Urea Volatilization and Enhanced Efficiency Nitrogen Fertilizers for Small Grains

Crop Pest Management School

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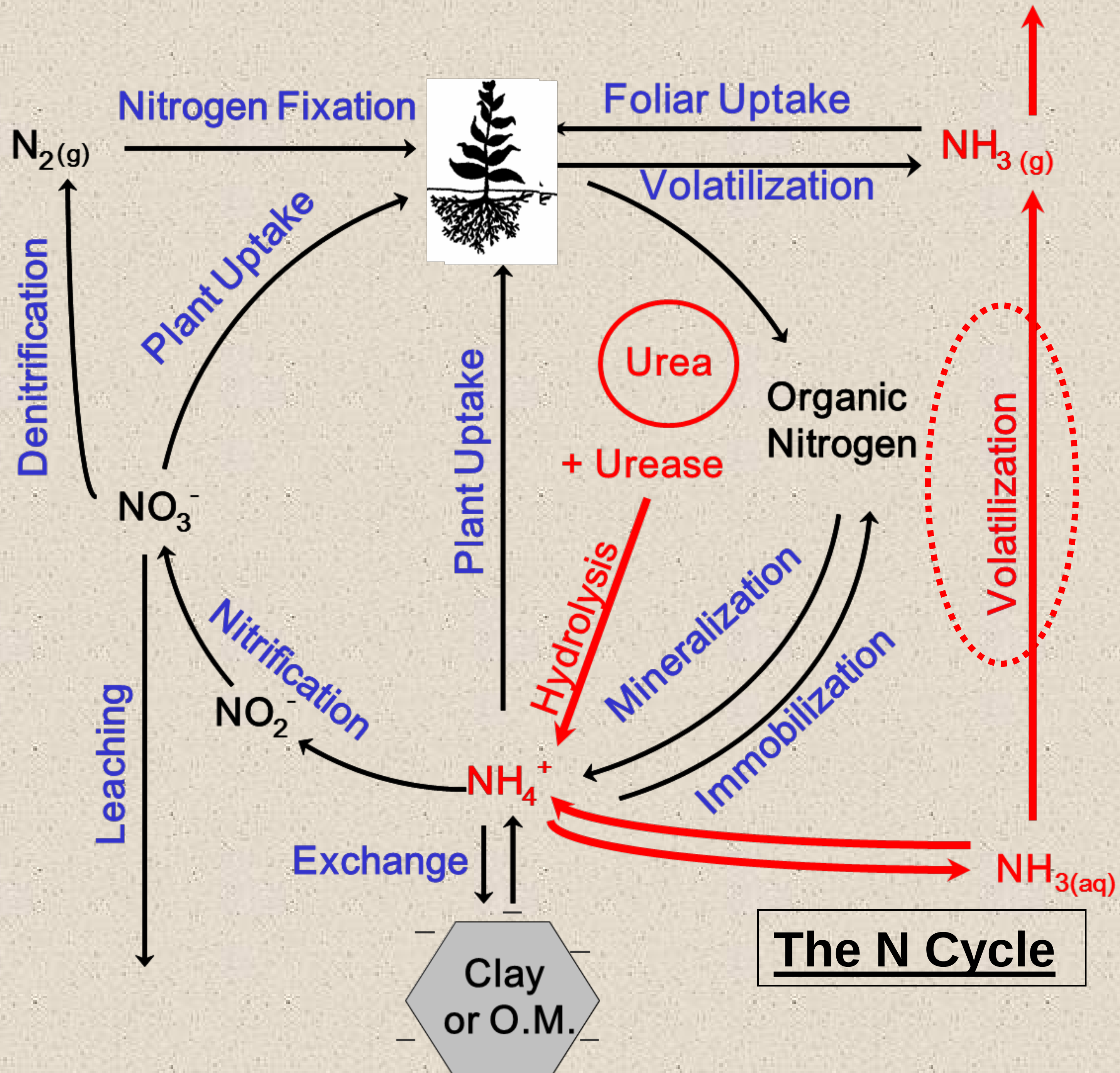
MONTANA STATE UNIVERSITY EXTENSION

AGRICULTURE

MAKING A DIFFERENCE IN MONTANA COMMUNITIES

Objectives

- Present urea volatilization study results
- Present fertilizer management options to decrease volatilization
- Explain pros and cons of enhanced efficiency fertilizers (EEFs)
- Show research results for EEFs



N2(g)
Nitrogen Fixation
Foliar Uptake
NH3 (g)
Volatilization
Denitrification
Plant Uptake
Plant Uptake
Urea
+ Urease
Organic Nitrogen
Volatilization
NO3-
Hydrolysis
Mineralization
Immobilization
Nitrification
NO2-
Leaching
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)

