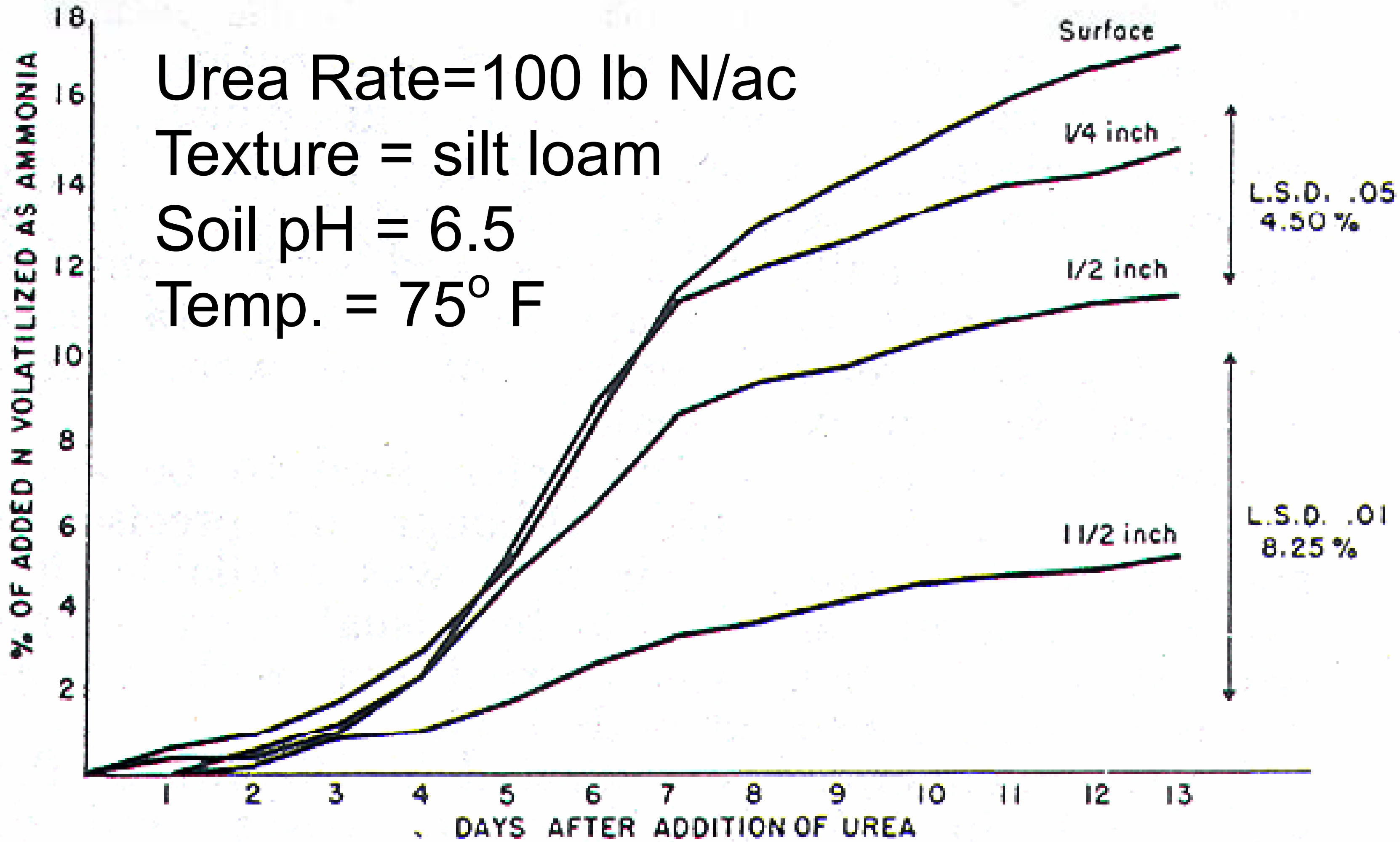
5. Effect of Soil Water Content



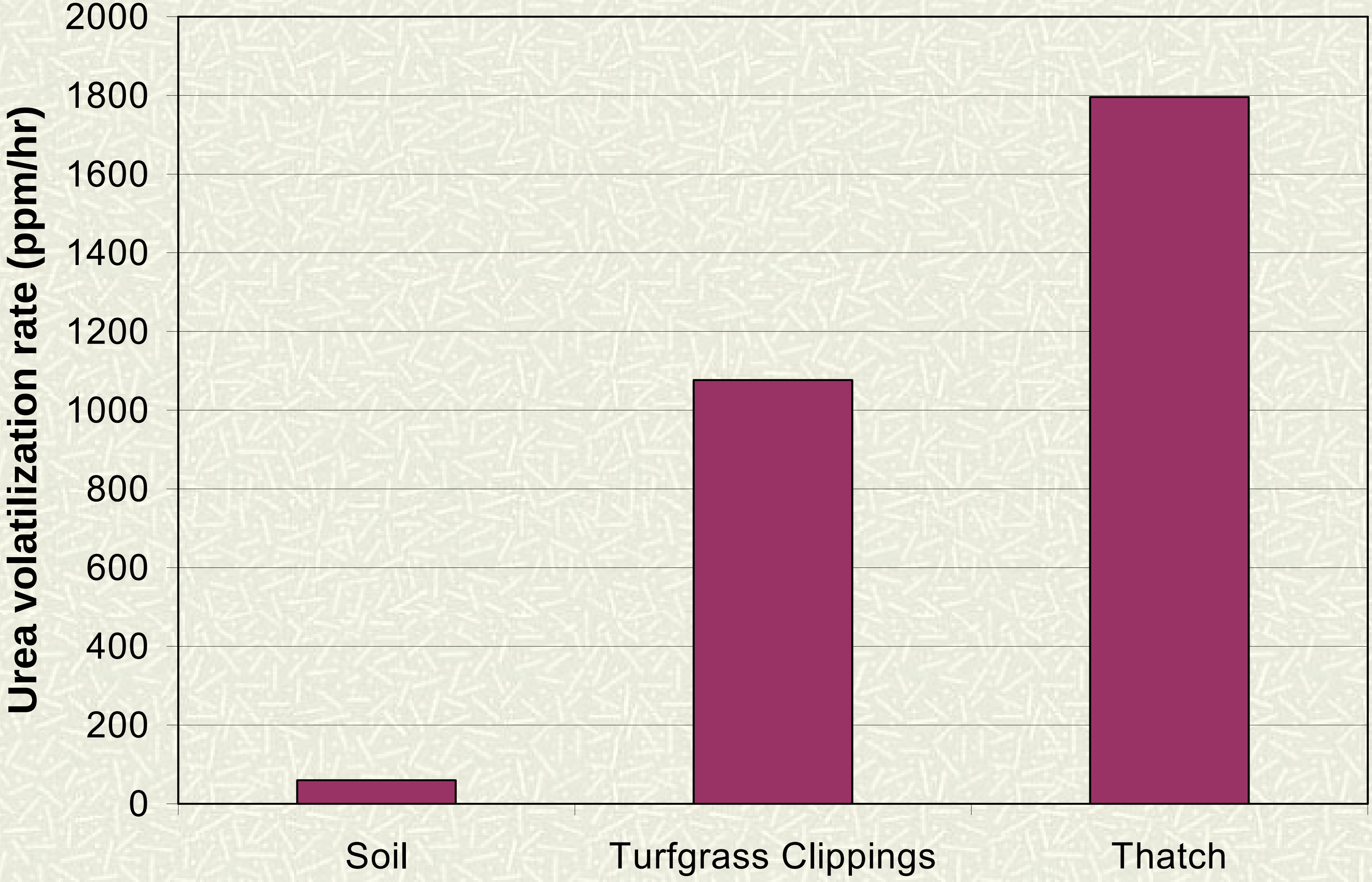
6. Rainfall/Irrigation

- 1/10 inch of rain/irrigation dissolves fertilizer, allowing volatilization.
- 1/2 inch of rain/irrigation pushes dissolved fertilizer about 2 in. into soil, essentially stopping volatilization if within about 2 days of fertilization (Meyer et al., 1961;Lloyd, 1992)

Effect of Incorporation Depth



7. Effect of Grass Residue



Effect of Residue, Cont’d

- Volatilization was found to be approximately 2 times higher in the upper 1.5 inches under no-till than under conventional tilled systems (Dick, 1984).

