# Nitrogen Rate Economics for Small Grains, Fertilization of Pulses, and Urea Fertilizer Volatilization

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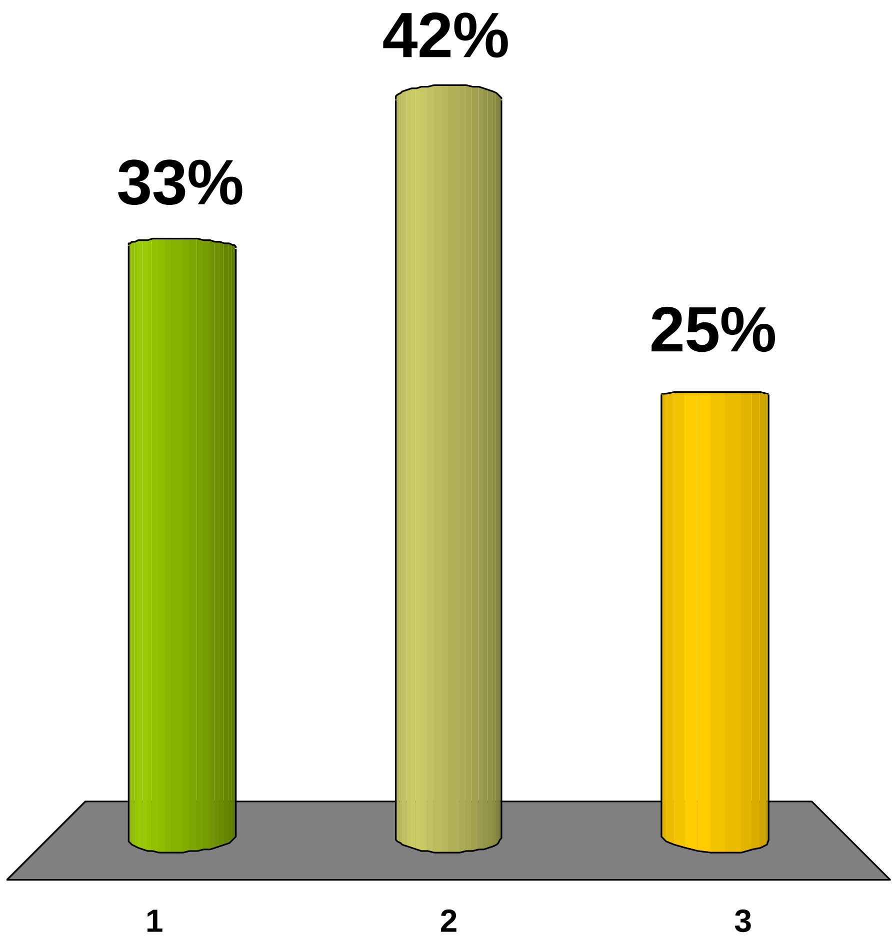
Prepared for Valley County, November 16, 2010

MONTANA STATE UNIVERSITY EXTENSION

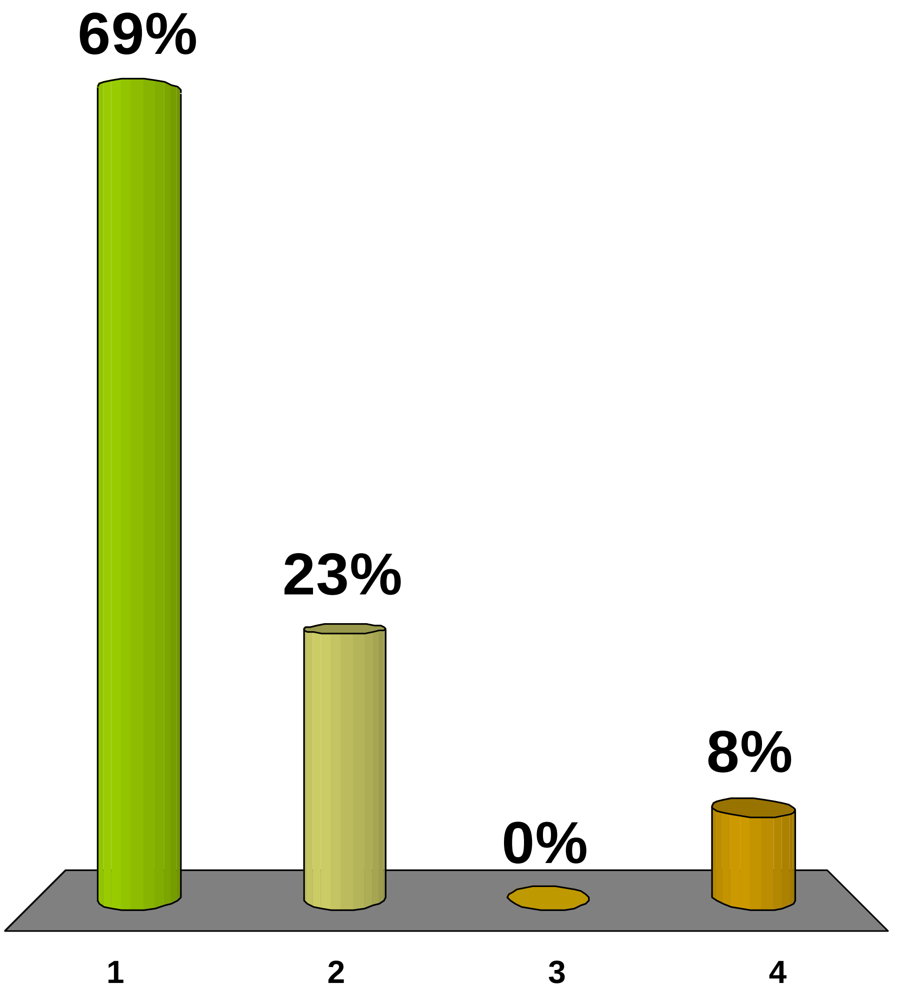
# Why are clickers better than cell phones?

1. No monthly fee
2. They don’t ring in the middle of a talk
3. They never say “service not found”



# How do you or your crop adviser determine your N fertilizer rate on wheat?

1. Soil test nitrate and yield goal
2. Historical N rates (what worked in the past)
3. What the bank tells me I can afford
4. Other



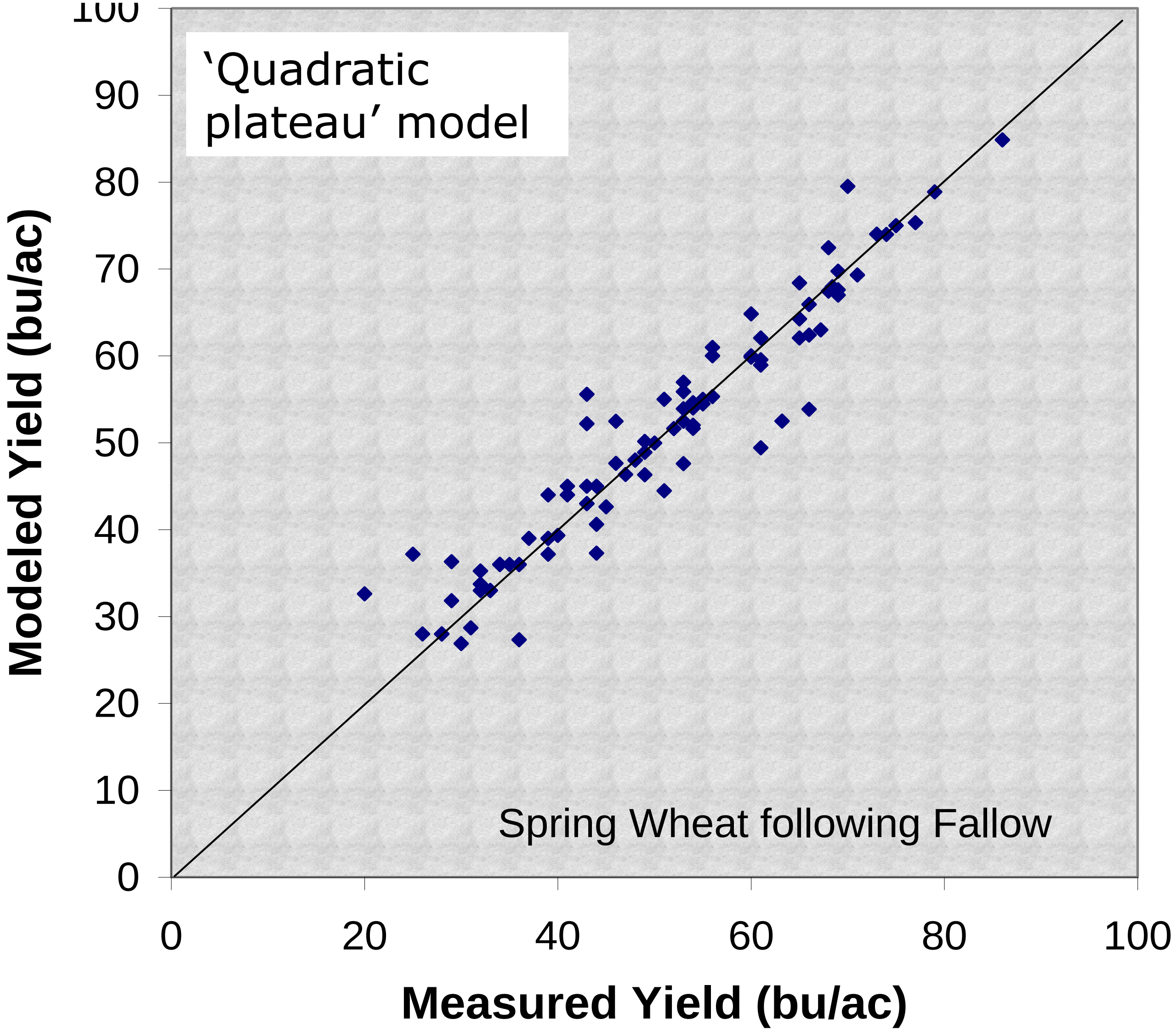
# Background

- With recently high and variable nitrogen and commodity prices, economic models are needed in MT to optimize net return.
- Yield goal based economic models for MT had not been developed prior to this project, and first require yield, protein, and plump (for barley) N response data.
- A review of existing N response studies found sufficient data for spring wheat, winter wheat, and barley.

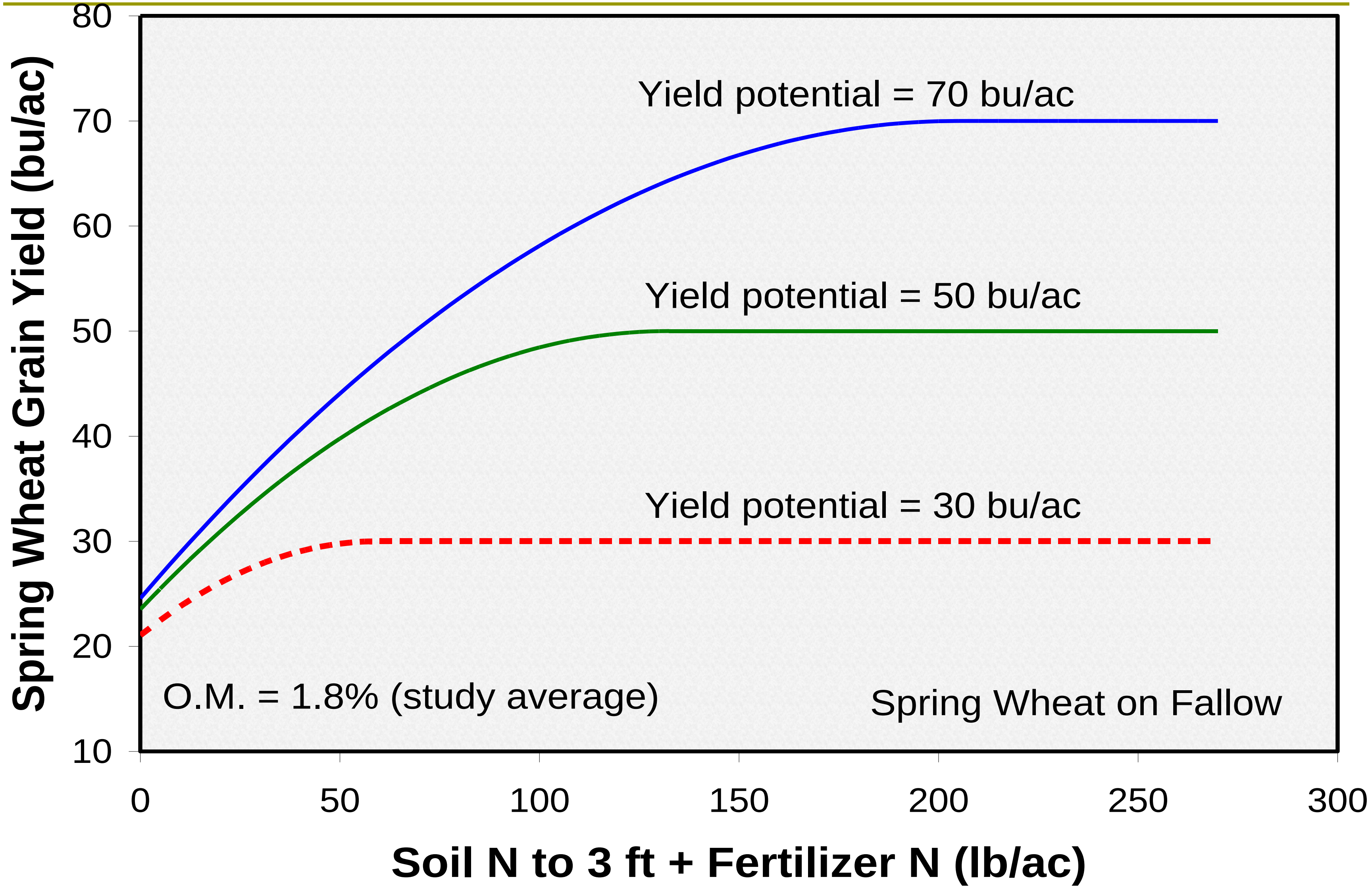
# Economic Model Development

- Models based on N responses from plot studies, mostly on fallow.
- Spring Wheat: 25 site-years all in Golden Triangle, 1993-2006 (my focus today)
- Winter Wheat: 70 site-years from wide range of Montana. 1970-2006
- Barley: ~30 site-years from Golden Triangle and Moccasin. 1981-2006
- Not enough recrop data so all models are for on fallow (perhaps work on recrop in moist years??)