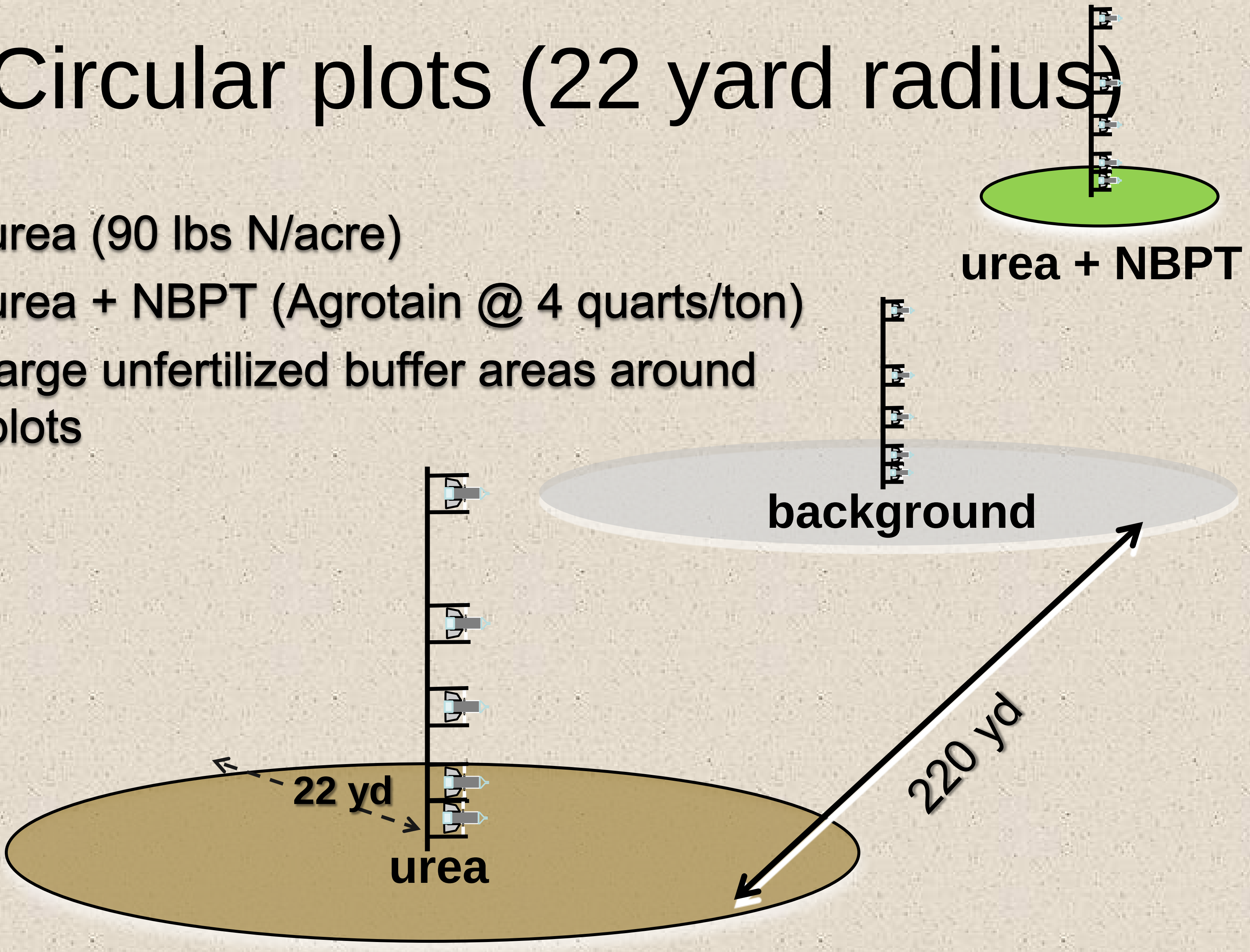
Integrated horizontal flux method

- 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)

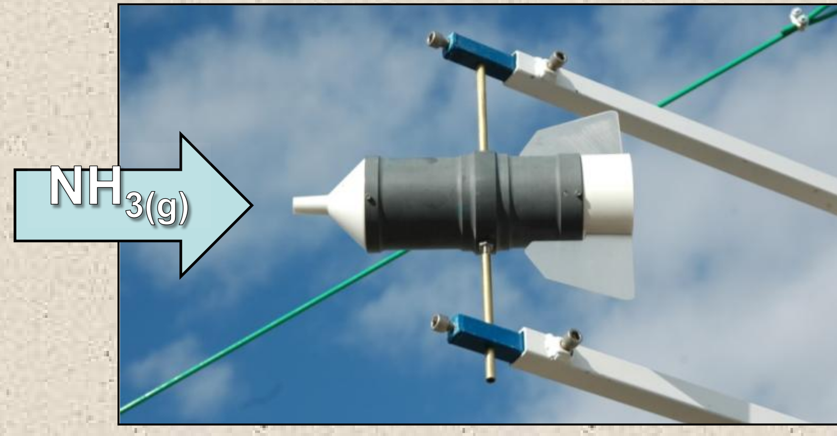
- urea (90 lbs N/acre)
- urea + NBPT (Agrotain @ 4 quarts/ton)
- large unfertilized buffer areas around plots