8. Exchangeable Ca^{2+} Decreases Volatilization (Fenn and Kissel, 1976)

$$CO(NH_2)_2 + 2H_2O + Ca^{2+}\text{-soil} \rightarrow 2NH_4^{+}\text{-soil} + CaCO_3$$

In words: Calcium can tie up a carbonate ion, preventing pH rise AND opening up 2 exchange sites for ammonium.

NOTE: No generation of OH^-, so no pH rise.

Implication: Less concern with volatilization on soils with high exchangeable Ca levels (generally indicated by high CEC). Good news for MT. Doesn't matter though if urea doesn't reach soil.

QUESTIONS?

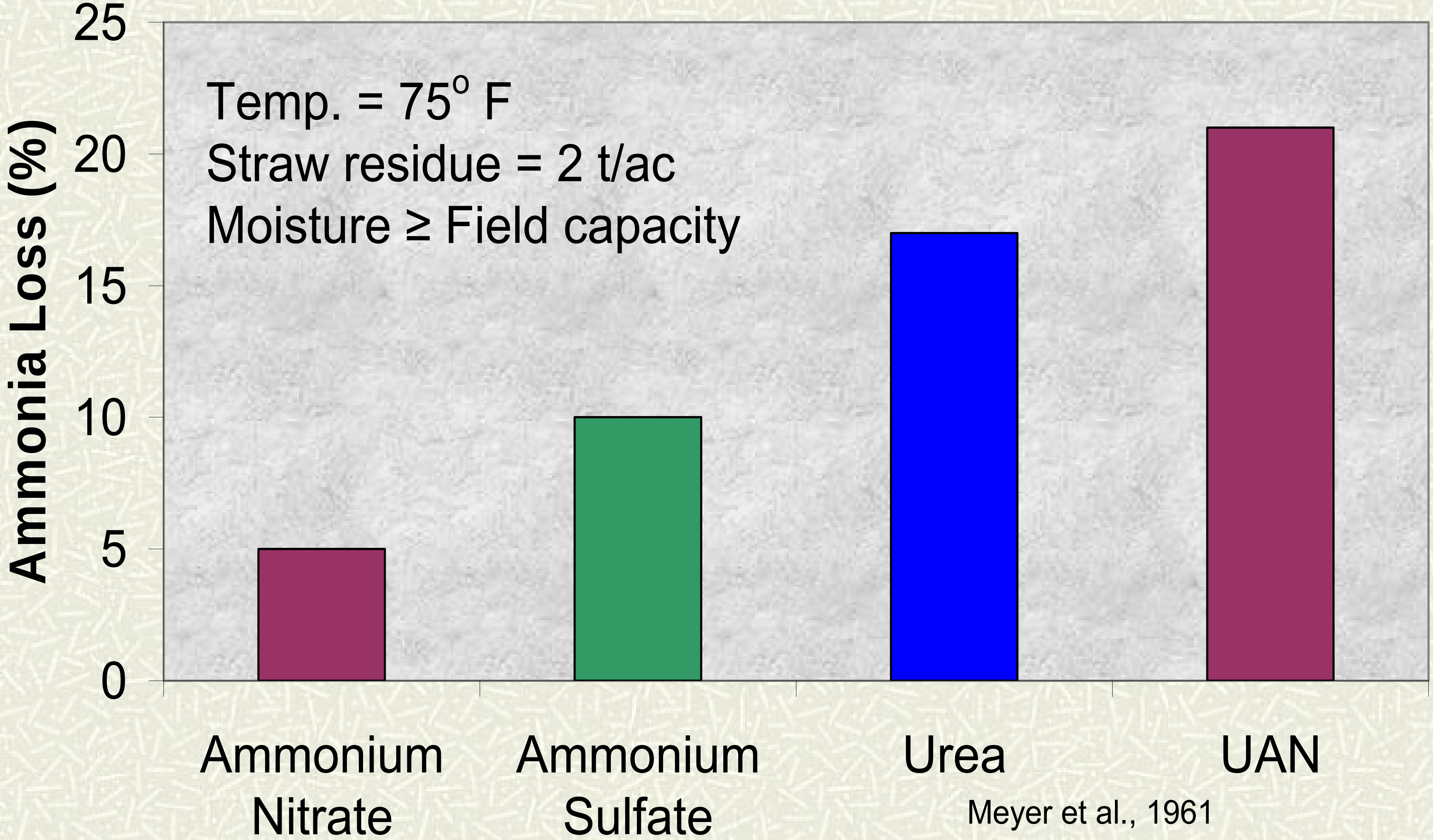
Demonstration

Urea Treatment (500 lb N/ac)	Ammonia odor	Ammonia test in air (ppm)
Incorporated-Loam	no	.25
Surface-Loam	slight	3.0
Surface-Sand	low	5.0