# Modeled vs Measured Spring Wheat Grain Yield following Fallow



# Effect of N and Yield Potential on SW Grain Yield

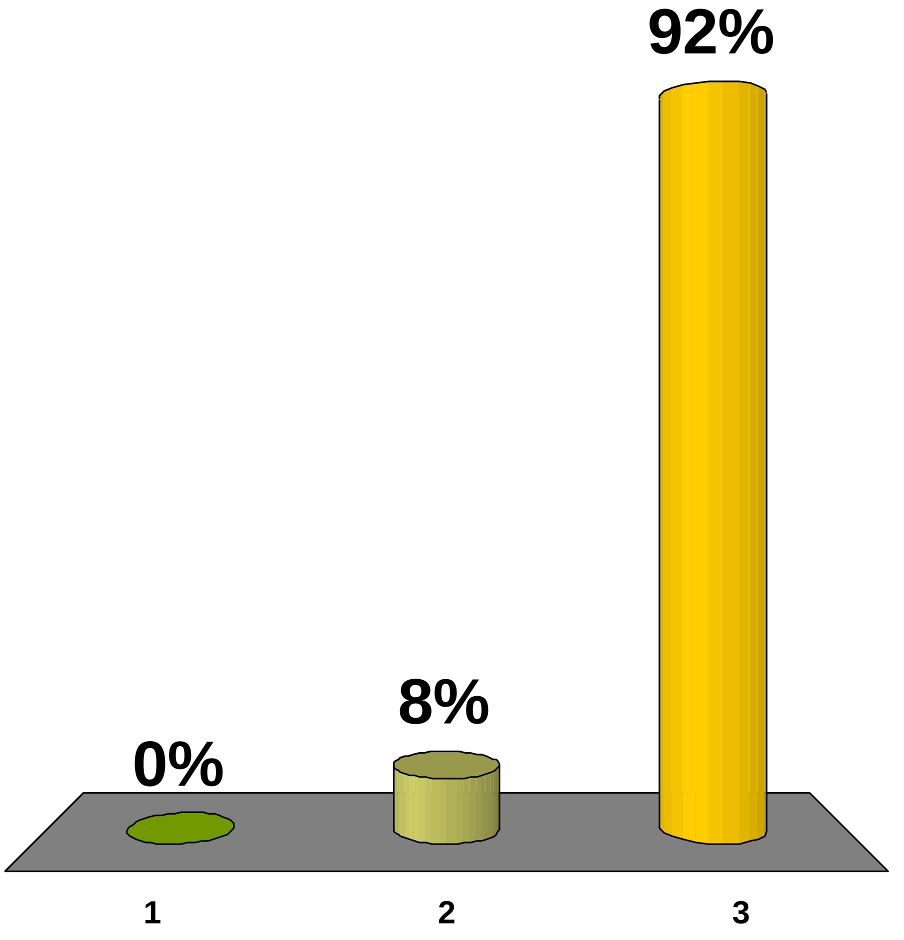


# Yield Maximizing N

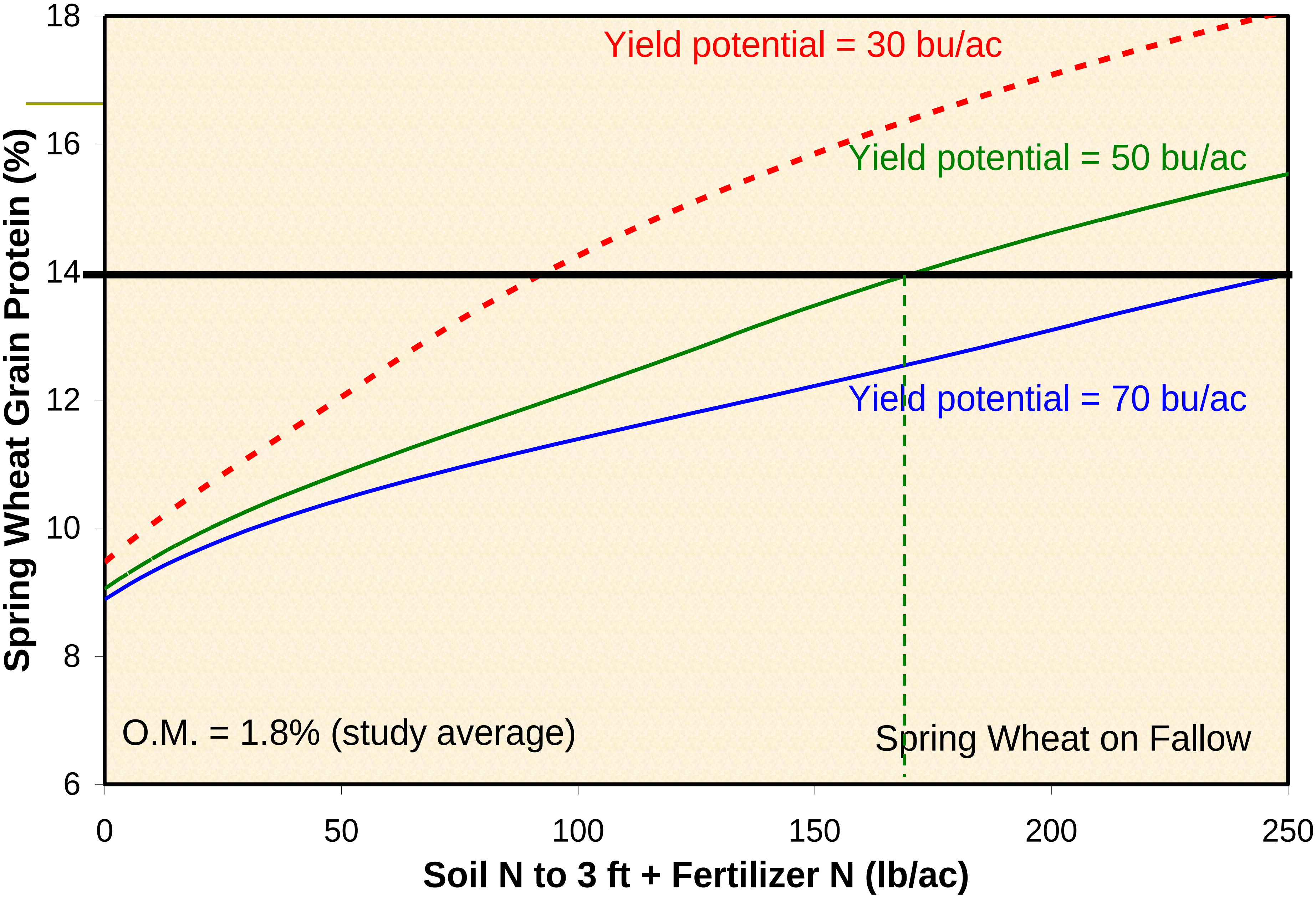
- 30 bu/ac: 2.0 lb N/bu
- 70 bu/ac: 2.8 lb N/bu
- MSU Guidelines: 3.3 lb N/bu

# Why do MSU Fertilizer Guidelines recommend more N than what is needed to maximize yield?

1. MSU owns stock in fertilizer companies
2. The authors aren't very smart
3. 3.3 lb N/bu is about what is needed to get 14% protein



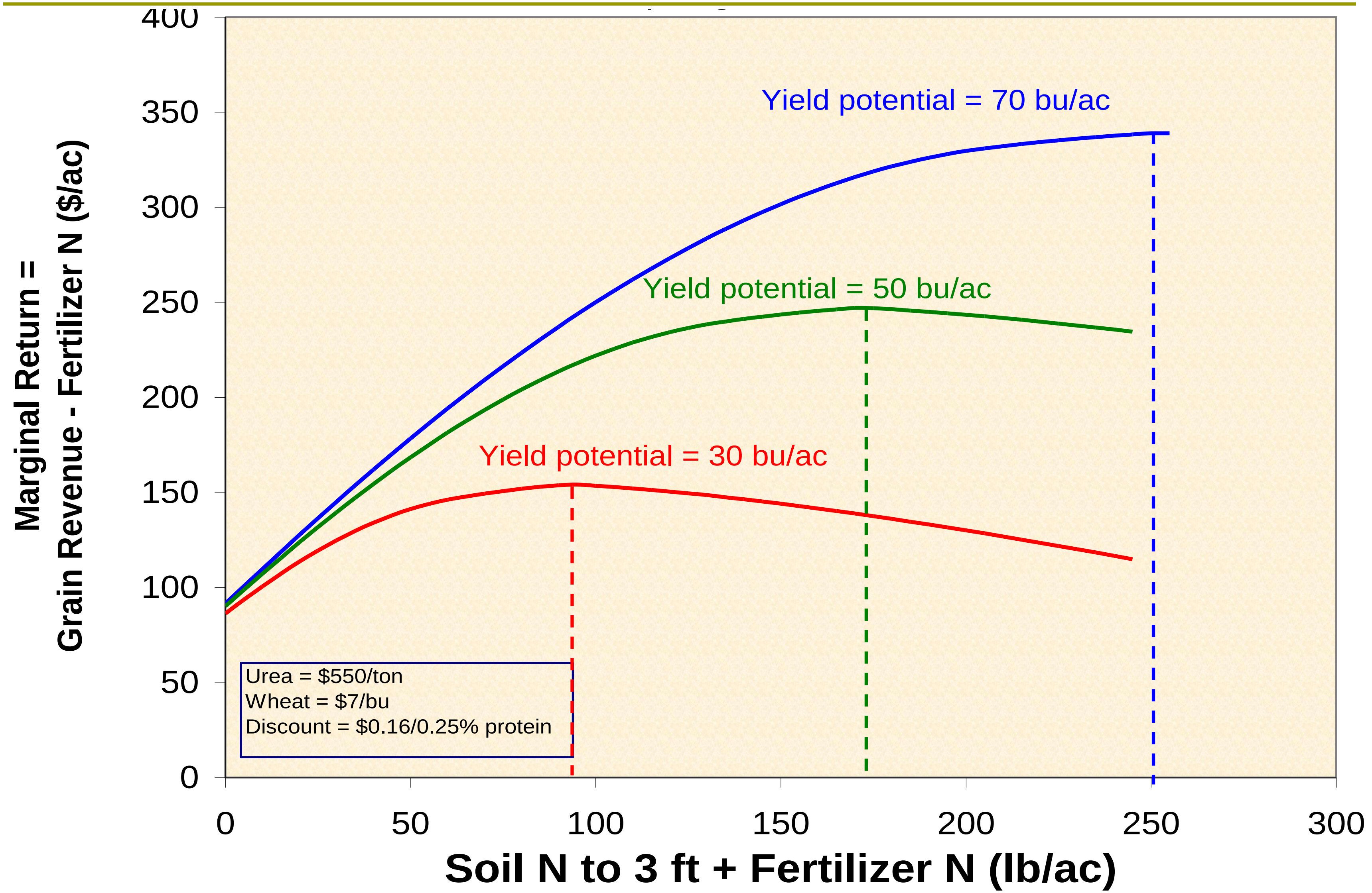
# Effect of N and Yield Potential on Grain Protein



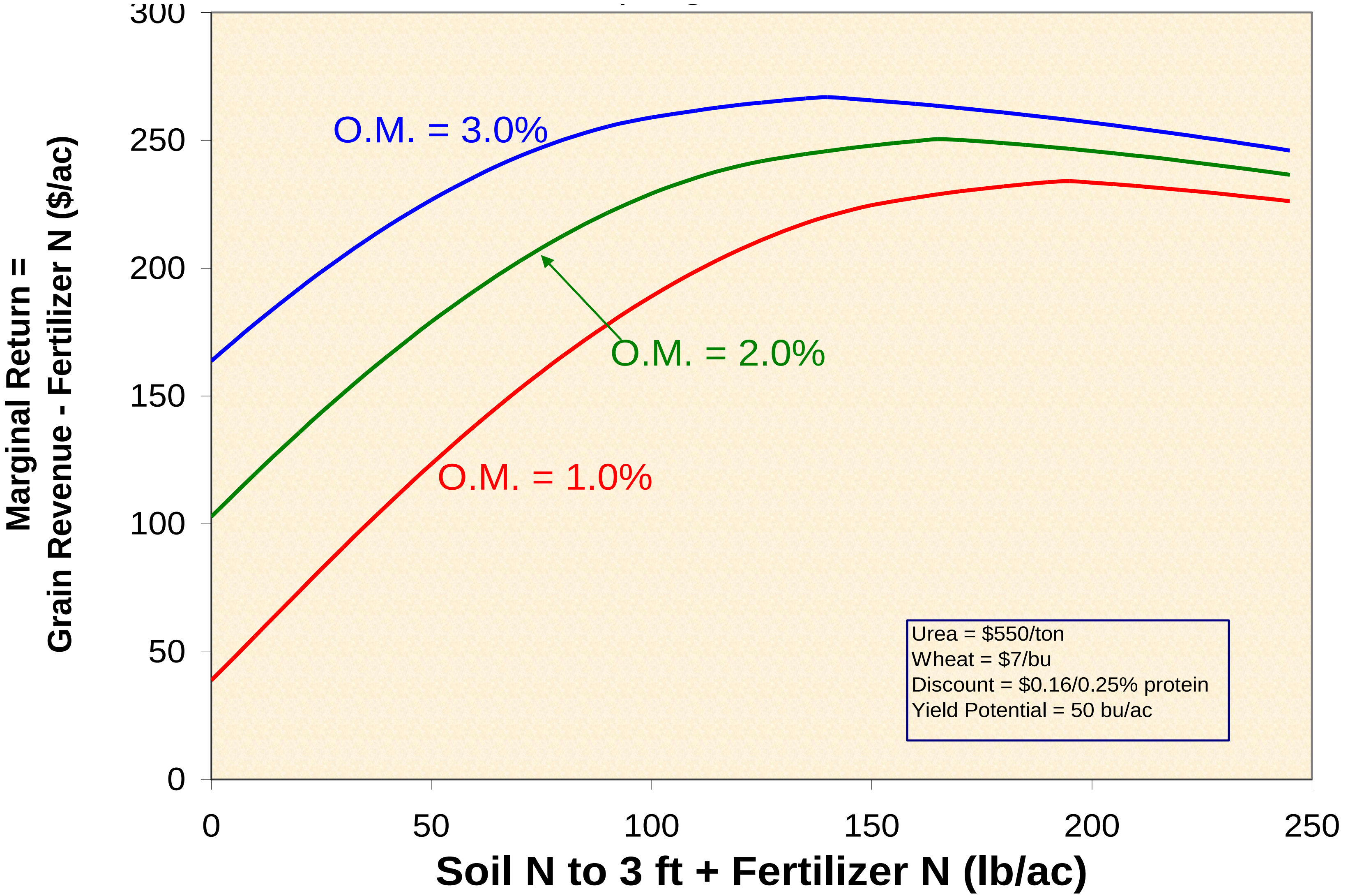
# Net Marginal Return for N Fertilizer

- NMR = Grain price +/- protein premium/discount – N fertilizer cost

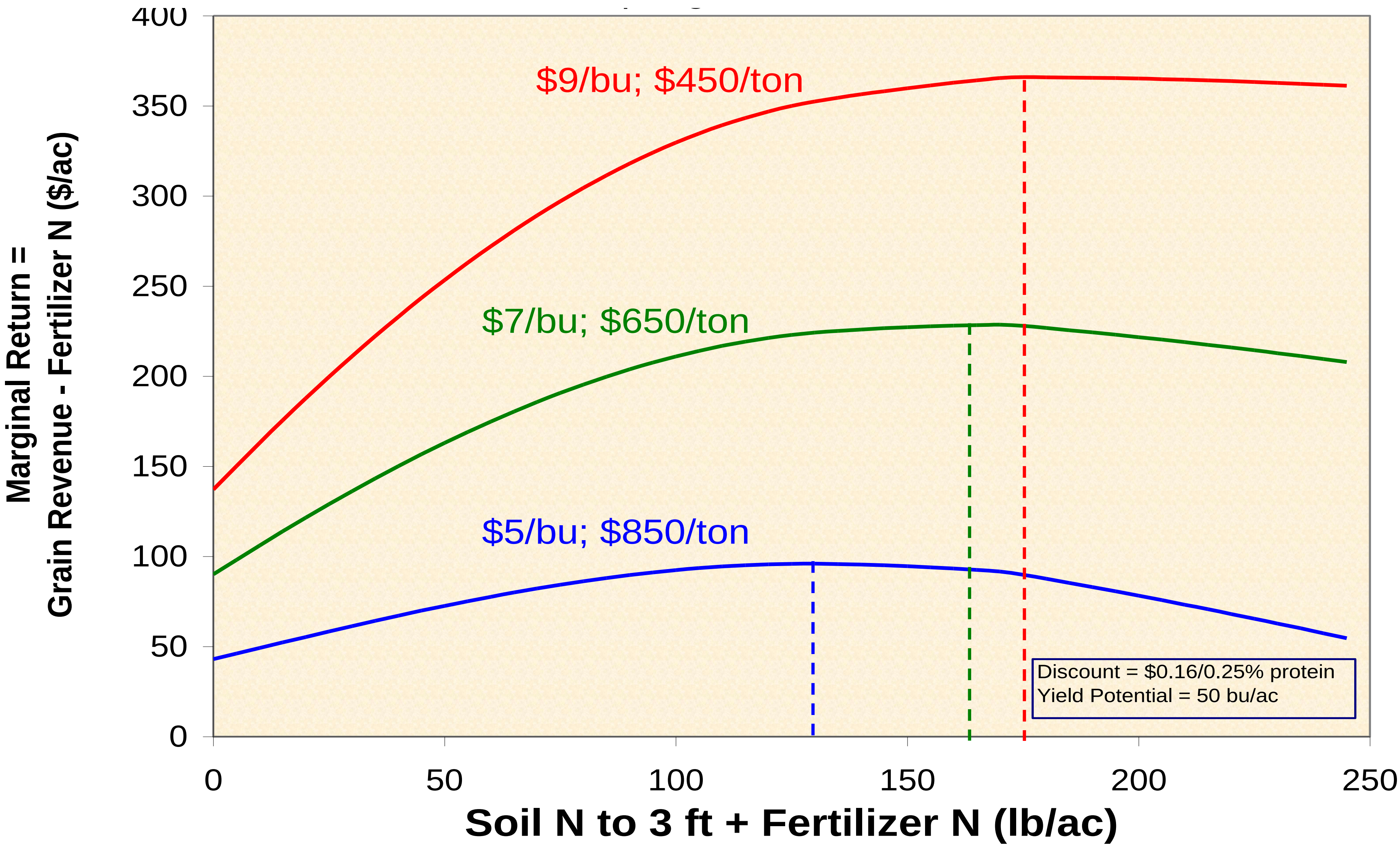
# Effect of N and Yield on Marginal Return



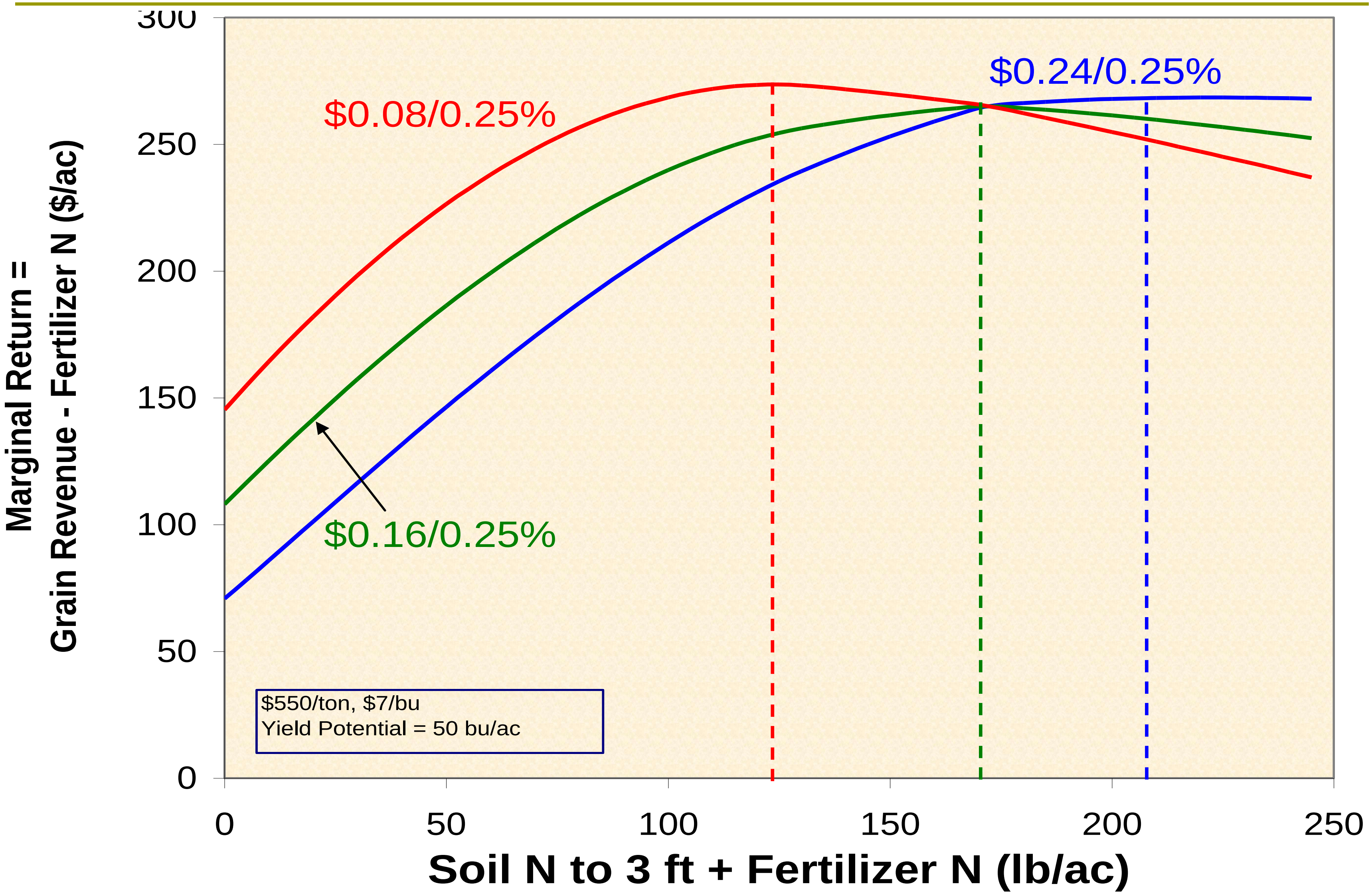
# Effect of Organic Matter on Optimum N Rate



# Effect of Grain Price and Urea Cost on Marginal Return



# Effect of available N and protein discount on marginal return



# Total Available N for Maximum Return on SW following Fallow (lb N/bu)

| Protein Discount (¢/0.25%) | $450/ton | $650/ton | $850/ton |
|---|---|---|---|
| 8 | 2.6 | 2.4 | 2.2 |
| 16 | 3.5 | 3.4 | 2.6 |
| 24 | 5.6 | 3.6 | 3.4 |

Based on $7/bu, 50 bu/ac, 2% O.M.