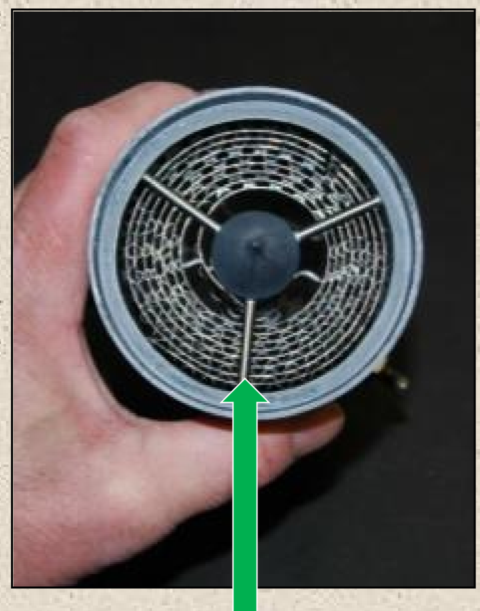
Methods

Shuttles

- traps for collecting ammonia



front



stainless steel spiral coated with oxalic acid

back

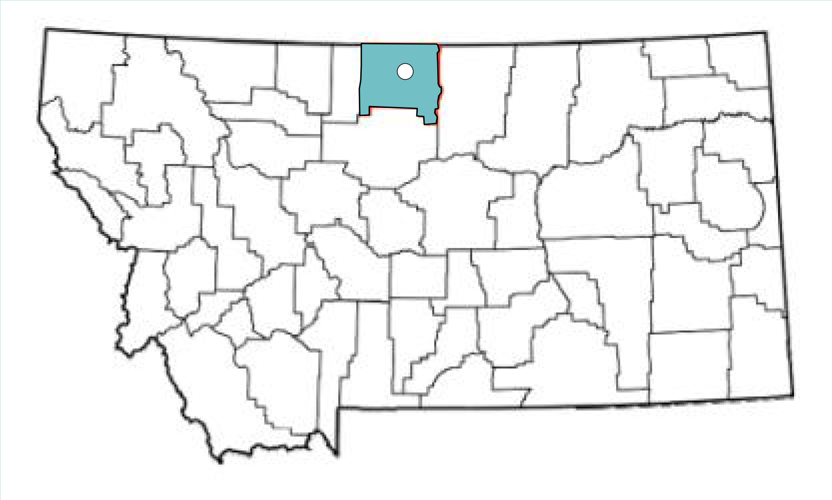
rotate on pivot & face into wind

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



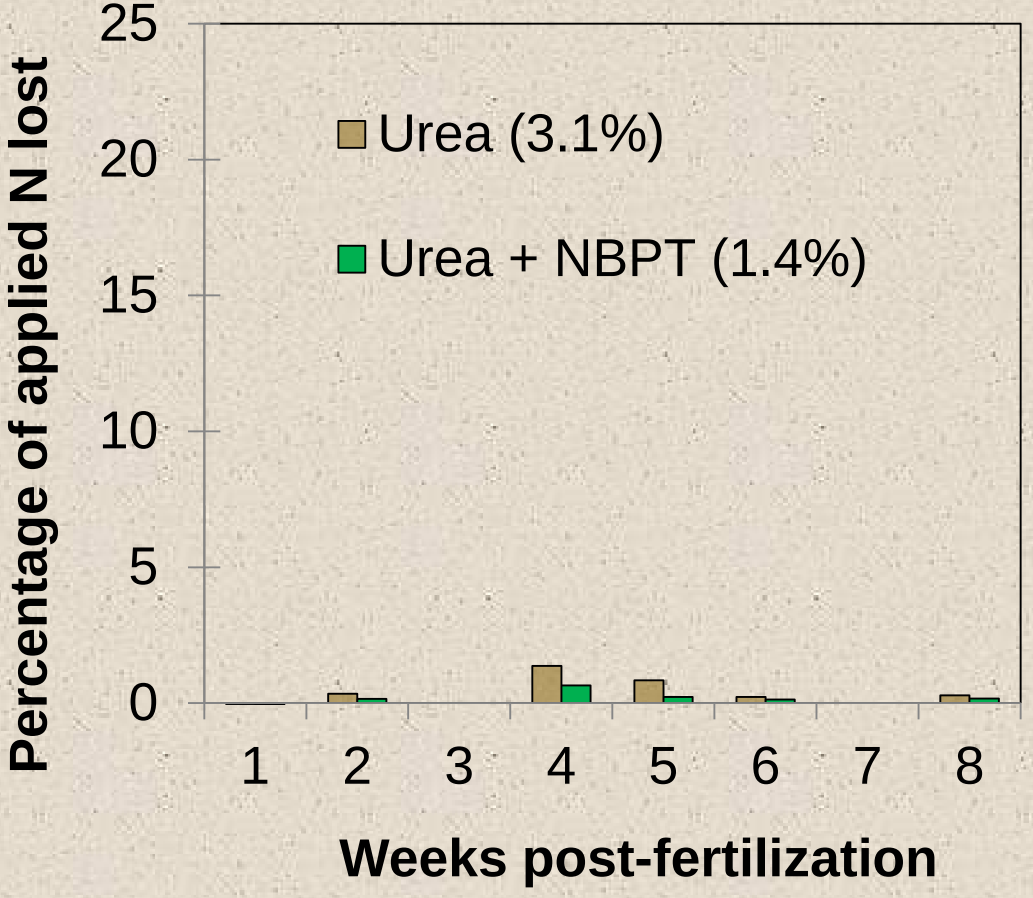
Campaign #2 – low NH_3 losses observed

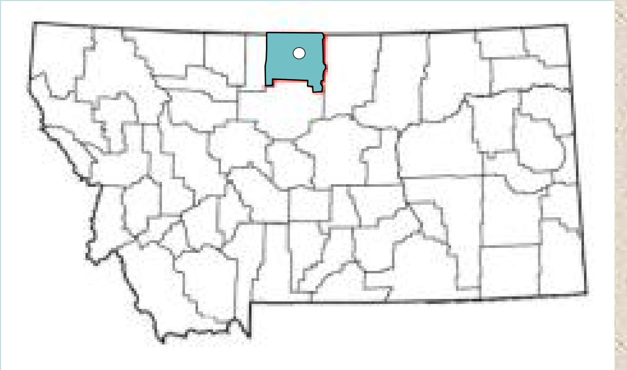
- October 9, 2008 application, air-temp. 45 °F, dry soil surface