Surface-Grass residue	med	>6.0
Surface-Grass residue (100 lb N/ac)	slight	6

N Management

- Source
- Urease Inhibitors
- Placement
- Timing

Ammonia Volatilization Losses from a Calcareous Soil



Meyer et al., 1961

Why differences in volatilization?

- Urea, UAN, and AS cause larger pH increases than AN.
- ½ of N in AN is nitrate which can't volatilize

Volatilization of Urea vs UAN

Mixed results (out of state studies):

1. In 3 of 5 studies located, UAN volatilized slightly more than urea
2. In 2 of 5 studies, urea volatilized approximately twice as much as UAN

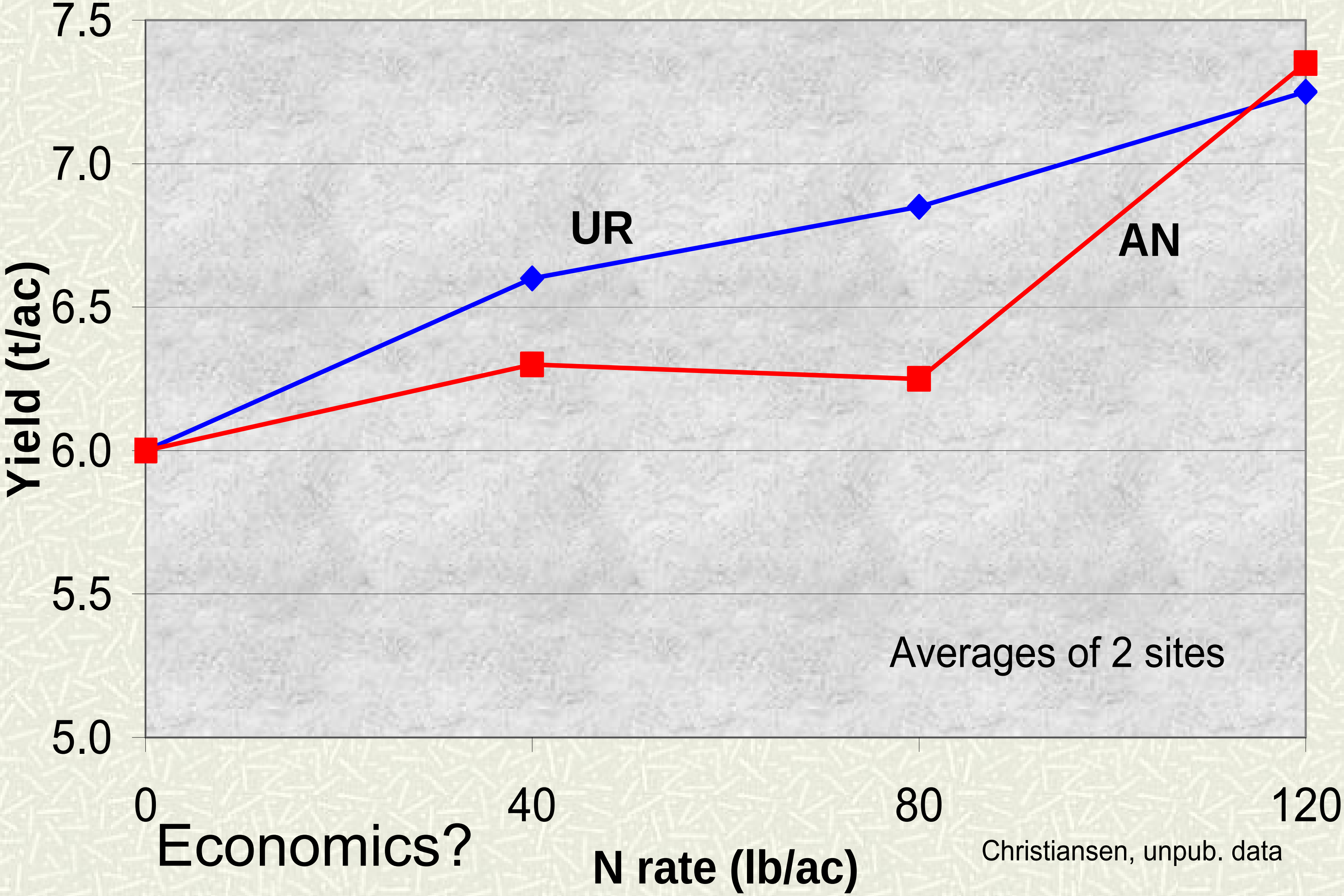
Bottom line: Both urea and UAN can volatilize- selection should likely be based on equipment and price.