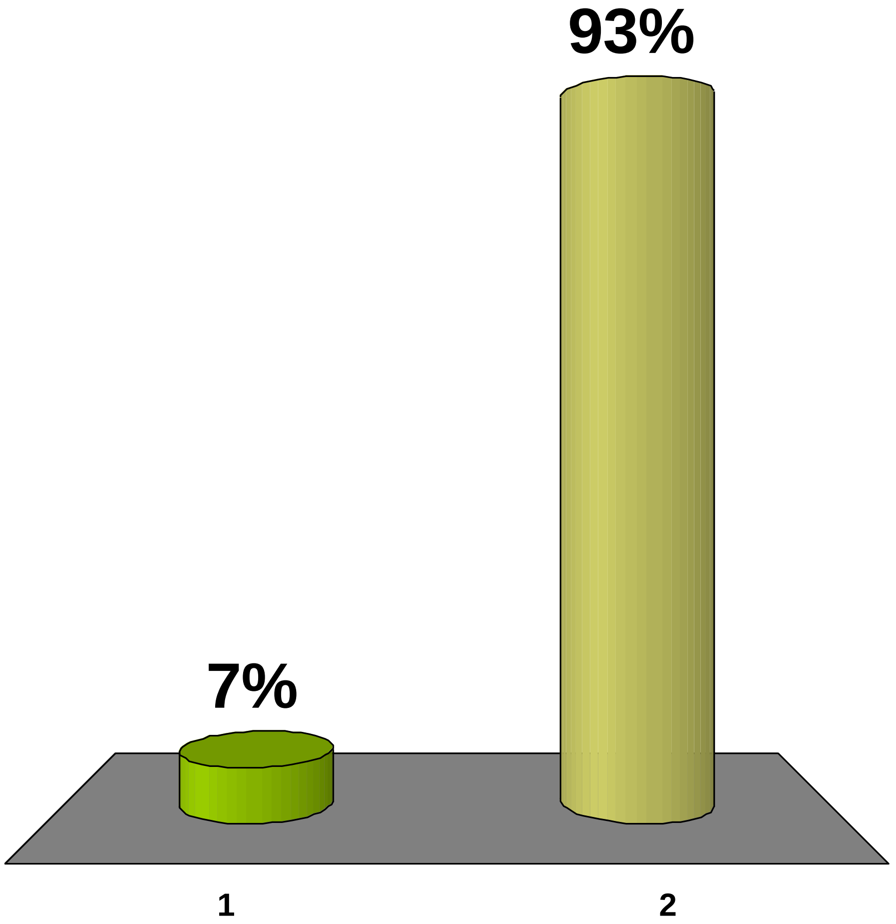
# Economic model for spring wheat fertilizer rates


**Montana State University Extension Service**

www.montana.edu/softwaredownloads/software/SWFertilizerEconomics.swf

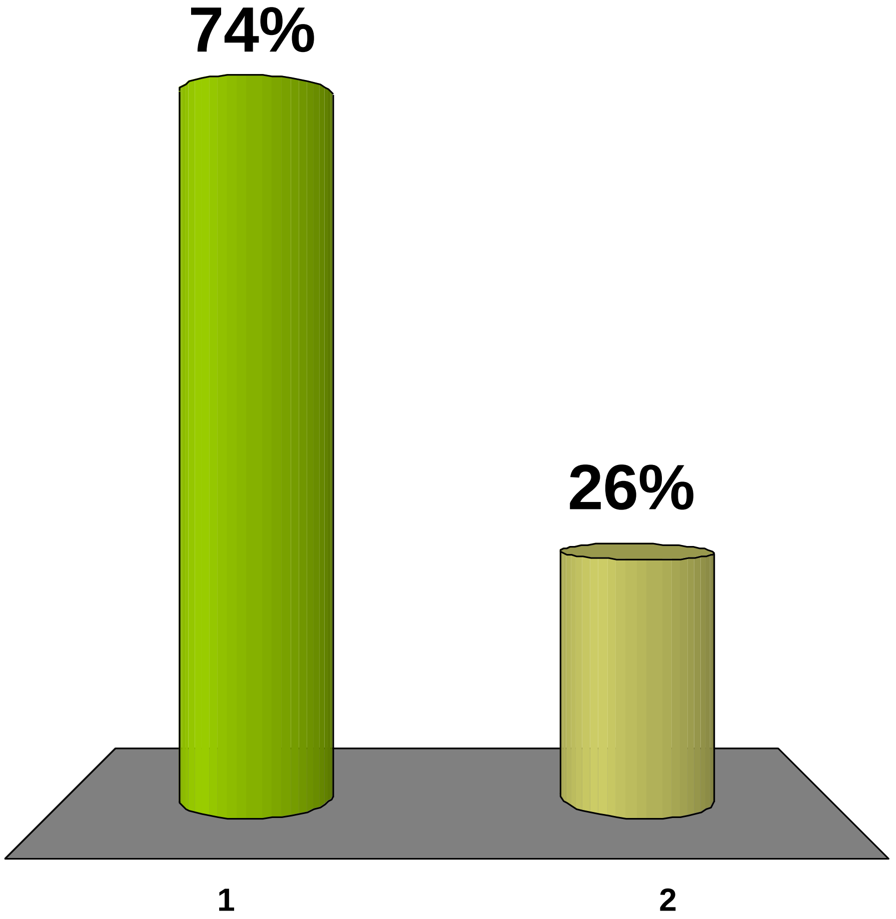
# Were you aware of this model before today?

1. Yes
2. No



# Would you use this model?

1. Yes
2. No



# Conclusions on economic N rate calculator

- Based on this model, economic optimum N rates (EONRs) depend on fertilizer N cost, grain price, protein discount/premium, organic matter, and yield goal.
- The model predicts that recommended rates of N fertilizer should be higher than the MSU rate (i.e. 3.3 lb N/bu SW) when fertilizer price is ‘low’ and protein discount is high.
- Fertilizer N rates should be close to MSU rate when commodity and protein discounts are closer to average.
- The models are currently online with ‘slider-driven’ inputs.

# Acknowledgments

- This study was funded by the Montana Fertilizer Advisory Committee

To work with models go to:
http://landresources.montana.edu/soilfertility

Then click on Fertilizer Information and then Fertilizer Economics.

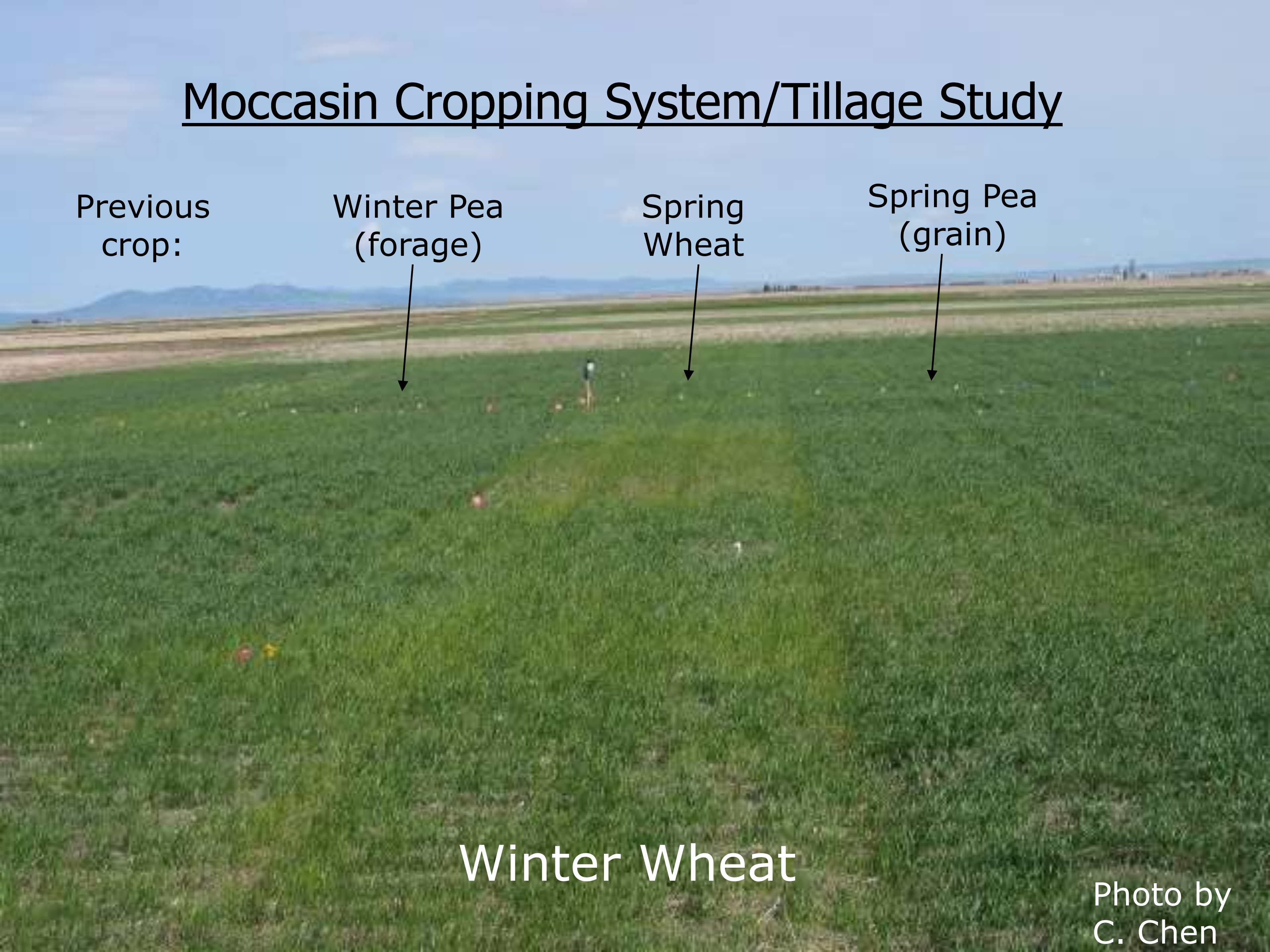
# QUESTIONS?

# Optimizing Pulse Yields with Phosphorus and Potassium

# Questions for you

- How many of you grow annual legumes?
- Small grain replacement or fallow replacement?

Your experiences? Both good and bad?


Moccasin Cropping System/Tillage Study
Previous crop:
Winter Pea (forage)
Spring Wheat
Spring Pea (grain)
Winter Wheat
Photo by C. Chen

# How do I maximize N benefit?

- Seed legume into soil with low available N
- Inoculate, especially if field never had legumes
- Provide sufficient phosphorus (P), potassium (K), and sulfur (S)


Not Fertilized
Fertilized w/ P, K, and S
ORG1 # 308 CDR
Winter Pea, Bozeman, 5/17/07

# Winter Pea Roots

Not Fertilized | Fertilized with P, K, and S


Winter Pea, Bozeman, 5/17/07

What looks different?

# Phosphorus and Potassium Uptake

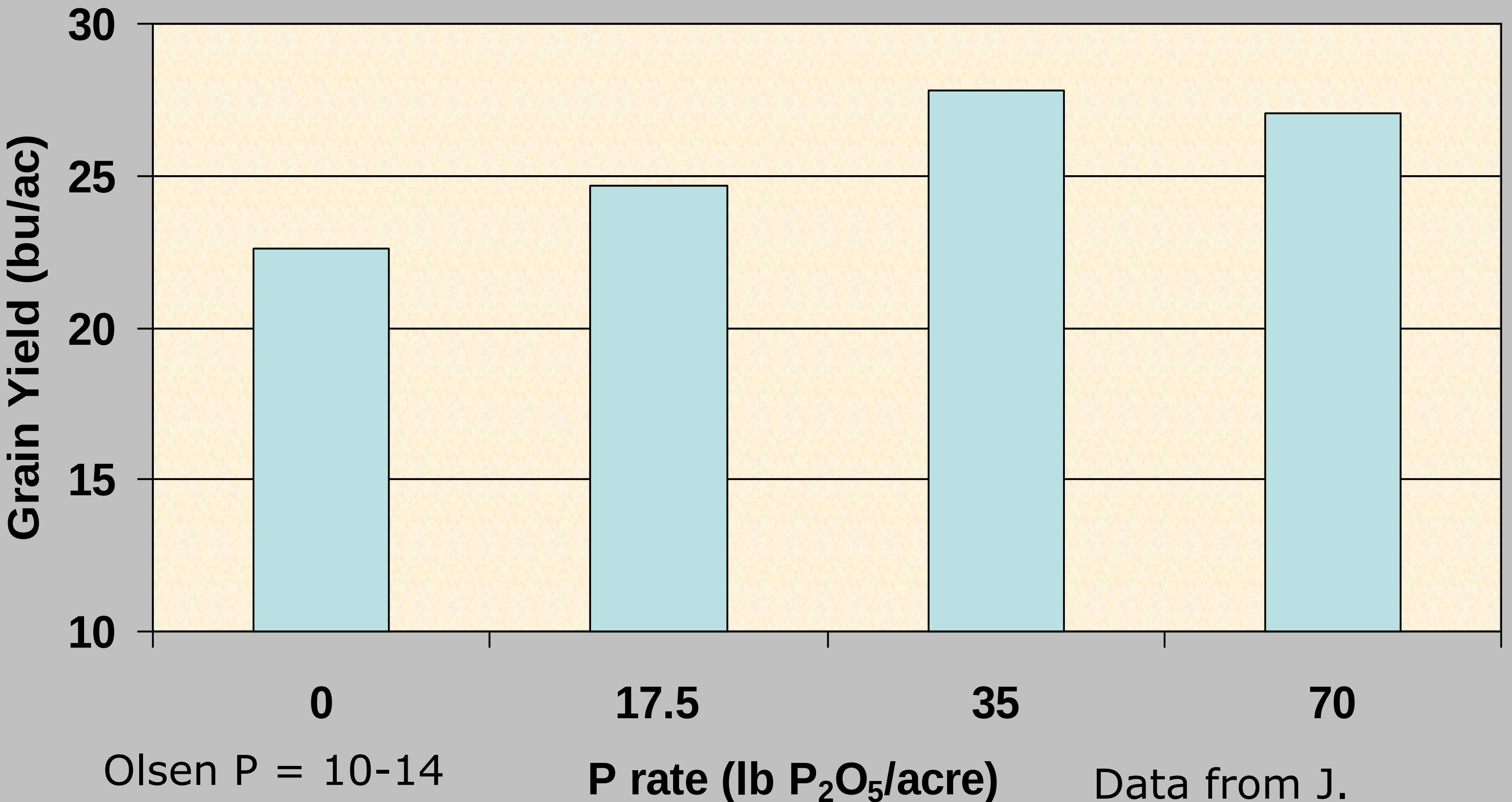
| Nutrient | Peas, Lentils, Chickpeas | Wheat |
|---|---|---|
| Phosphorus (lb/bu) | 0.67 | 0.62 |
| Potassium (lb/bu) | 0.87 | 0.38 |

P levels are often low in Montana (due to calcareous soils).

K levels are often moderate to high in Montana. No research located on K and legumes in region.

BOTH P and K needed for N fixation!