- 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

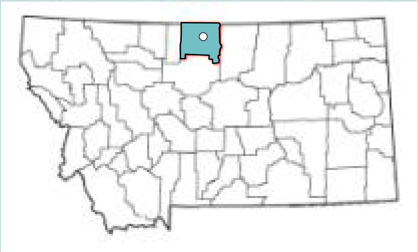




Mean Air Temp ~ 42 F

Mean Soil Temp ~ 41 F

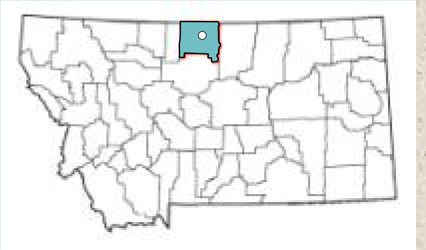
Campaign #5 - high NH_3 losses observed

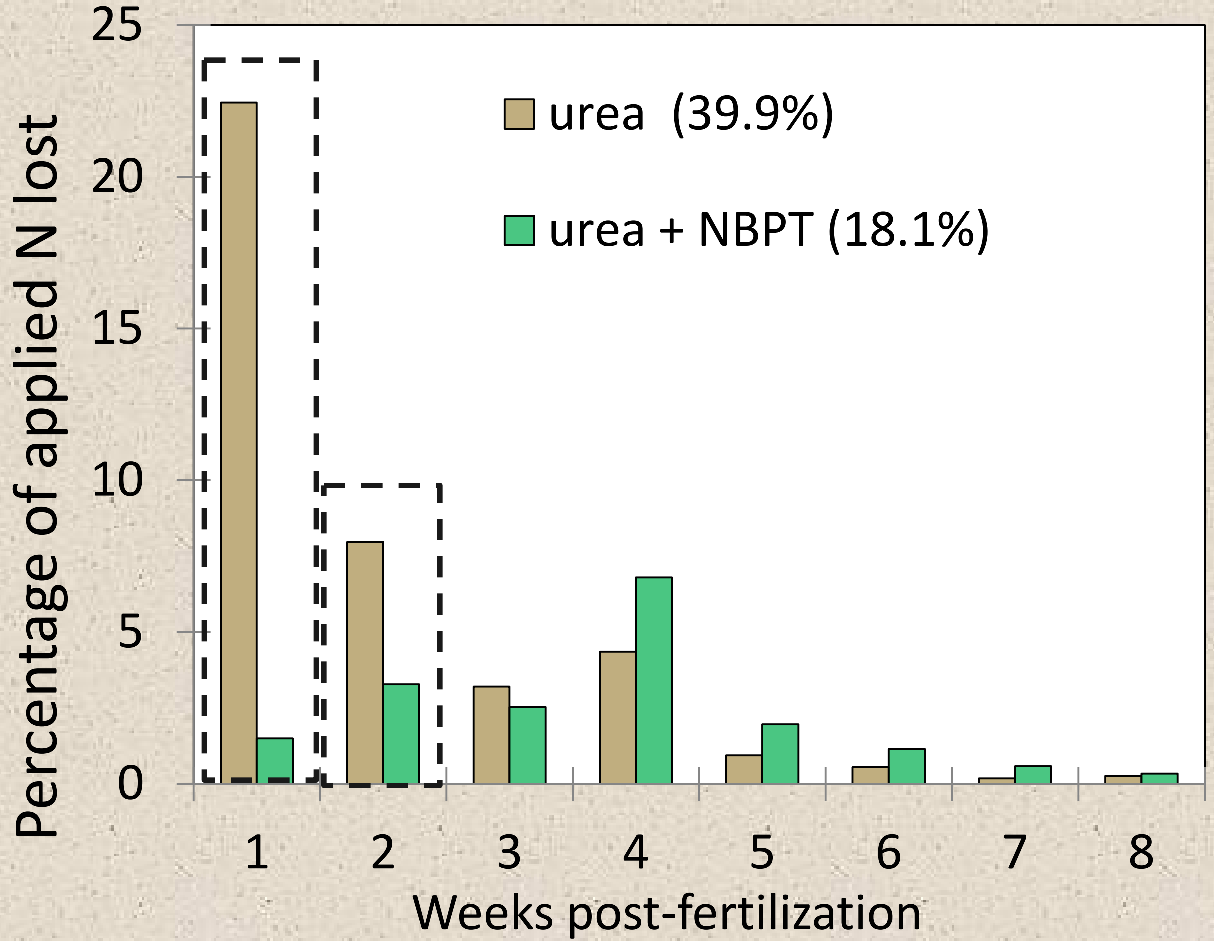


Fertilizer applied on Mar 26, 2009 light snow on soil surface and air temp = 21 F

soil surface with fertilizer prills beginning to dissolve

Campaign #5 - Kaercher farm





Precipitation

no rain 0-2 wks

1.54” 2-8 wks

Mean temperature

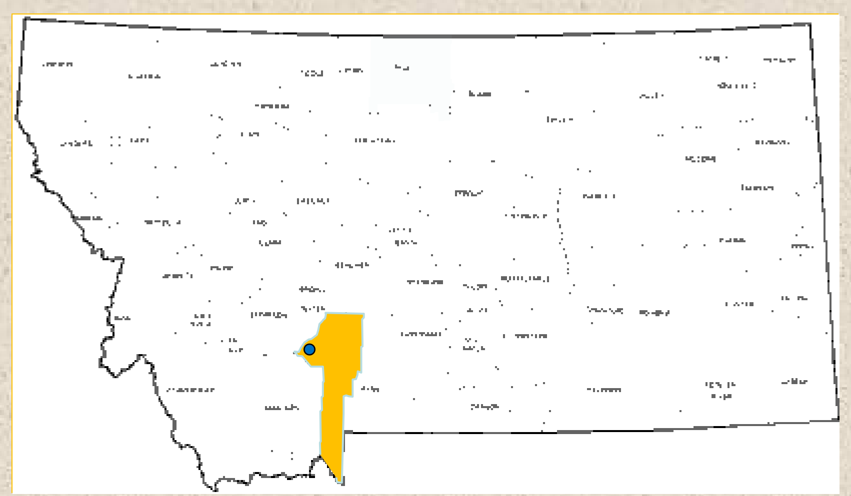
Soil = 38 °F

Air = 39 °F

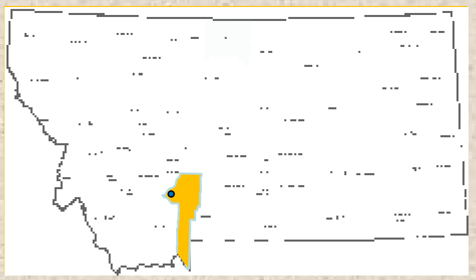
Conclusion: High losses observed even though temperatures were cold!