Effect of Granular N Source on Yield

Montana Research Results

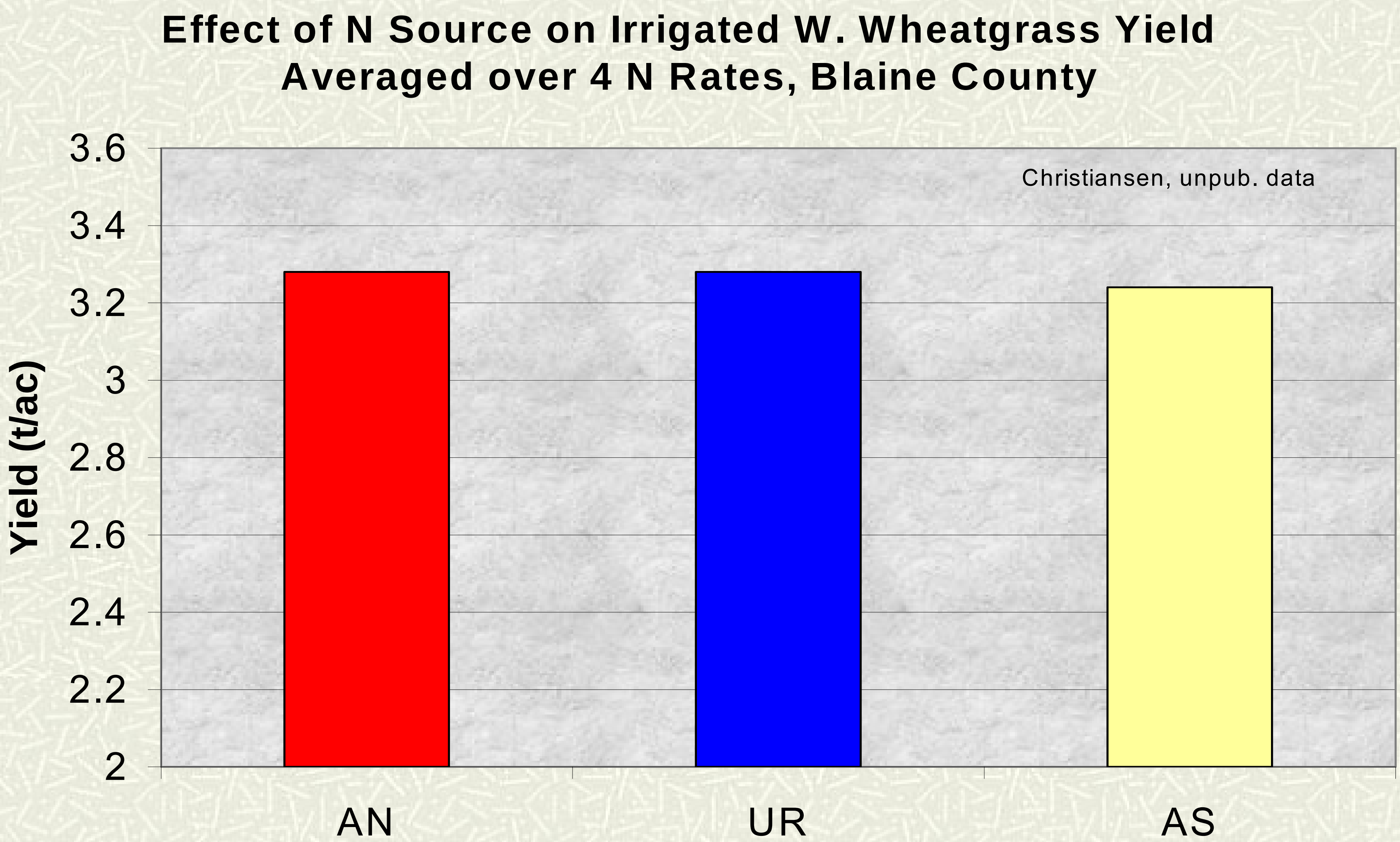
Note: No journal-published data in Montana on effect of N source on volatilization and only one known published study on yield