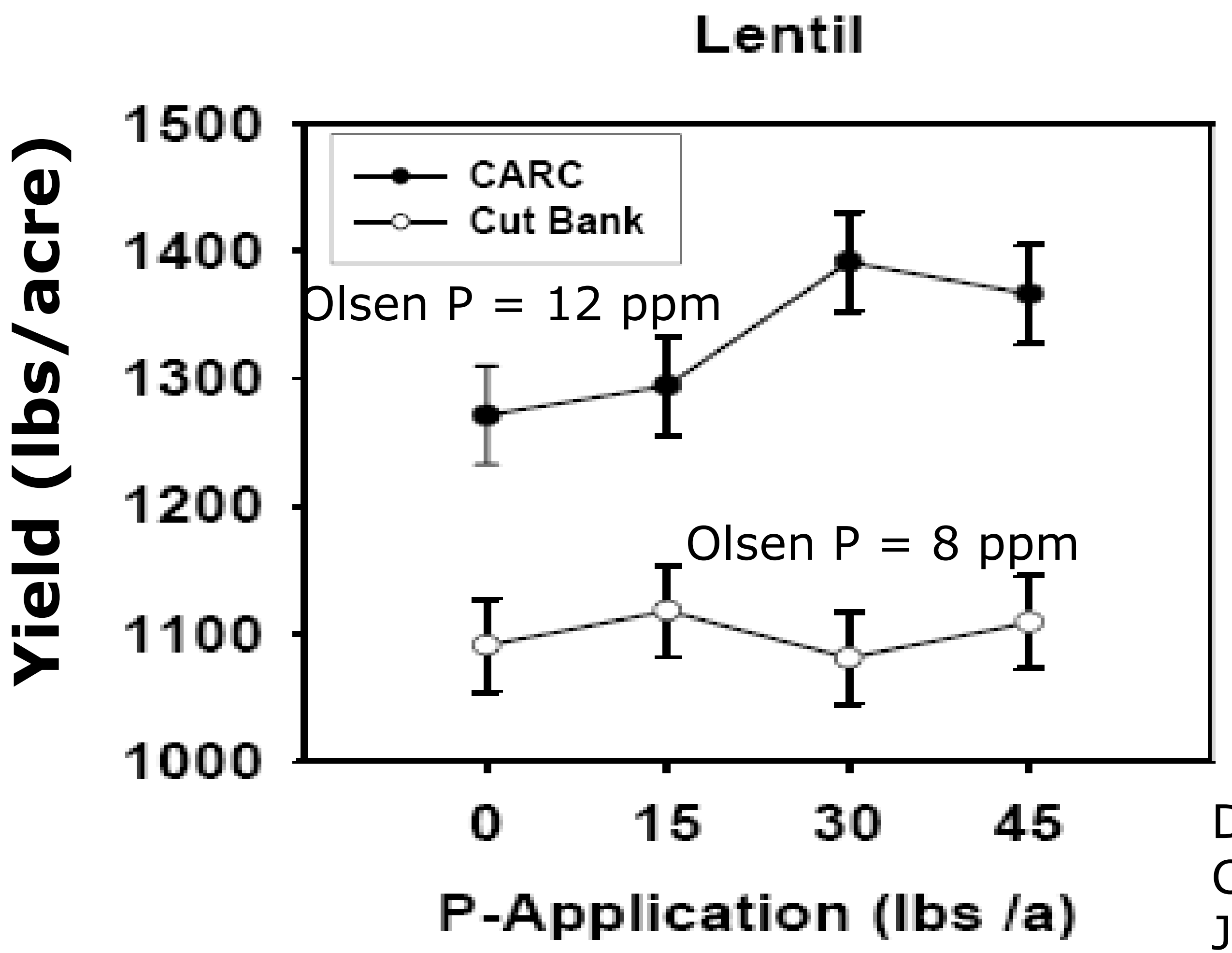
# Effect of P on Spring Pea Yield (2004-2005) Sidney




Olsen P = 10-14 ppm

Data from J. Waddell

# Effect of Pea on Spring Lentil Yield
## Moccasin (CARC) and Cutbank




Data from C. Chen and G. Jackson

http://landresources.montana.edu/fertilizerfacts (#38)

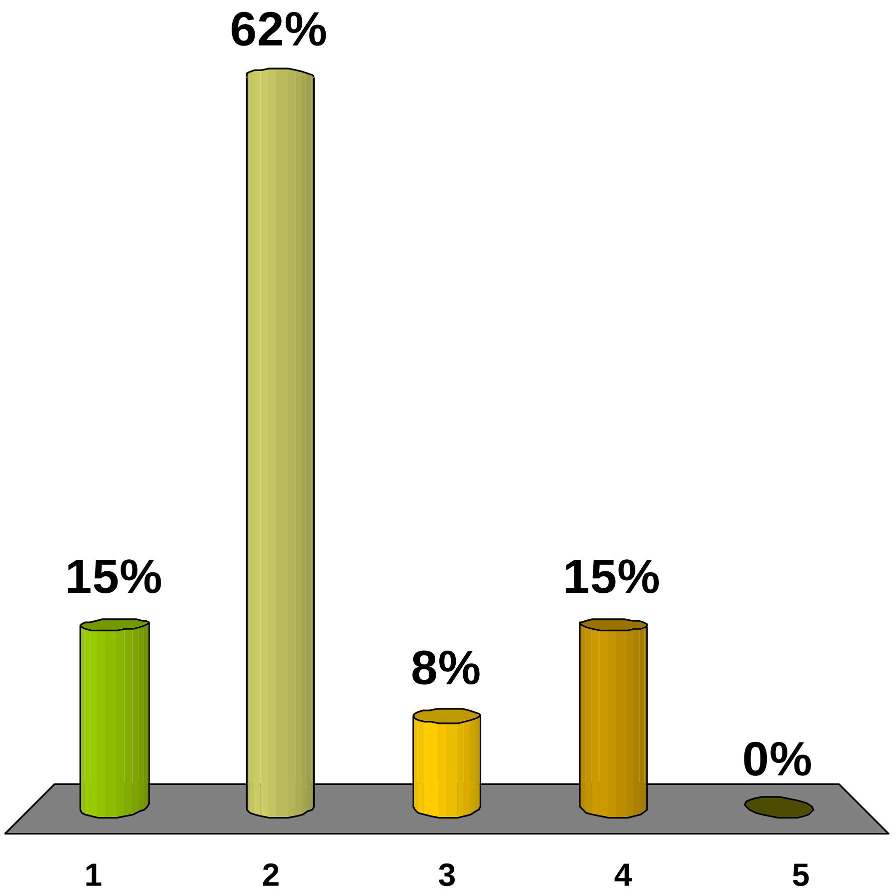
# Montana Phosphorus Fertilizer Guidelines for Annual Legumes

| Olsen P (ppm) 0 to 6 inches | Application rate ($lb\ P_2O_5/acre$) |
|---|---|
| 4 | 30 |
| 8 | 25 |
| 12 | 20 |
| 16 | 15 |
| Above 16 | 0 up to crop removal* |

* - Assume 2/3 lb $P_2O_5$ per bushel of grain

# My farm's average Olsen P level is:

1. Less than 8 ppm
2. 8-16 ppm
3. More than 16 ppm
4. I don't know, but my fertilizer dealer does
5. I don't soil test for P

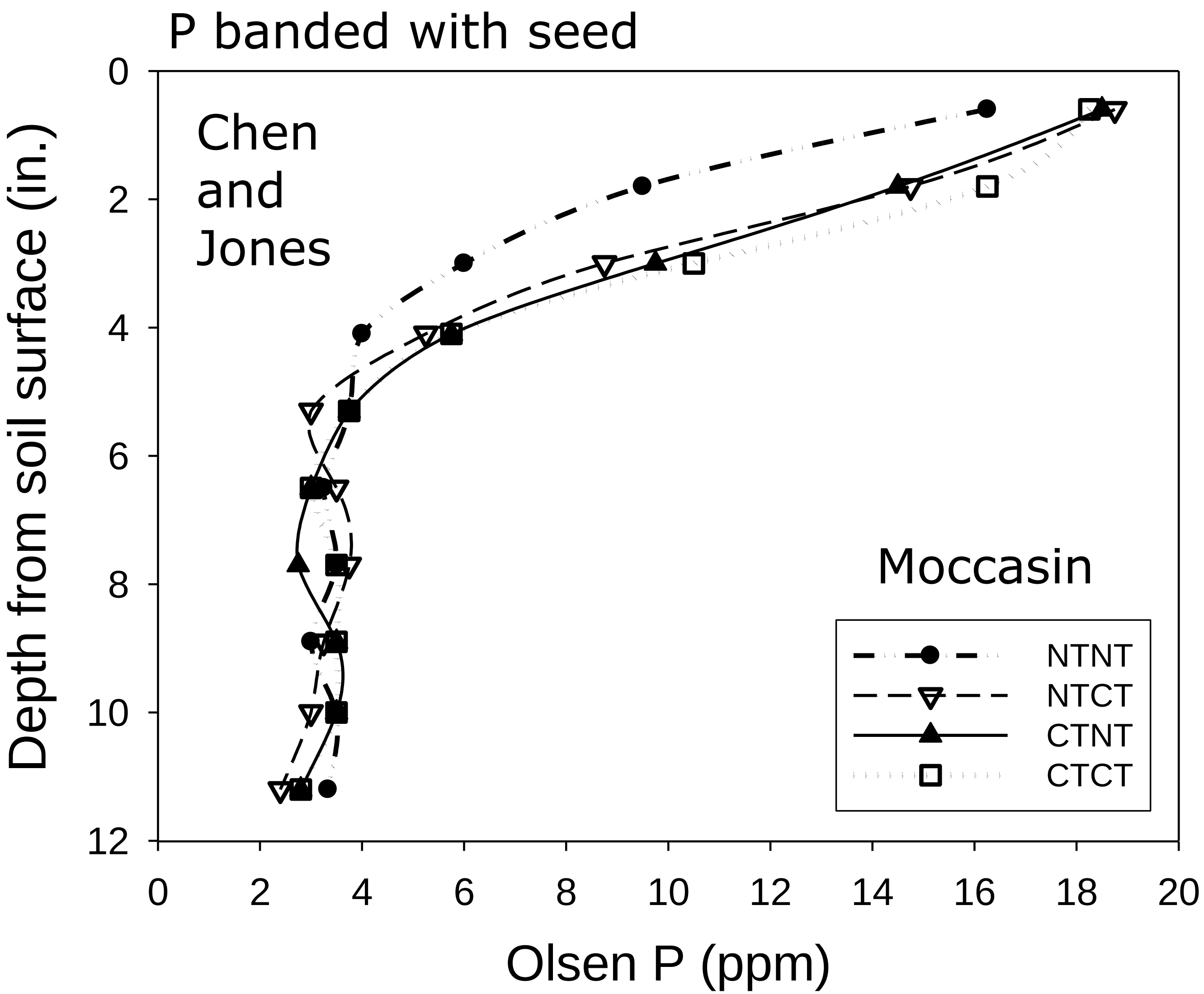


# Why are P needs of annual legumes somewhat less than for small grains and oilseeds?

- Lower yields
- Annual legumes root shallower:

  Better able to take advantage of higher P levels in upper 6 inches
- Legumes lower soil pH, mobilizing P

# Why does rooting depth matter?
## P accumulates near surface




Why important ?

Shallow rooted crops can better utilize P from near surface

# Take home messages on P

- Annual legumes need similar amounts of P PER bu.
- P is necessary for N fixation.
- Legumes are better able to access soil and fertilizer P than small grains.

# Montana Potassium Fertilizer Guidelines for Annual Legumes

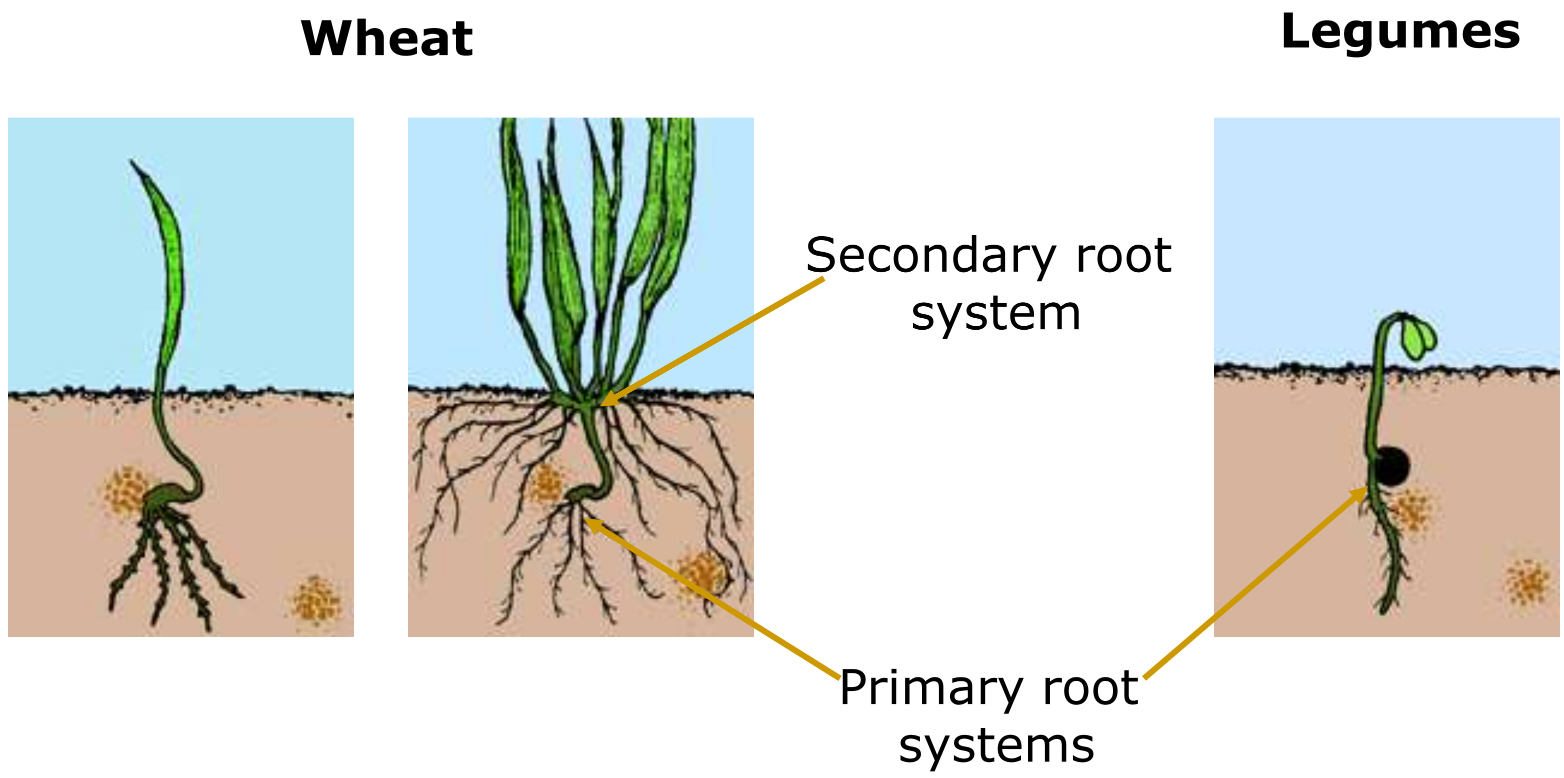
| Soil Test K (ppm) 0 to 6 inches | Application rate (lb $K_2O$/acre) |
|---|---|
| 100 | 35 |
| 150 | 30 |
| 200 | 25 |
| 250 | 20 |
| Above 250 | 0 up to crop removal* |

* - Assume 0.87 lb $K_2O$ per bushel of grain

# Fertilizer placement for legumes

- No nitrogen or potassium fertilizer with the seed
- Small amounts of phosphorus (<10 lb $P_2O_5$/ac) with the seed
- Ideal placement is below the seed

# Rooting patterns and starter and deep band fertilizer placements



# Conclusions on fertilization of pulses

- N benefits from legumes will be higher when soil N is low, seed is inoculated, and P, K, and S are adequate.
- Phosphorus has been shown to have both positive and neutral results on pea and lentil yields, but response should be higher on low P soils.
- Potassium needs are high for legumes, partly b/c needed for N fixation, but little research has been conducted on pea or lentil responses.
- With high pulse prices, maximizing yield with fertilization can easily pay for itself.