Campaign 9 & 10 – Willow Creek Brocko silt loam

- calcareous soils, pH 8.3

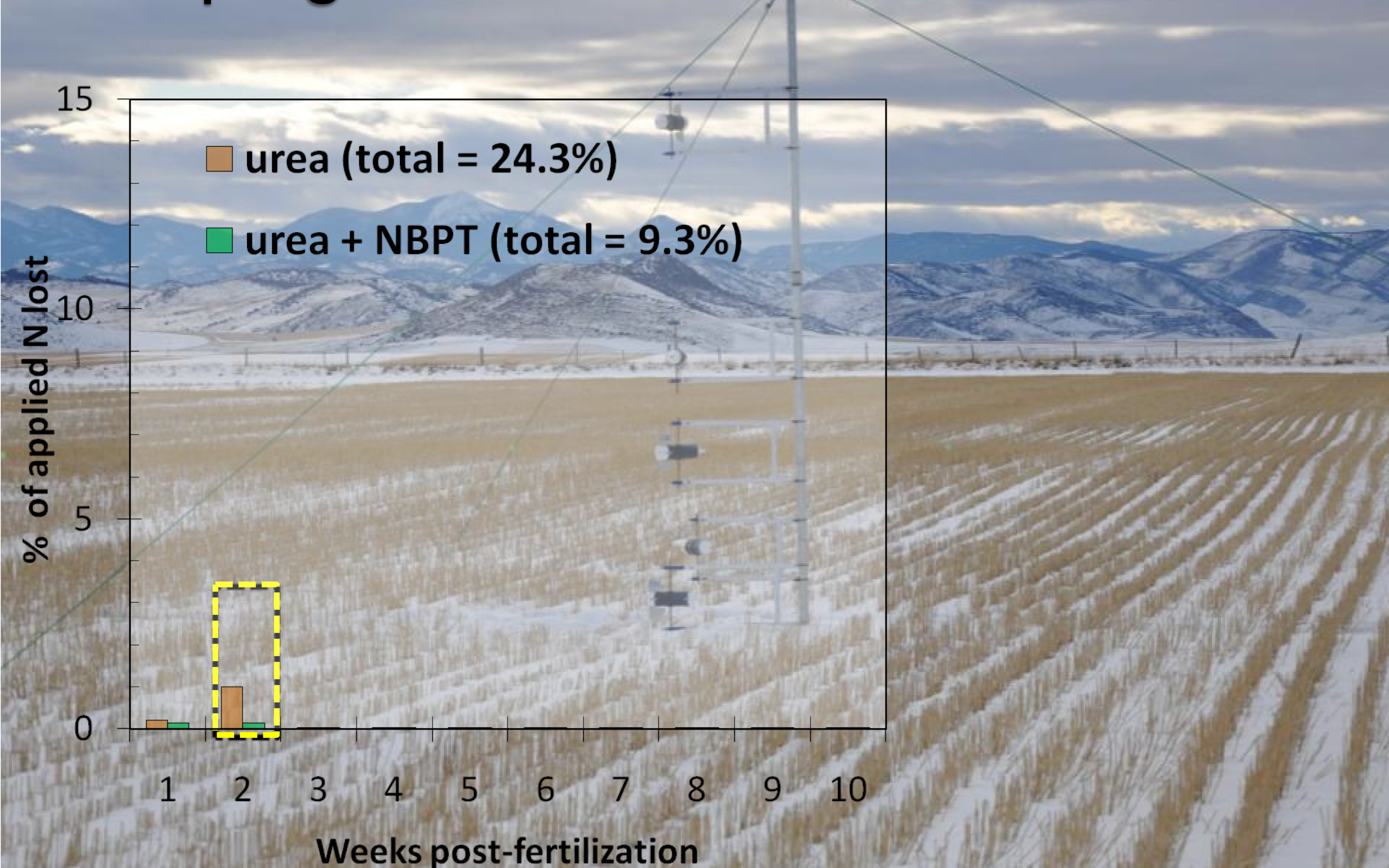


Campaign 9 – Willow Creek – Jan. 27



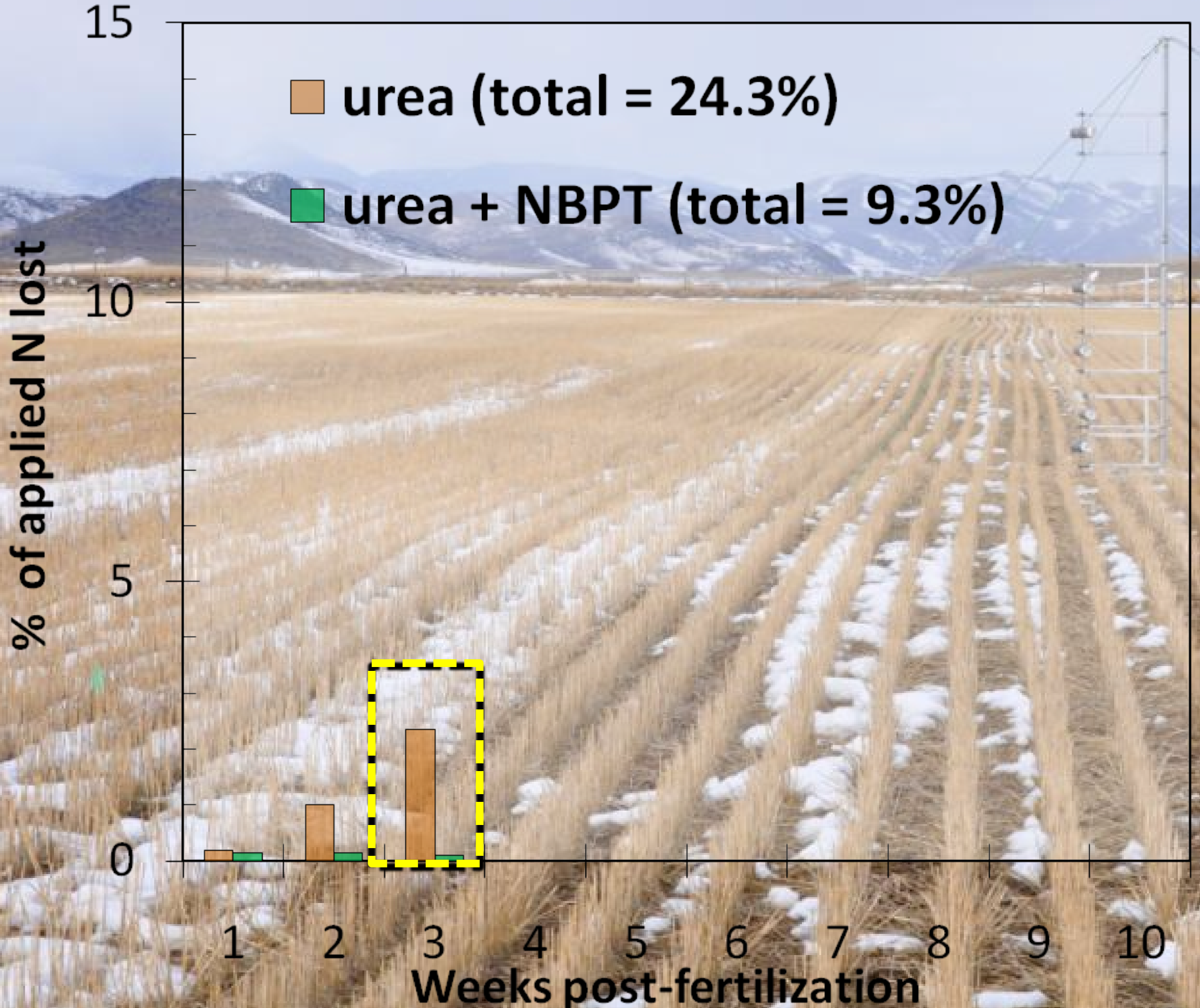
Results

Campaign 9 – Willow Creek – Feb. 10



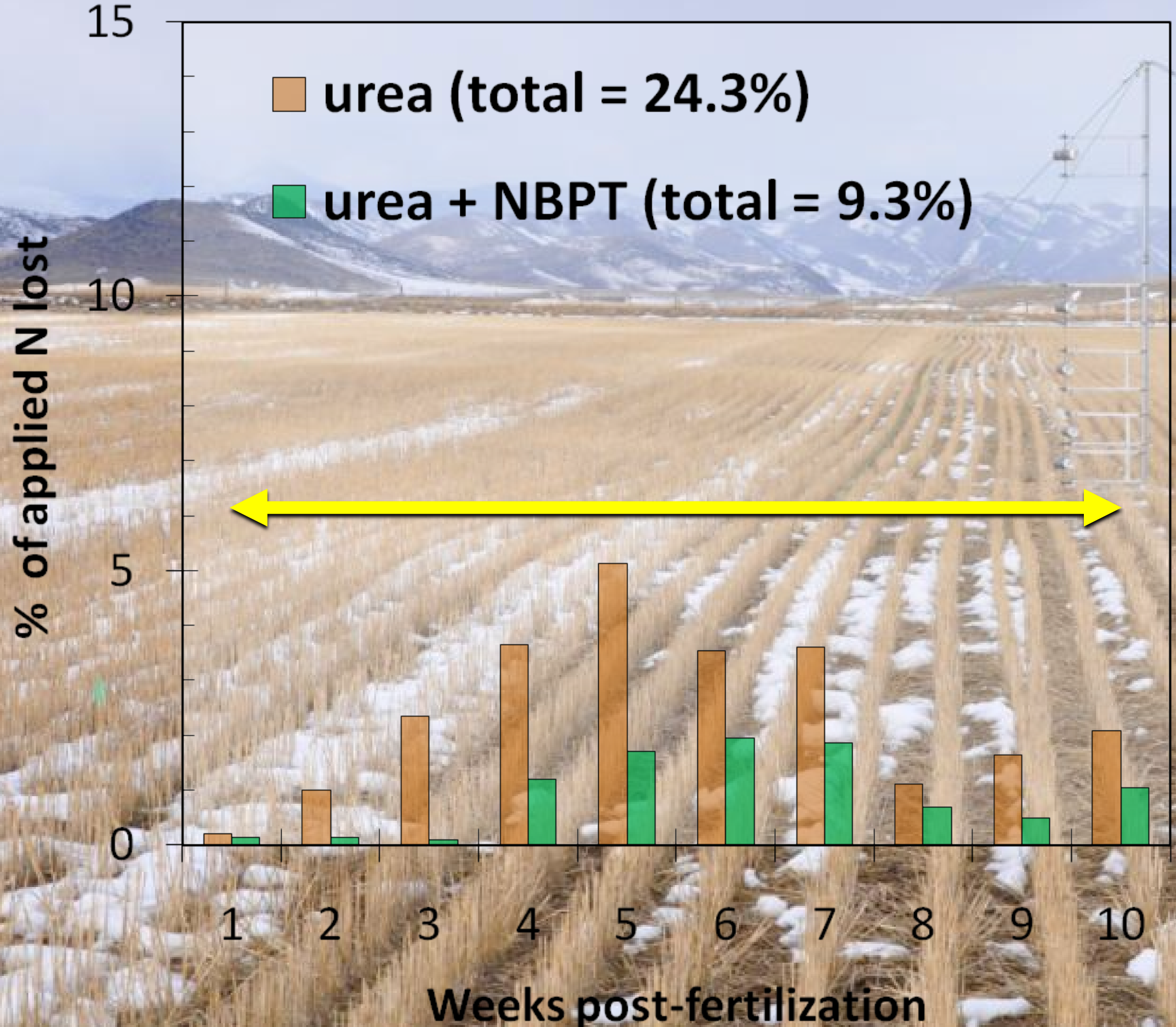
Results

Campaign 9 – Willow Creek – Feb. 17