Effect of N Rate and Source
70% Orchardgrass/30% Alfalfa, W. Montana



Economics?

Christiansen, unpub. data

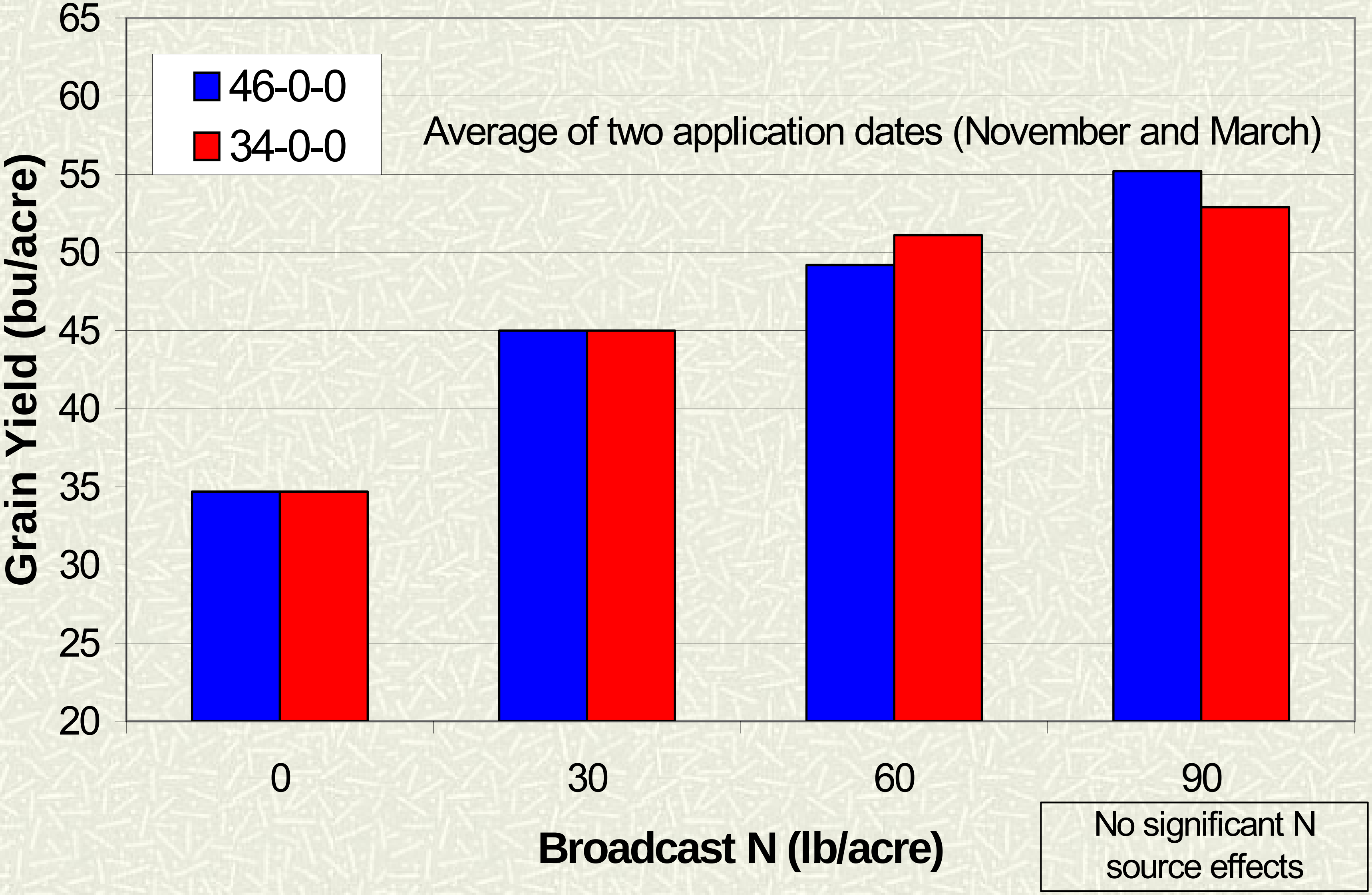


Still, need to apply when cool, calm or some ammonia will volatilize, especially from UR and AS.

Effect of N Source on Winter Wheat Grain Yield

North Central MT

Christensen and Meints. Agron J. 74:840-844.



How could UR produce similar yields as AN if UR volatilizes more?

1. AN leaches more readily
2. Takes less energy for plant to convert ammonium-N than nitrate-N to protein.
3. Not much urea volatilized

Summary: Urea volatilization can happen, but in Montana studies it generally did not have a significant effect on yield compared to other granular N fertilizers. STILL need good management!

QUESTIONS?

Urease Inhibitors

- Agrotain (NBPT) is main product. Delays hydrolysis by up to 14 days

  -advantage: allows more chance for rain or irrigation to push N into ground

  -disadvantage: will delay time to become available, volatilization can still occur, and cost (adds ~$50/t-urea).

Research Results on Urease Inhibitors

Spring wheat

1st study: NBPT had a 1.3 bu/ac increase. Cost breakeven would need 2 bu/ac increase. (Ontario, MAFRA website)

2nd study: Seed-placed, approximately doubled grain yield due to higher emergence (Malhi et al., 2003)

Forages

1st study-NBPT significantly reduced ammonia volatilization (Watson, C.J. et al., 1994) on grassland.

2nd study-Kentucky bluegrass yield increased 15% with NBPT (Joo et al., 1991).

Urease Inhibitors, Continued

Would you recommend their use?

Depends on:

1. Potential for volatilization (ex: temperature when apply)
2. Cost

Placement

- Granular:

  -Established forage-surface broadcast is essentially only option.