# With good fertility you can grow big pods

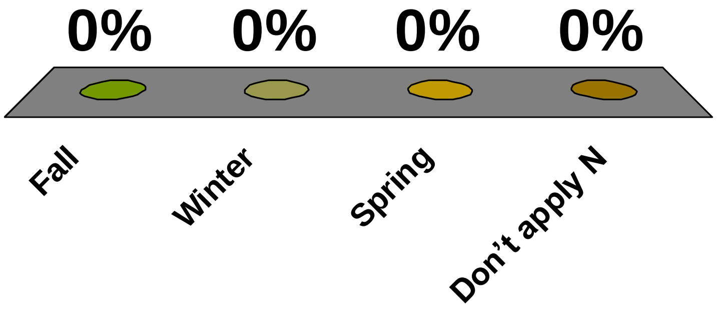
# Management Practices to Minimize Urea Volatilization

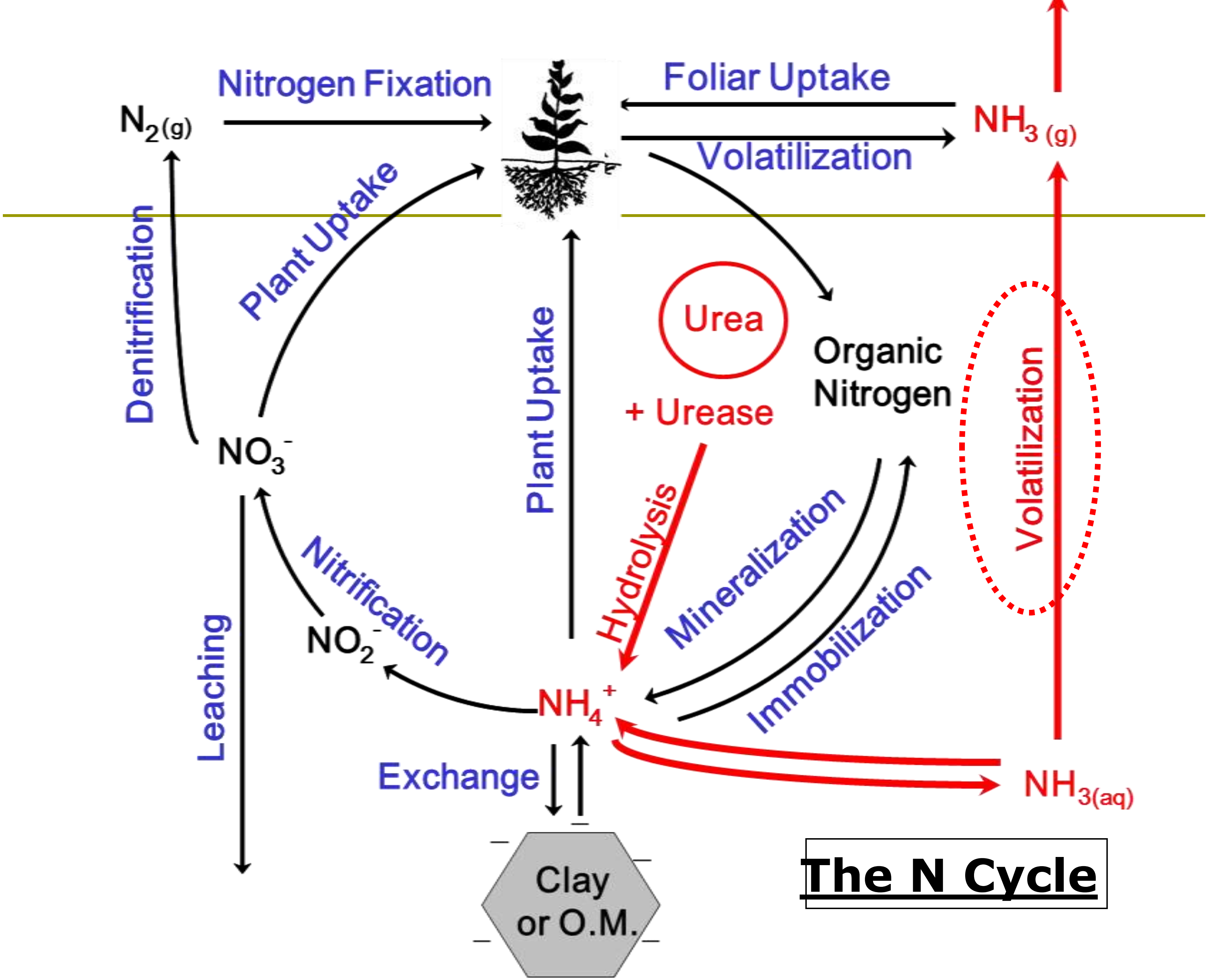
- Know your soil and yield potential for proper N management
- Recrop rather than fallow
- Reduce tillage
- Diversify to include perennial and/or deep rooted crops
- Consider legumes since don't need to fertilize w/ N
- Select appropriate variety
- Space crops for optimal yields to optimize resource use; ex. SW in 6" rows and 30 plants/$ft^2$ – Fertilizer Fact # 37
- Use variable rate technology

# Do you apply N in fall, winter or spring?

1. Fall
2. Winter
3. Spring
4. Don’t apply N

**0 of 35**





Nitrogen Fixation
N2(g)
Foliar Uptake
NH3 (g)
Volatilization
Plant Uptake
Denitrification
Plant Uptake
Urea
+ Urease
Organic Nitrogen
Volatilization
NO3-
Hydrolysis
Mineralization
Immobilization
Nitrification
Leaching
NO2-
NH4+
Exchange
NH3(aq)
Clay or O.M.
The N Cycle

# 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 north central Montana
- diversity of soils (texture, pH)
- ammonia emissions quantified over 8-wk gas sampling campaign following fertilization (urea, NBPT-coated urea)

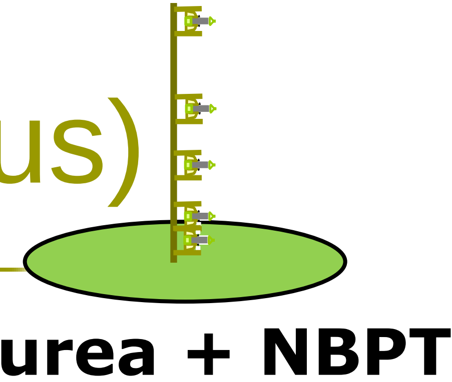
# Integrated horizontal flux method

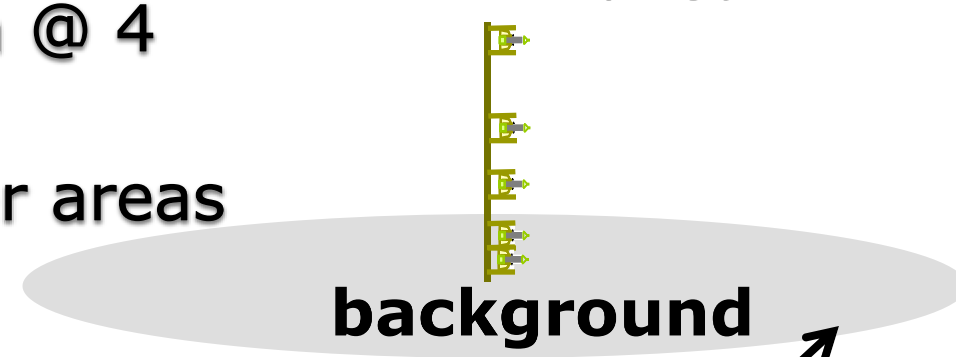
- preferred approach for quantifying gas loss
- moderate size plots (~0.3 acre)
- continuous measurement of $NH_{3(g)}$ loss over time

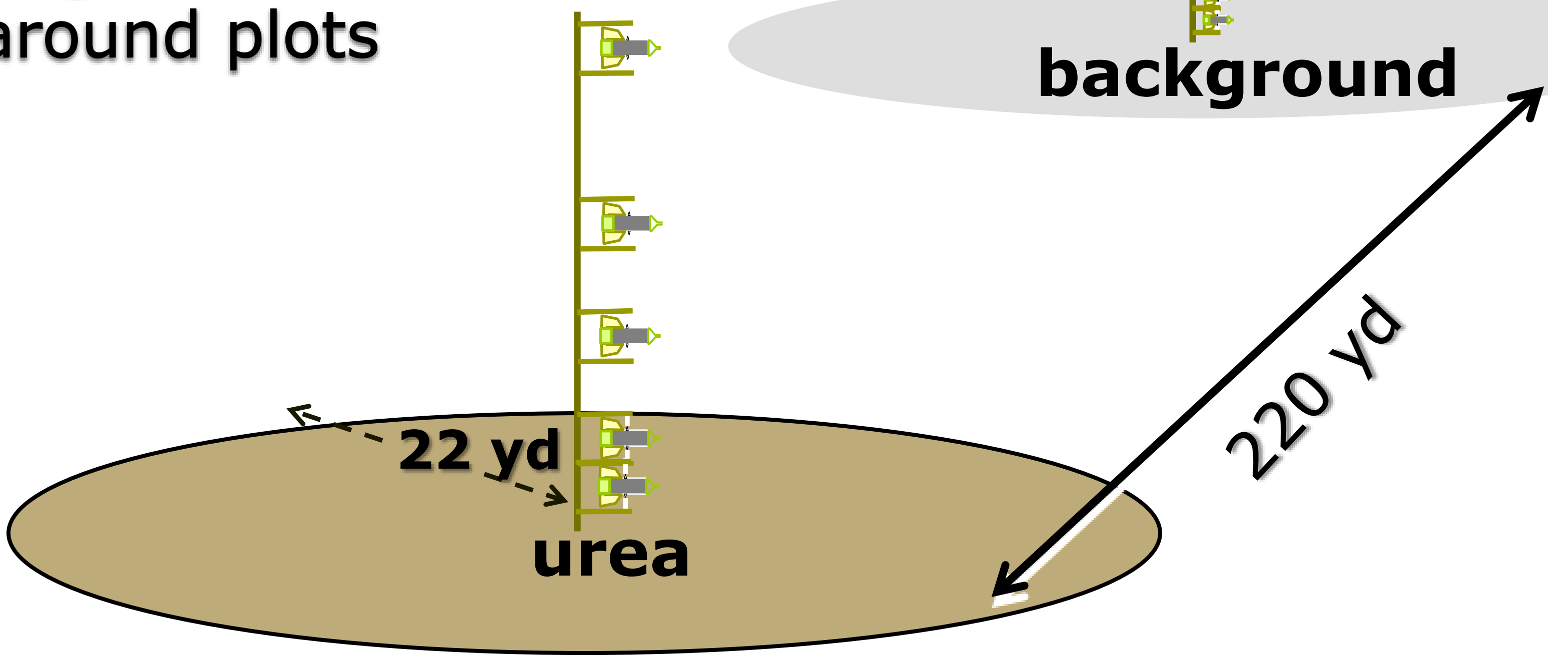
mast and shuttles

# Circular plots (22 yard radius)

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



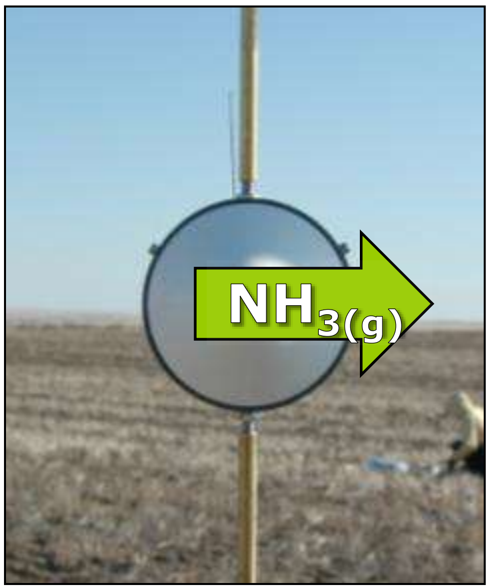



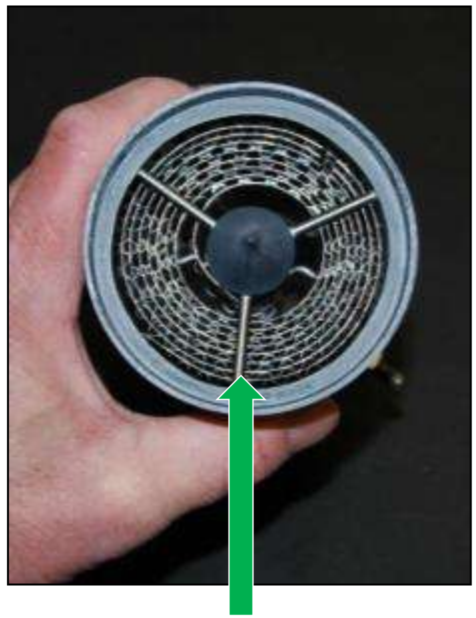

**Methods**

# Shuttles

- traps for collecting ammonia




***front***



***stainless steel spiral coated with oxalic acid***

***back***

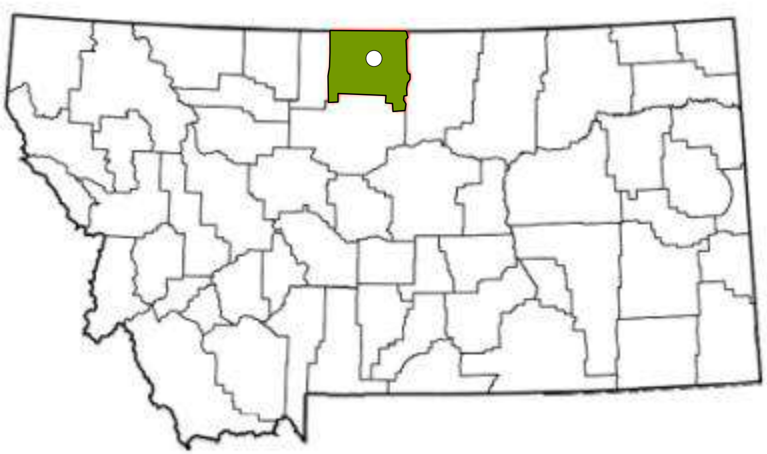
***rotate on pivot & face into wind***

# 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

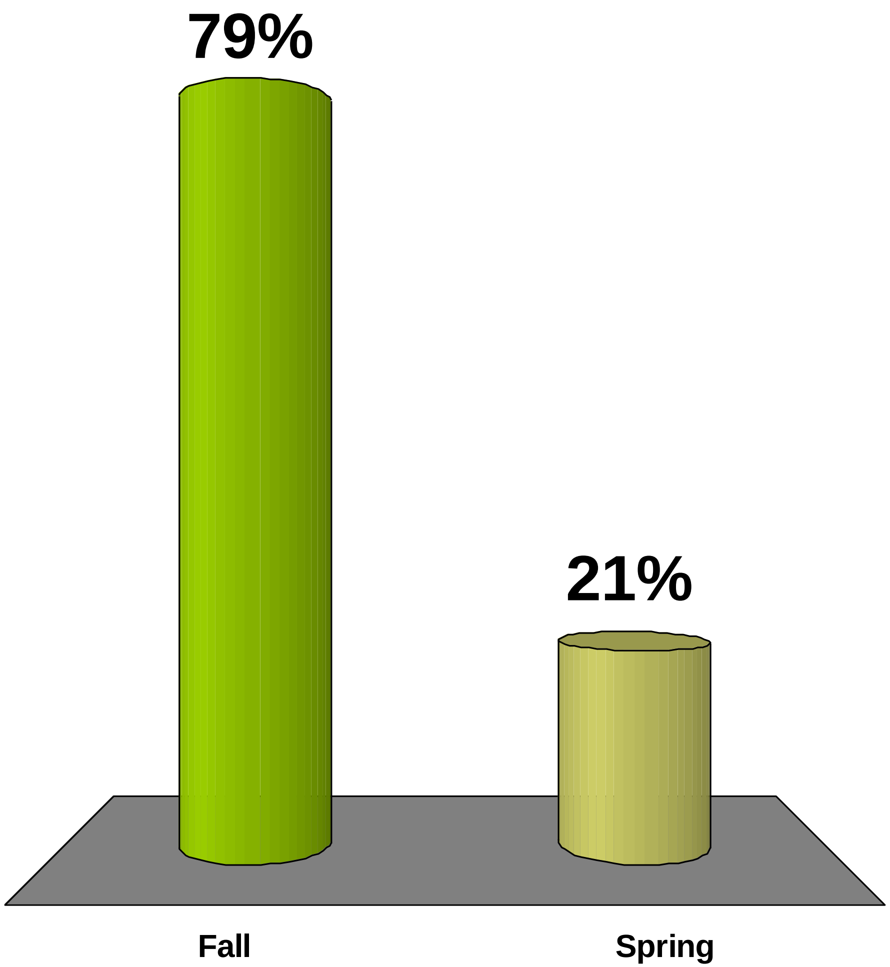
Campaign 2: October 9, 2008. Air temp = 45 F, Soil temp = 43 F