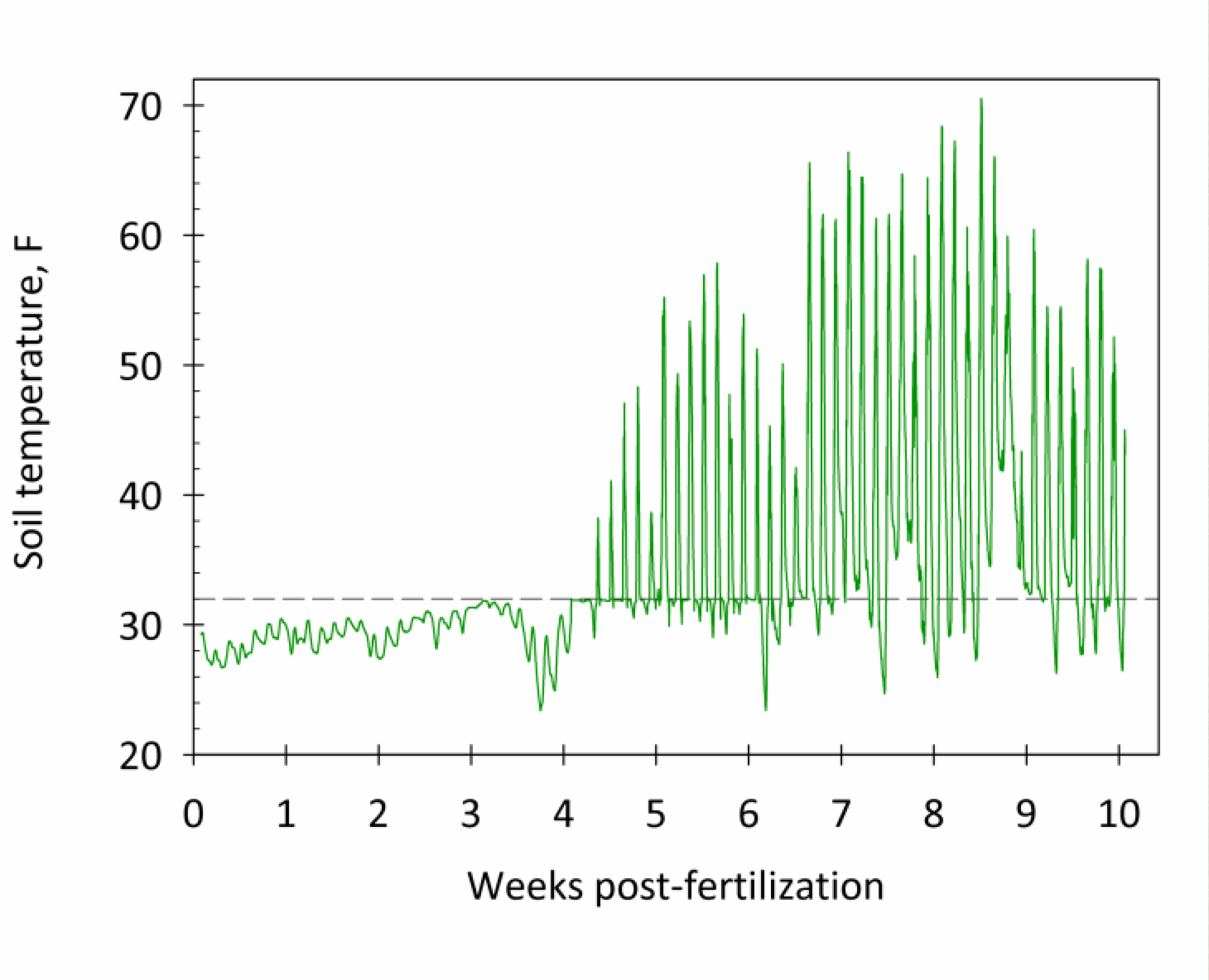
- no runoff

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

Contact Us

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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

Summary – take home messages

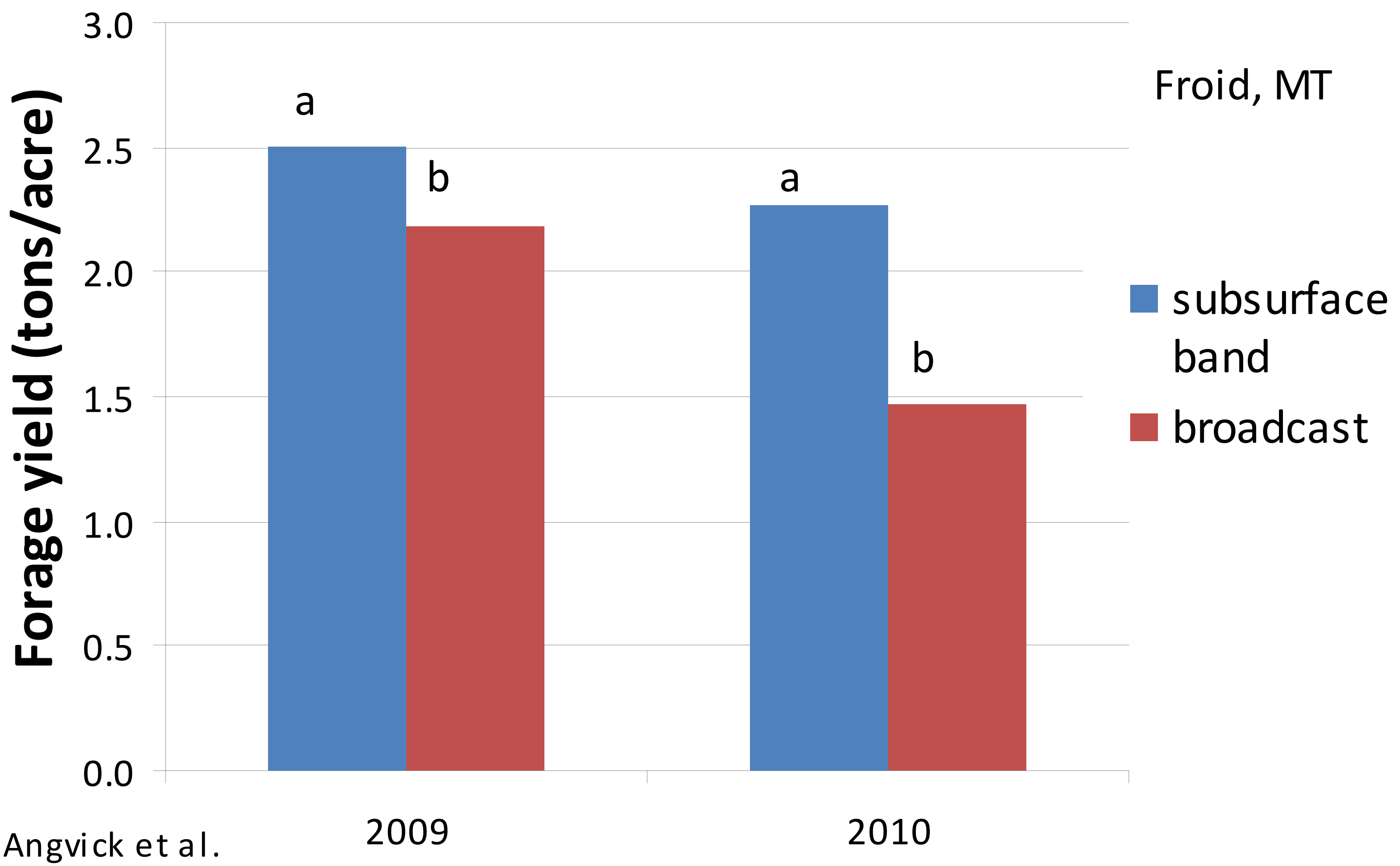
- Significant ammonia losses (30-40% of applied N) from surface-applied urea can occur even though soil temperatures are near freezing!
- Soil moisture conditions at surface that dissolve urea granules (i.e. prolonged damp) without rain promote high ammonia losses (*more common to find these conditions 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)