  -No-till small grains-can place with seed if have equipment, but urea can decrease germination (see Jacobsen et al., 2003 for recommended maximum amounts)

- Liquid (UAN; 32-0-0 or 28-0-0): Surface broadcast including fertigation, surface band, or knifed.

Method	Forage Yield
Broadcast	2.9 t/ac
Knife	2.8 t/ac
Surface Band	3.4 t/ac

N. Central Regional Extension Pub #326, KSU

WHY?

Likely due to limited urease concentration, slowing hydrolysis

Timing

- Because UR may take days to weeks to hydrolyze, UR should be applied earlier than AN historically was for fast green-up (AN simply dissolves, UR also requires hydrolysis reaction).

Timing, continued

- Fall vs Spring

  Generally better to apply near peak uptake to avoid losses (volatilization, denitrification, leaching, immobilization). However, weather conditions (temp., precip.) in first few days after application combined with soil texture may be more important.

1. Ex: Shallow, coarse soil. Fall or Spring? **Spring**
2. Ex: Cool Fall temps with ability to irrigate, or warmer spring temps before irrigation water delivered. Fall or Spring? **Fall**

Conclusions

- Urea has become the primary N granular option, so crop advisers will likely be getting more questions on its use.
- Urea volatilization is affected by a large number of factors, making predictions of volatilization amounts difficult.
- Volatilization doesn’t appear to have large effects on crop yield in Montana.
- Volatilization potential can be reduced with well thought out placement and timing.

QUESTIONS?

For more information on urea volatilization and management, see:
http://www.oznet.ksu.edu/library/crpsl2/NCR326.pdf

For more information on N cycling, fertilizer sources, placement and timing see:
http://landresources.montana.edu/nm

MSU Soil Fertility webpage:
http://landresources.montana.edu/soilfertility