Campaign 5: March 26, 2009. Air temp = 21 F, Soil temp = 34 F



# Do you think there was more volatilization after fall (soil = 42 F) or spring (soil = 34 F) fertilization?

1. Fall
2. Spring

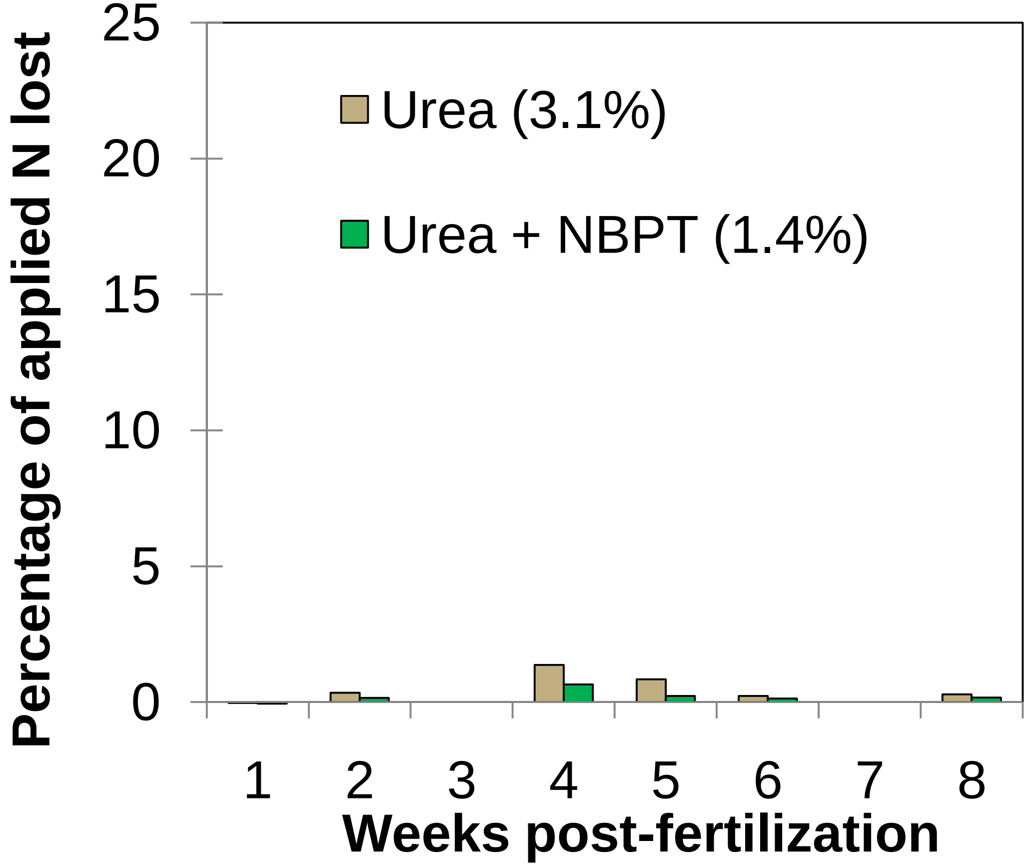


# Campaign #2 – low $NH_3$ losses observed

- 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




Mean Air Temp ~ 42 F

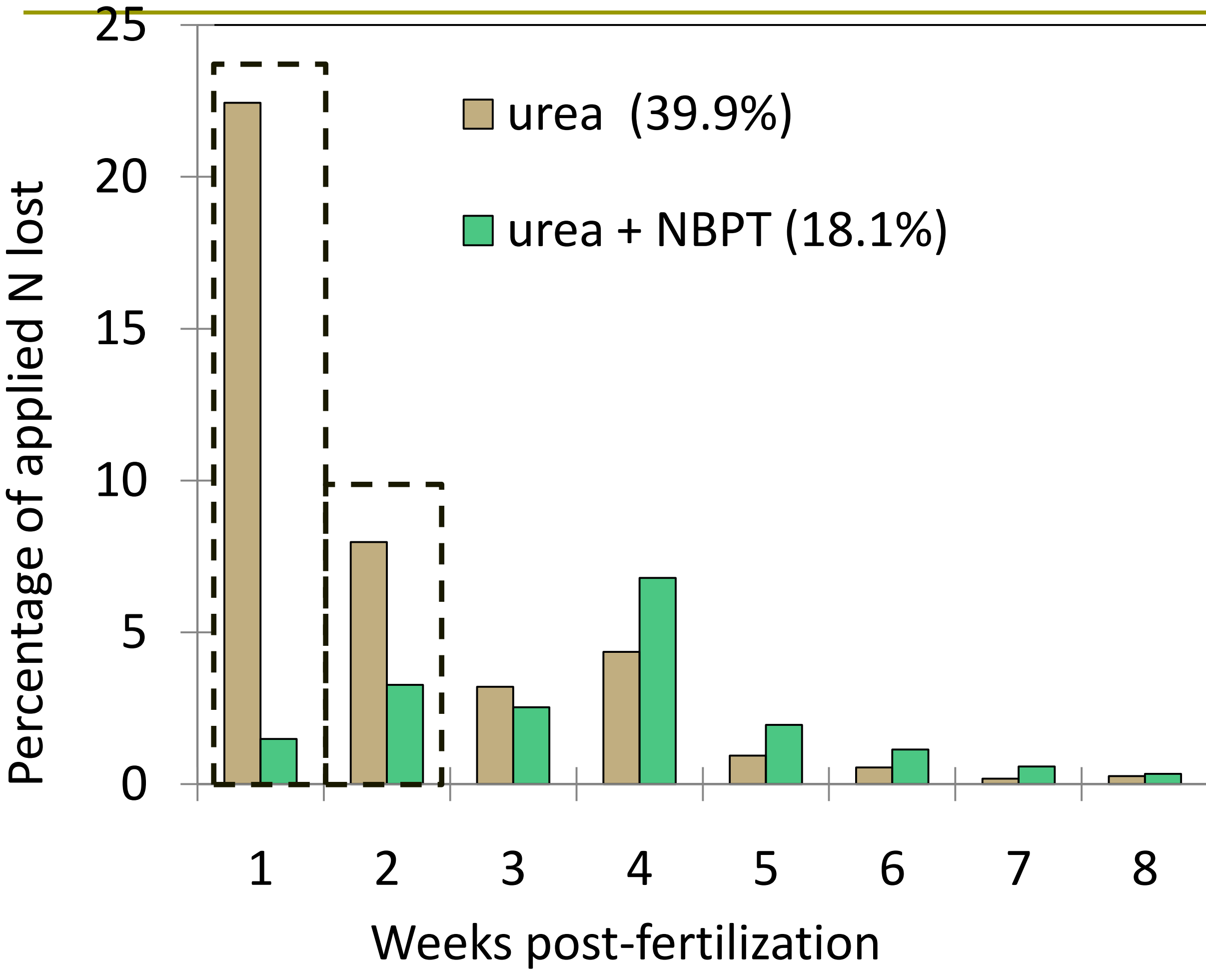
Mean Soil Temp ~ 41 F

# Campaign #5 - high $NH_3$ losses observed

Fertilizer applied on Mar 26, 2009 light snow on soil surface and air temp = 21 F

soil surface with fertilizer prills beginning to dissolve

# Campaign #5 - Kaercher farm




<u>Precipitation</u>

no rain 0-2 wks

1.54” 2-8 wks

<u>Mean temperature</u>

Soil = 34 °F

Air = 33 °F

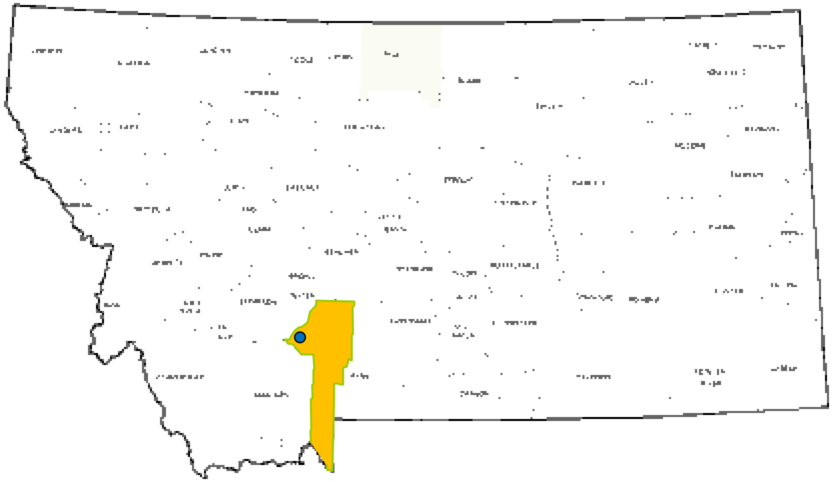
Soil = 38 °F

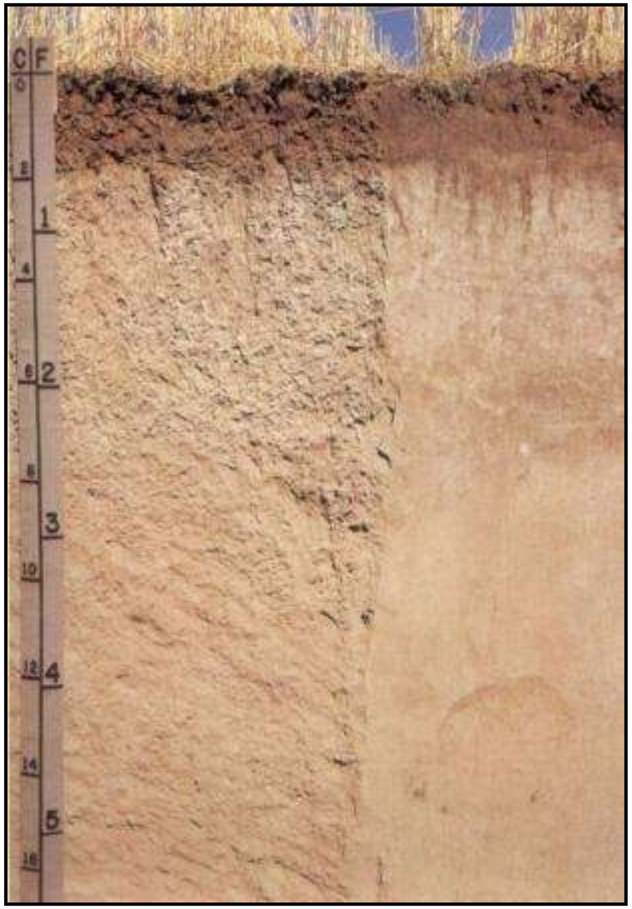
Air = 39 °F

***Conclusion: High losses observed even though temperatures were cold!***

# Campaign 9 & 10 – Willow Creek Brocko silt loam

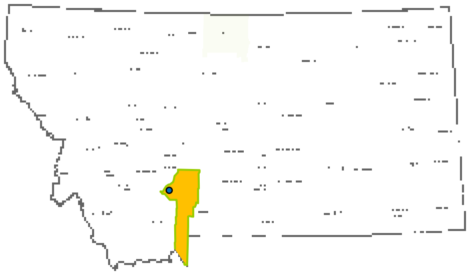
- calcareous soils, pH 8.3





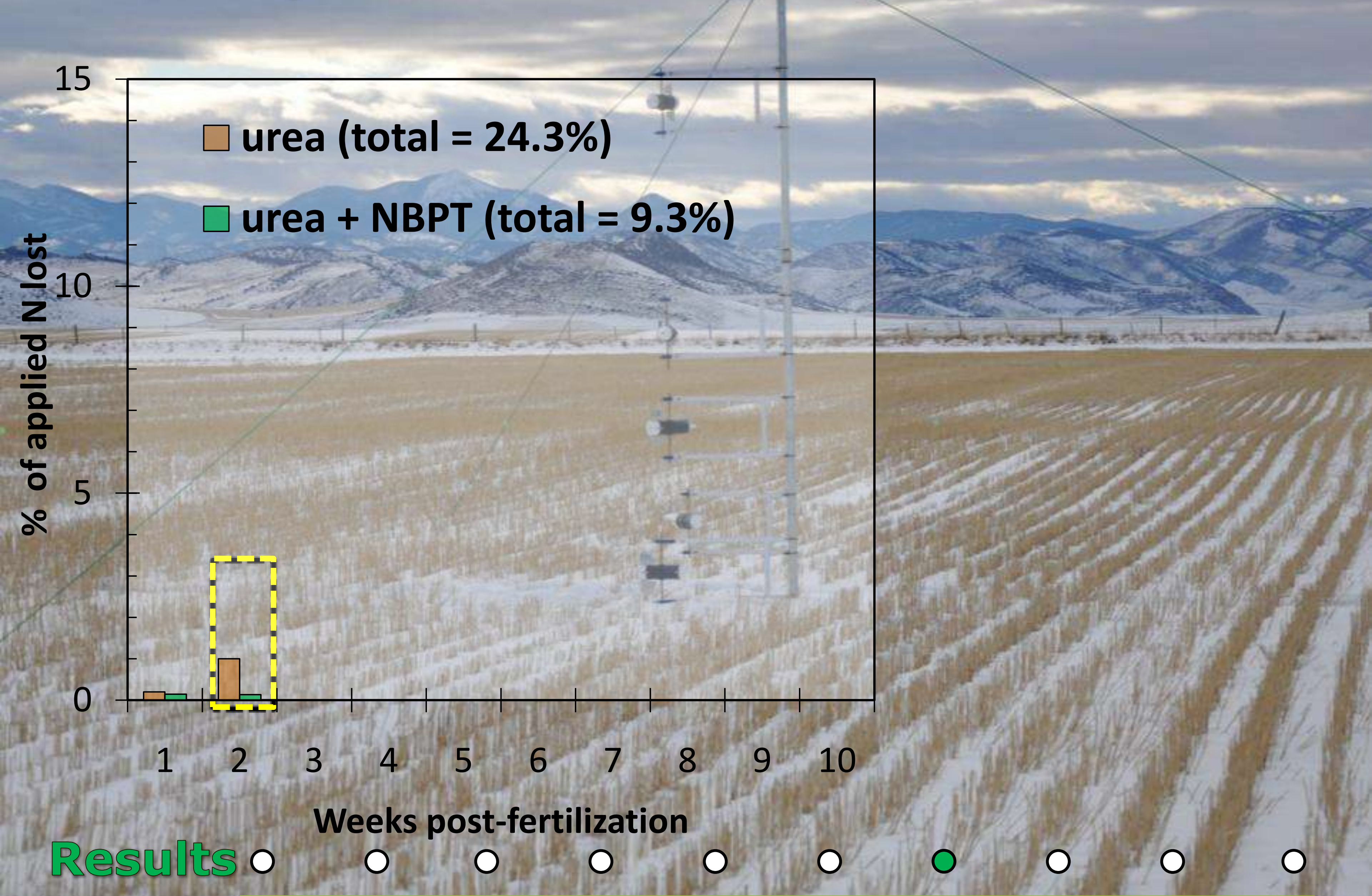
**Results**

# Campaign 9 – Willow Creek – Jan. 27

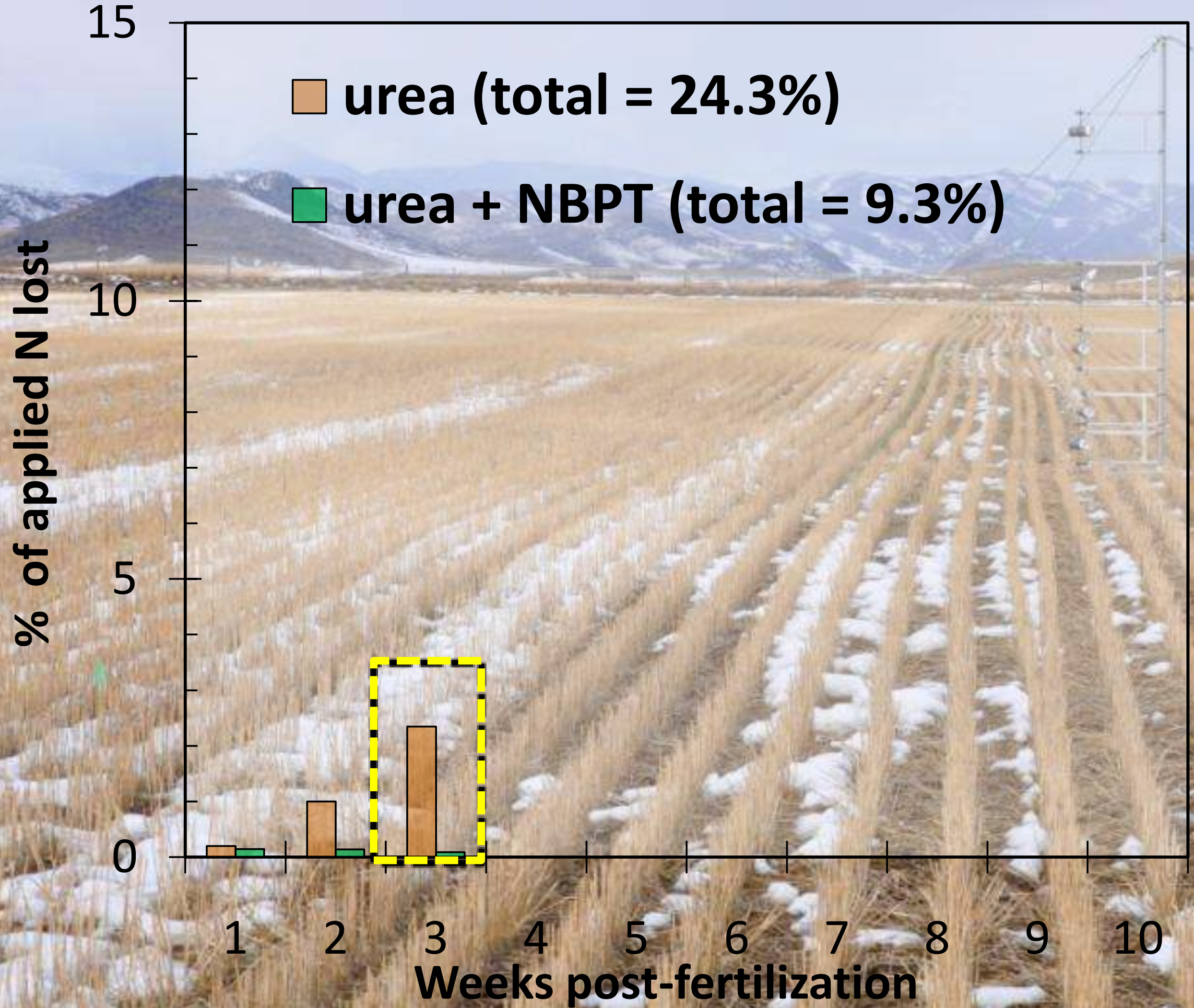



**Results**

# Campaign 9 – Willow Creek – Feb. 10

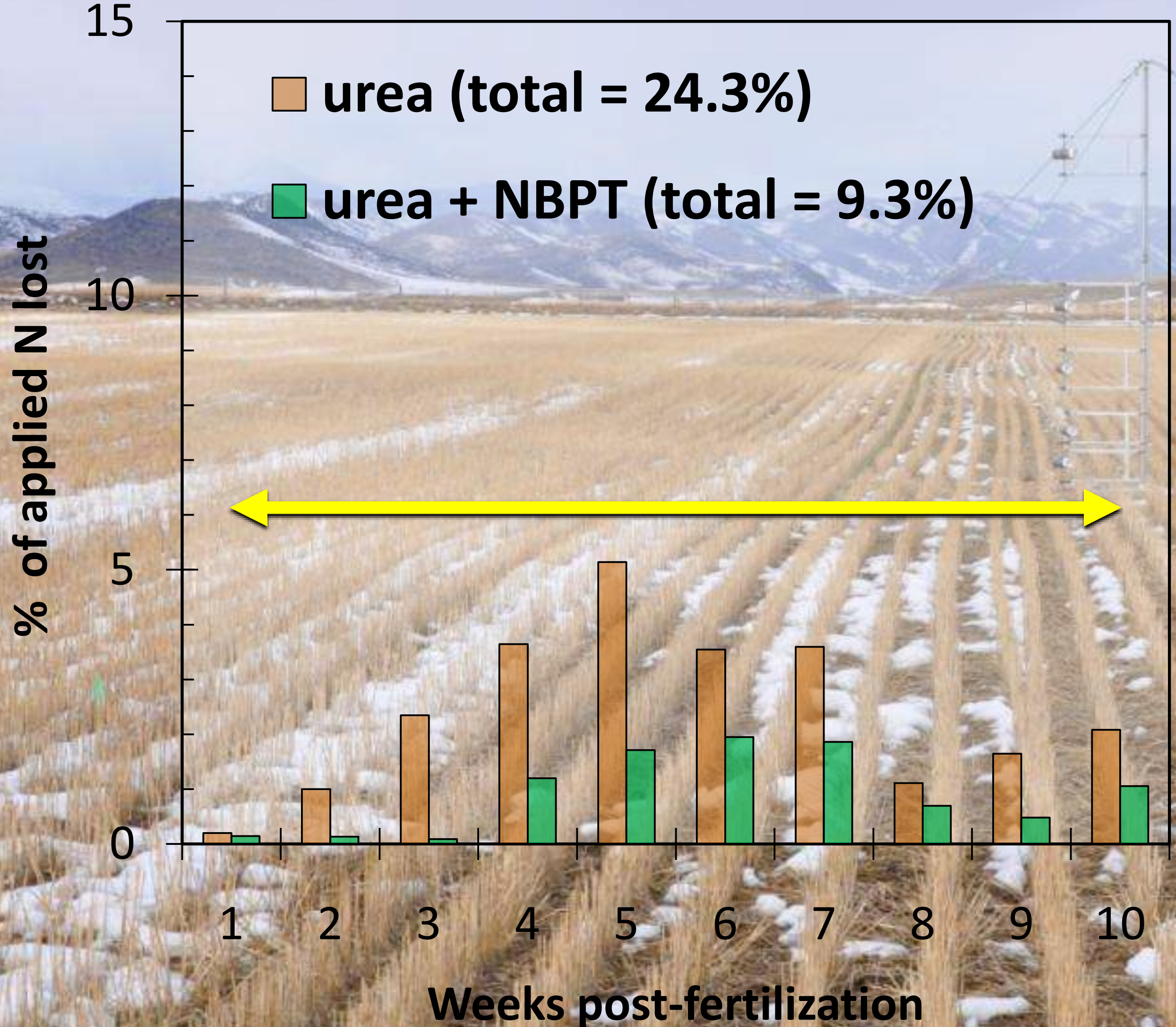


# Campaign 9 – Willow Creek – Feb. 17



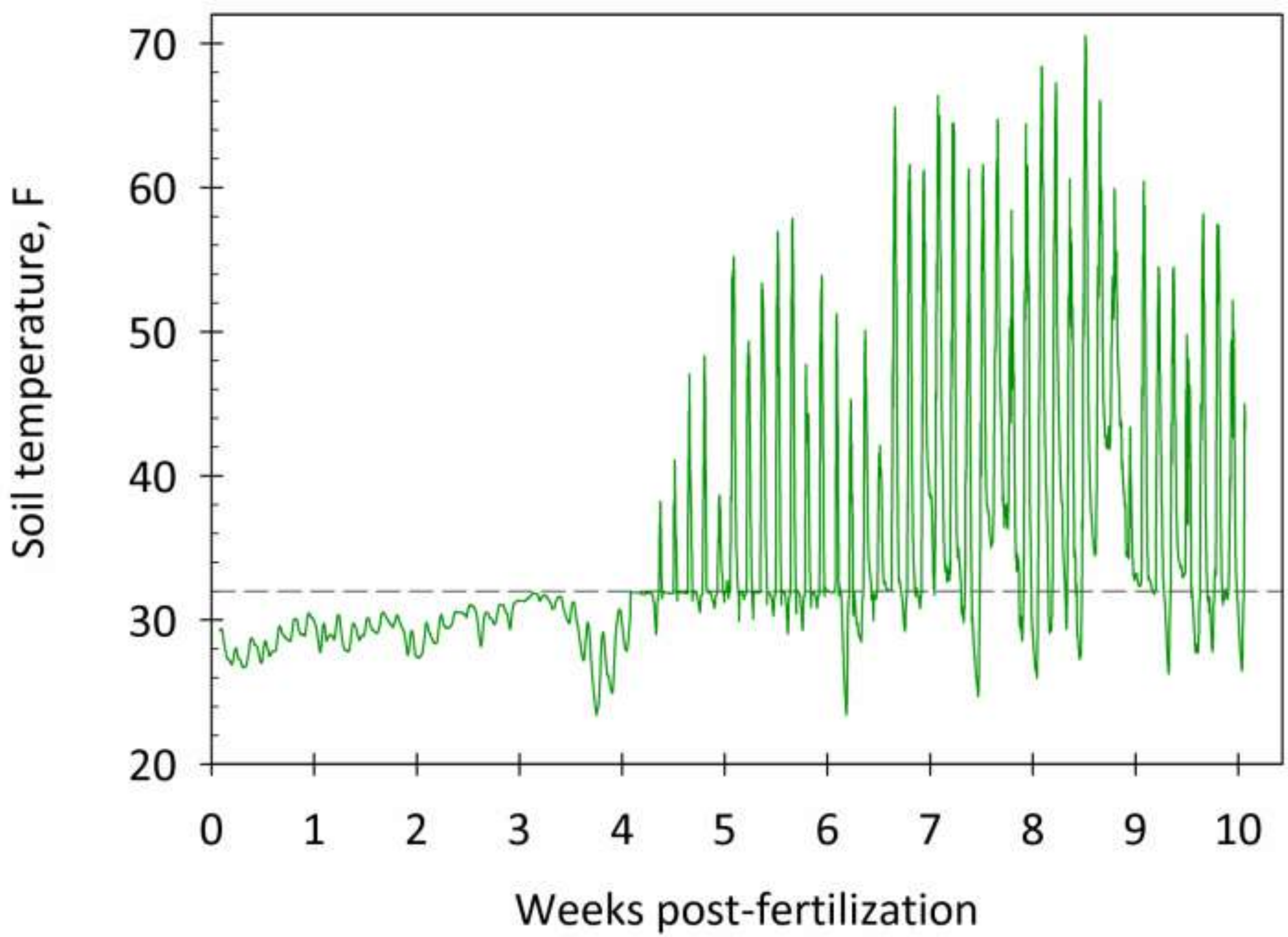

• no runoff

# Campaign 9 – Willow Creek – Feb. 17




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

# Soil temperature (0.4 inch) at Willow Creek, Campaign 9



# Campaign Summary (% N loss)

| Campaign | Fertilization date | Urea | Agrotain |
|---|---|---|---|
| 1 | April 3, 2008 | 8.4 | 4.4 |
| 2 | Oct 8, 2008 | 3.1 | 1.4 |
| 3 | Nov 14, 2008 | 31.5 | 4.0 |
| 4 | March 25, 2009 | 35.6 | 18.0 |
| 5 | March 26, 2009 | 39.9 | 18.1 |
| 6 | Oct 6, 2009 | 10.7 | 3.3 |
| 7 | Oct 13, 2009 | 10.4 | 4.8 |
| 8 | Oct 19, 2009 | 15.7 | 3.4 |
| 9 | Jan 27, 2010 | 24.3 | 9.3 |
| 10 | Feb 26, 2010 | 44.1 | 11.9 |
| 11 | March 29, 2010 | 6.3 | 1.7 |
| 12 | April 20, 2010 | 14.7 | 1.4 |
| **Average** | | **20.4** | **6.8** |

***wide range in N loss amounts***

# http://landresources.montana.edu/ureavolatilization

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Urea Volatilization Home
Background
Location of Studies
Methodology
Results
References and Links to Related Sites

Contact Us

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Tel: (406) 994-7060
Fax: (406) 994-3933
Location: 812 Leon Johnson Hall

rengel@montana.edu

> College of Agriculture > Land Resources & Environ. Sci. > Urea Volatilization

## 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 (pictured 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 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

Text-only

Updated: 08/29/2009

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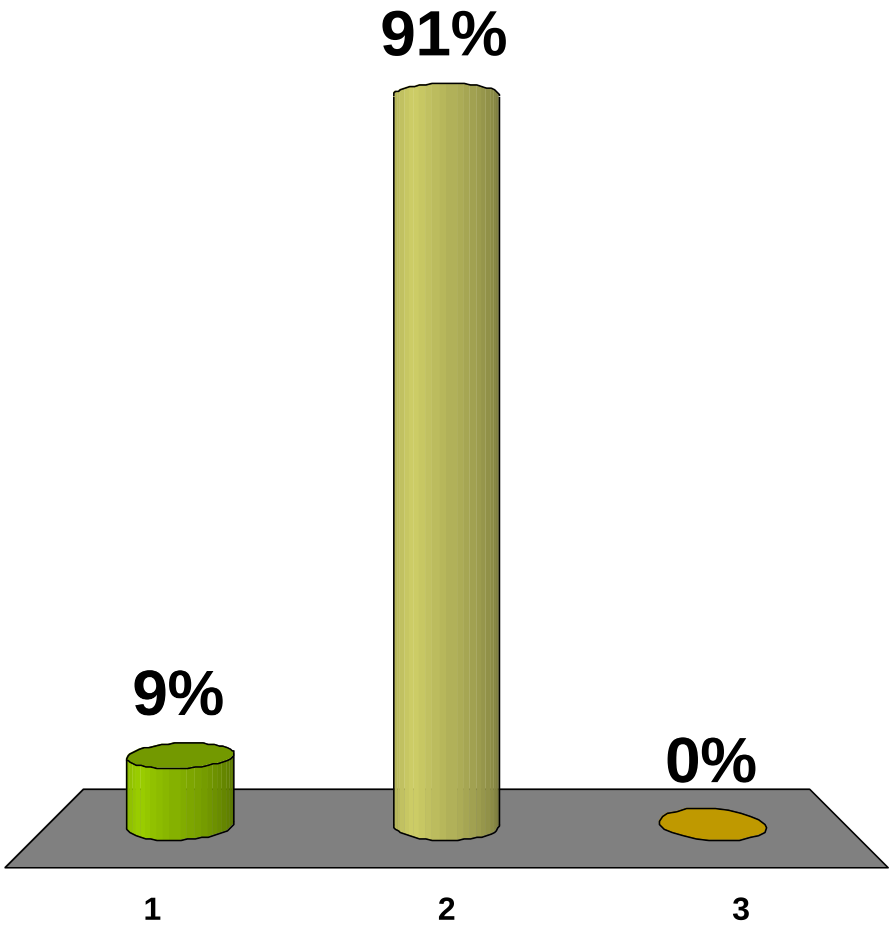
# Based on this study, urea volatilization losses were highest when applied:

1. On warm dry soil prior to extended dry period
2. On moist soil prior to extended dry period
3. On warm dry soil right before precipitation



# 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

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.

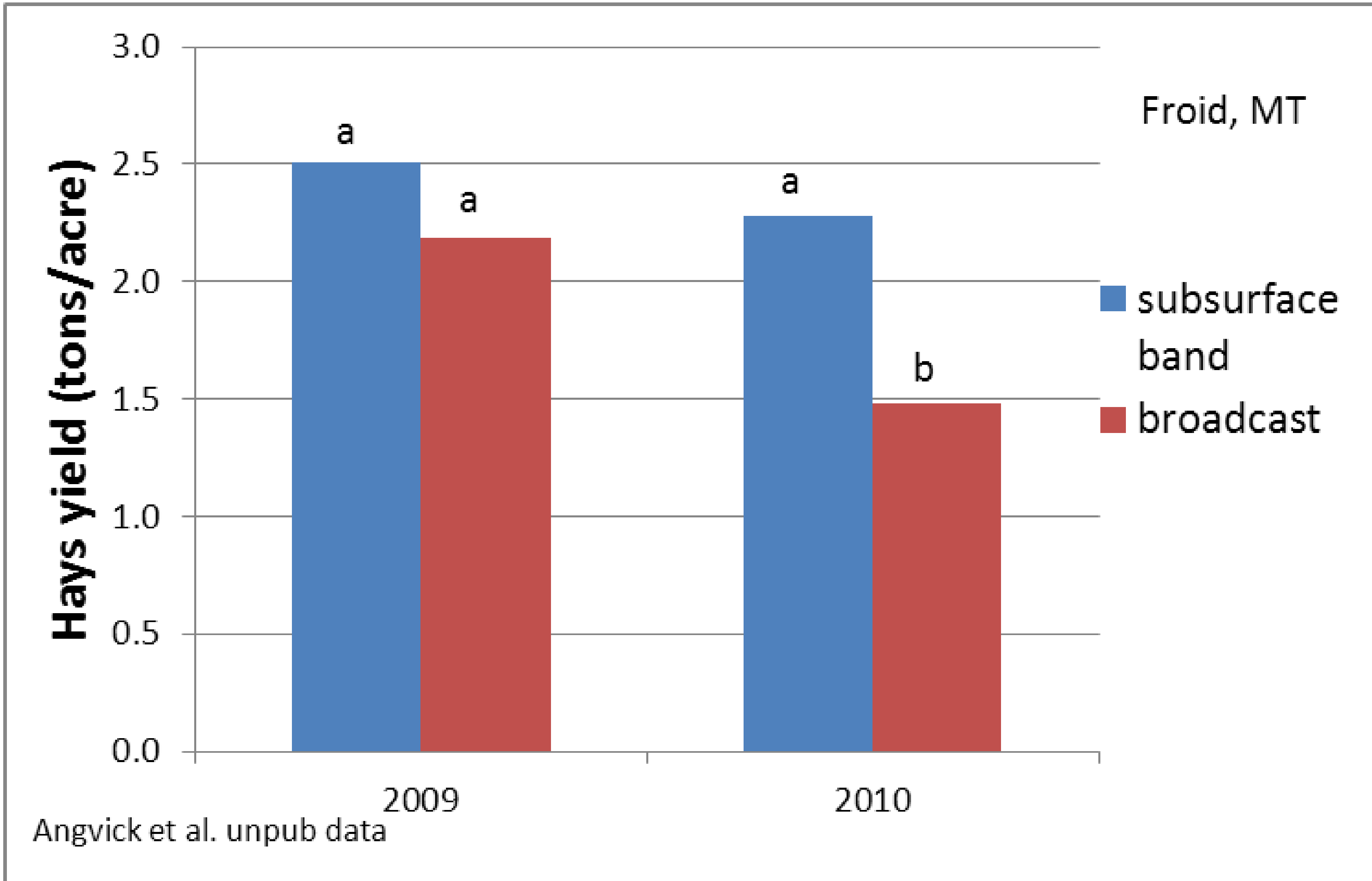
2. Urea takes 2 - 5 weeks to become available whereas AN is immediately available for plants and for other losses-urea's 'slow release' property may increase its efficiency, making up for loss.

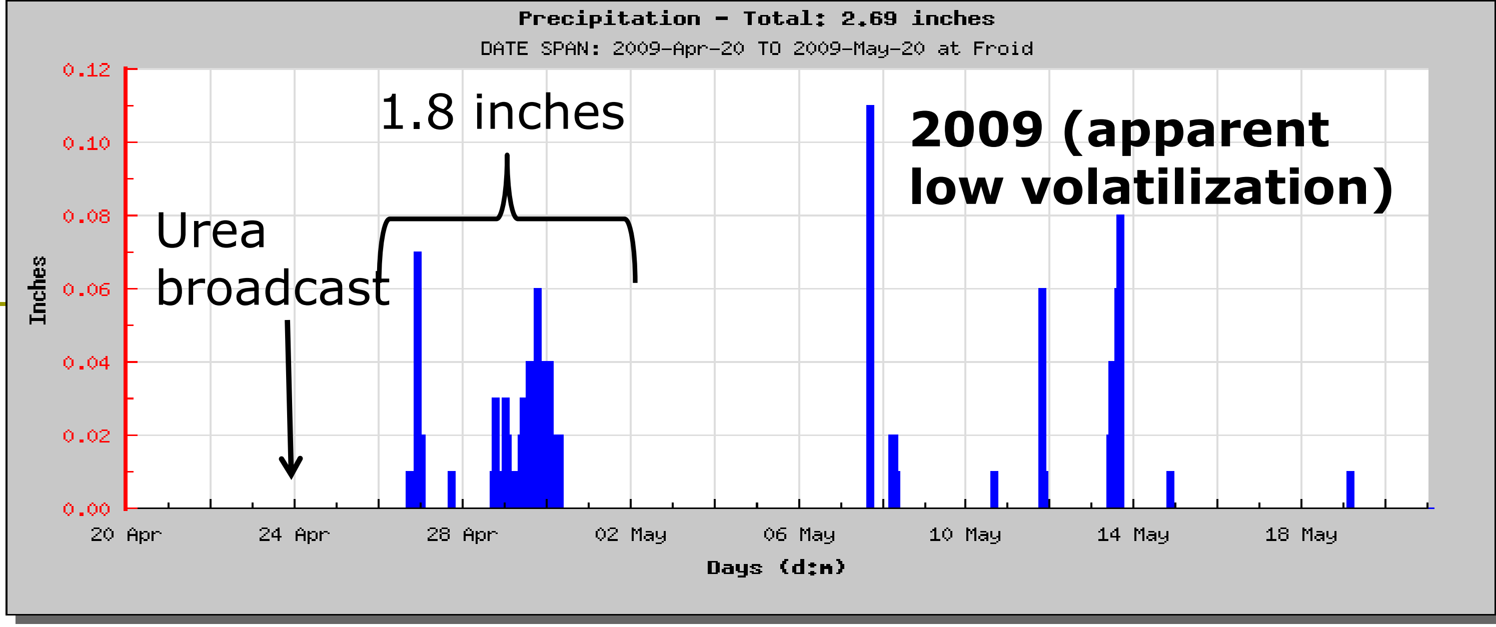
3. About 50% of N uptake comes from fertilizer (rest from soil). So 20% of 50% is 10% difference in N availability-might not make a statistically SIGNIFICANT difference (though still a bottom line difference).

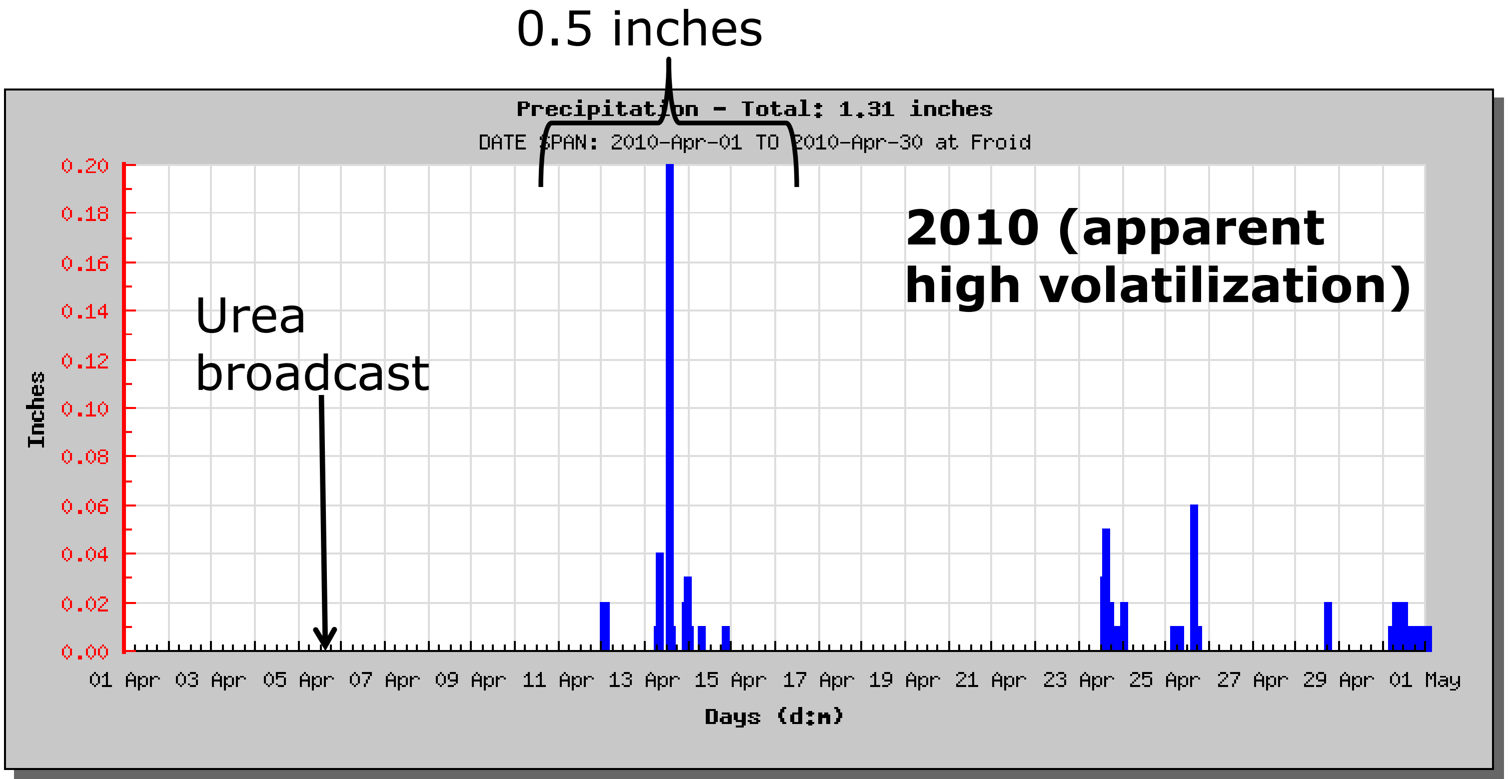
4. With longer term no-till could 'urease' enzyme concentrations have increased? It is known that residue contains more urease than bare soil.

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.

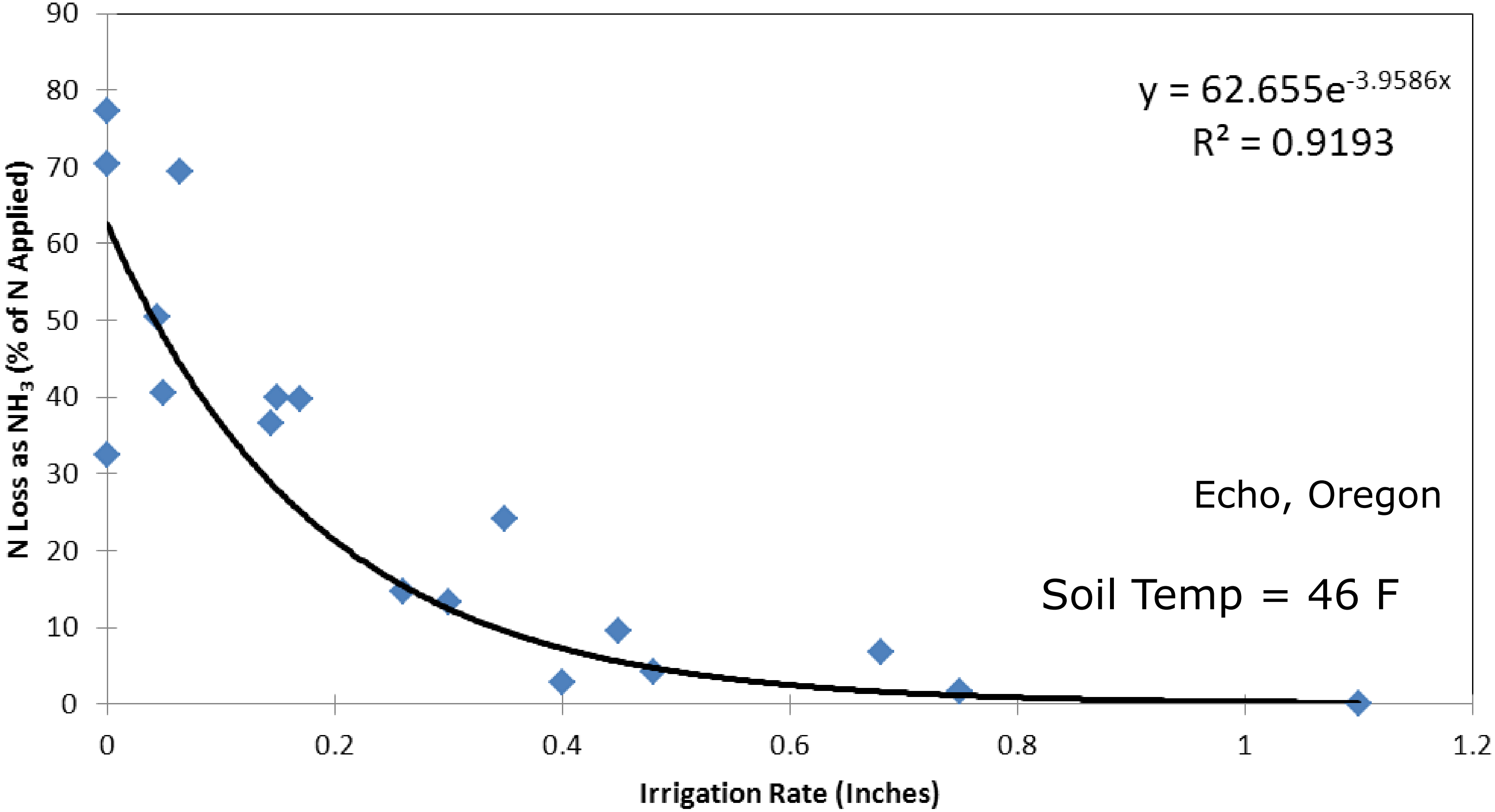
# Effect of Urea Placement on Hays Annual Forage Yield



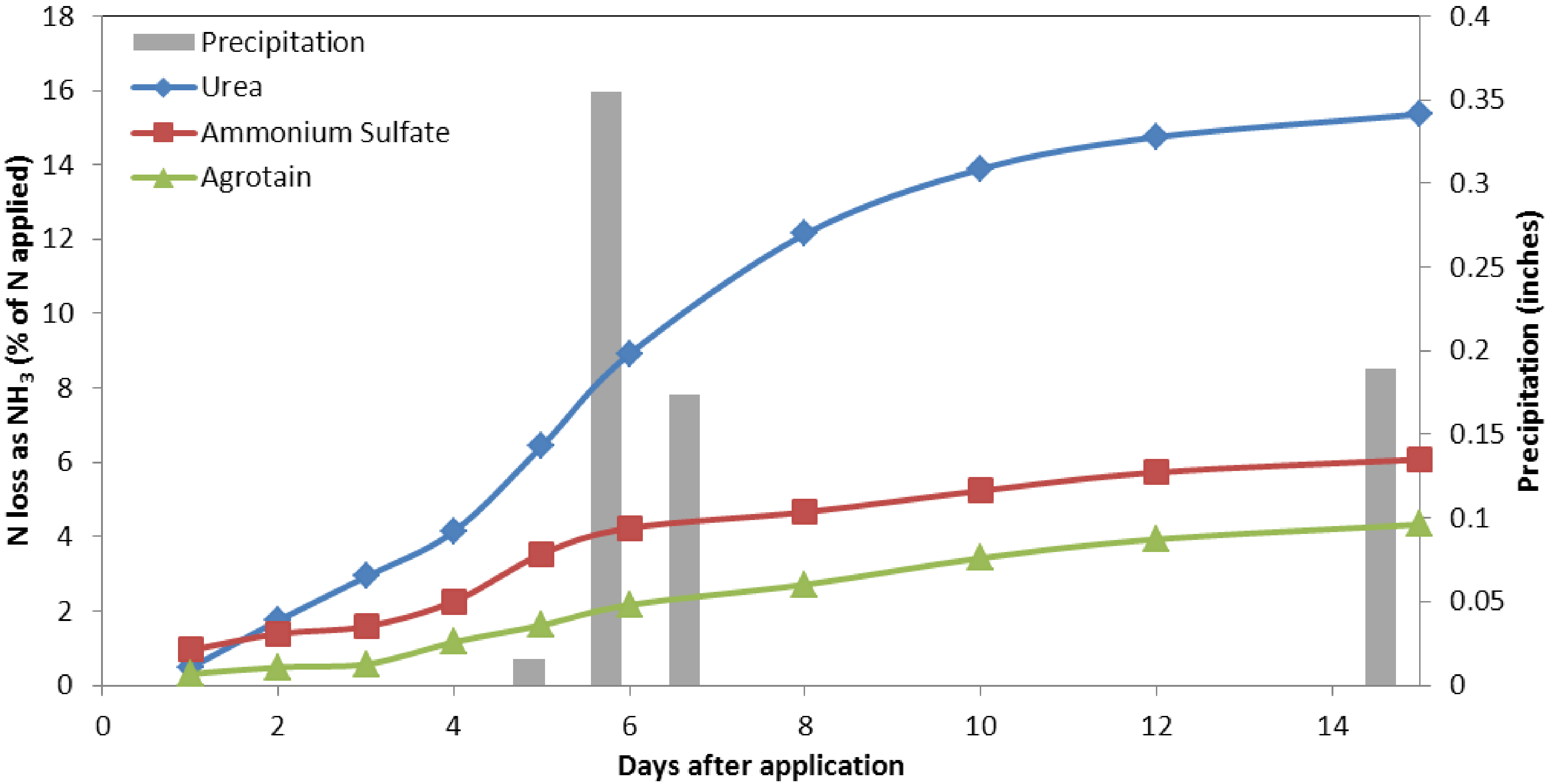

Precipitation - Total: 2.69 inches
DATE SPAN: 2009-Apr-20 TO 2009-May-20 at Froid
1.8 inches
2009 (apparent low volatilization)
Urea broadcast
Inches
0.12
0.10
0.08
0.06
0.04
0.02
0.00
20 Apr
24 Apr
28 Apr
02 May
06 May
10 May
14 May
18 May
Days (d:m)


0.5 inches
Precipitation - Total: 1.31 inches
DATE SPAN: 2010-Apr-01 TO 2010-Apr-30 at Froid
2010 (apparent high volatilization)
Urea broadcast
Inches
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
01 Apr
03 Apr
05 Apr
07 Apr
09 Apr
11 Apr
13 Apr
15 Apr
17 Apr
19 Apr
21 Apr
23 Apr
25 Apr
27 Apr
29 Apr
01 May
Days (d:m)

# Effect of irrigation rate on urea volatilization (Horneck, unpub data)

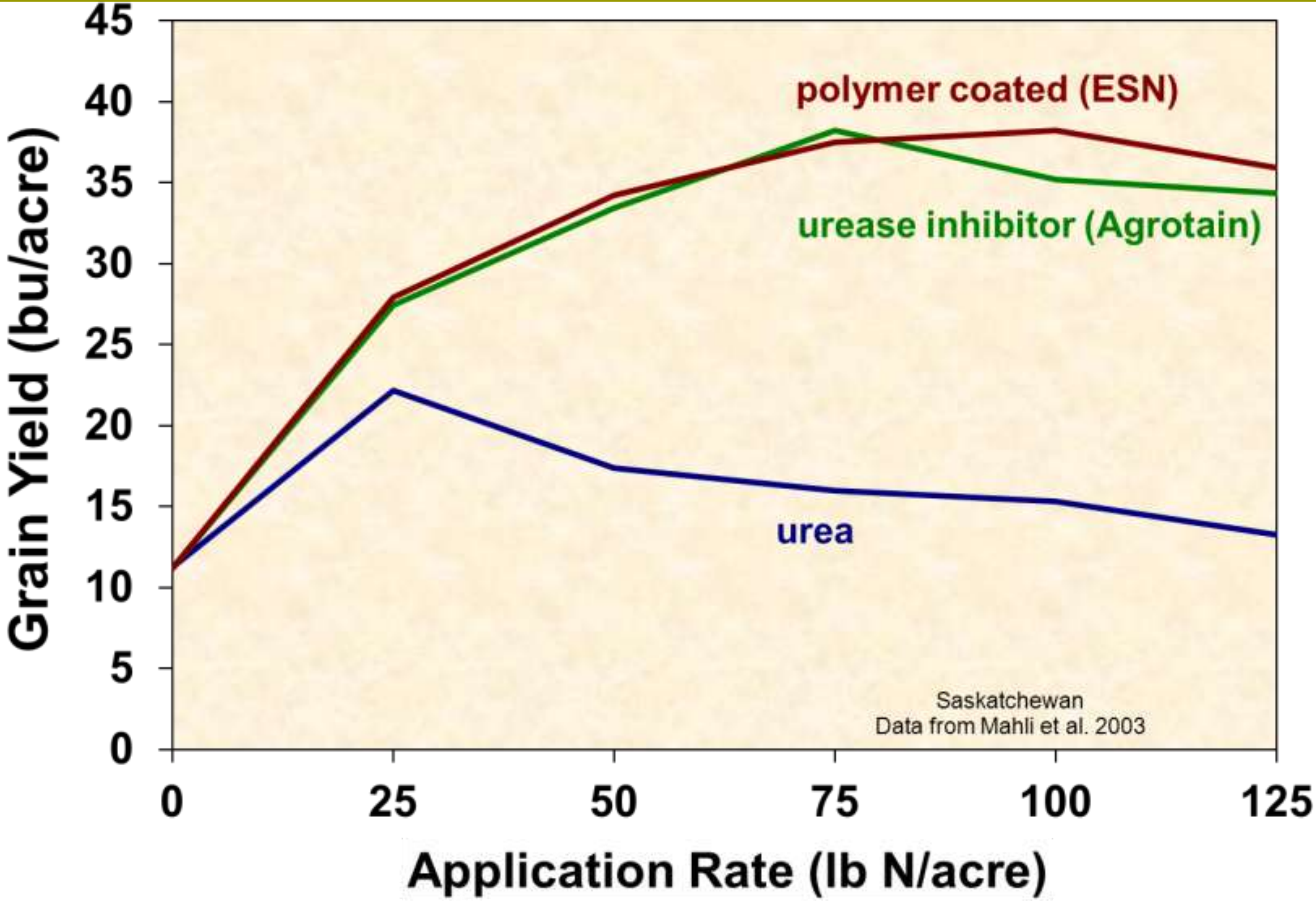


# Does ½ inch of rain also stop volatilization? (Horneck unpub data)




Not if spread out over 3 days

# Effect of N source applied with the seed on dryland spring wheat yield



# 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.

# For more information

- Soil Fertility Website: http://landresources.montana.edu/soilfertility
- Cropping Systems Website: http://scarab.msu.montana.edu/CropSystems