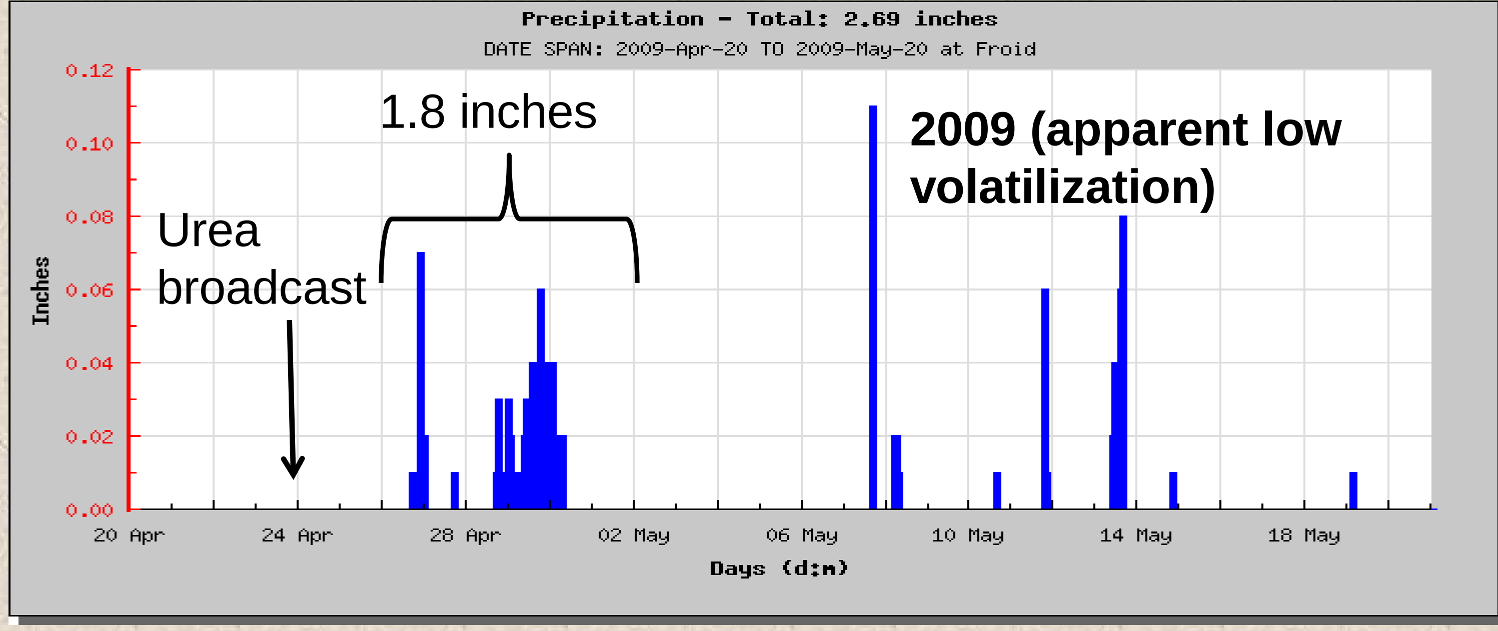
1. Adequate precipitation may have occurred after application.
2. Urea takes 2 - 5 weeks to become available whereas AN is immediately available for plants and for other losses-urea's 'slow release' property may increase its efficiency, making up for loss.
3. About 50% of N uptake comes from fertilizer (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 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

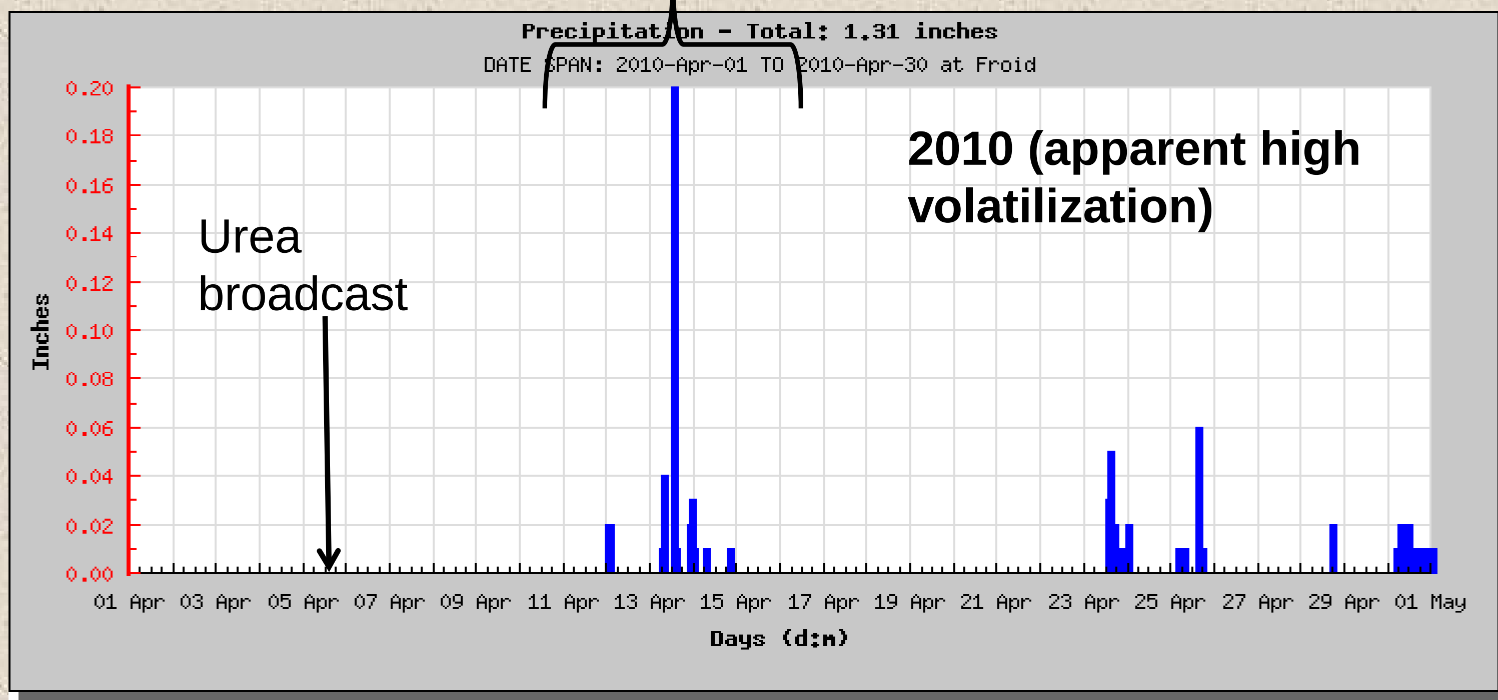
Effect of Urea Placement on Hays Barley (Annual Forage) Yield



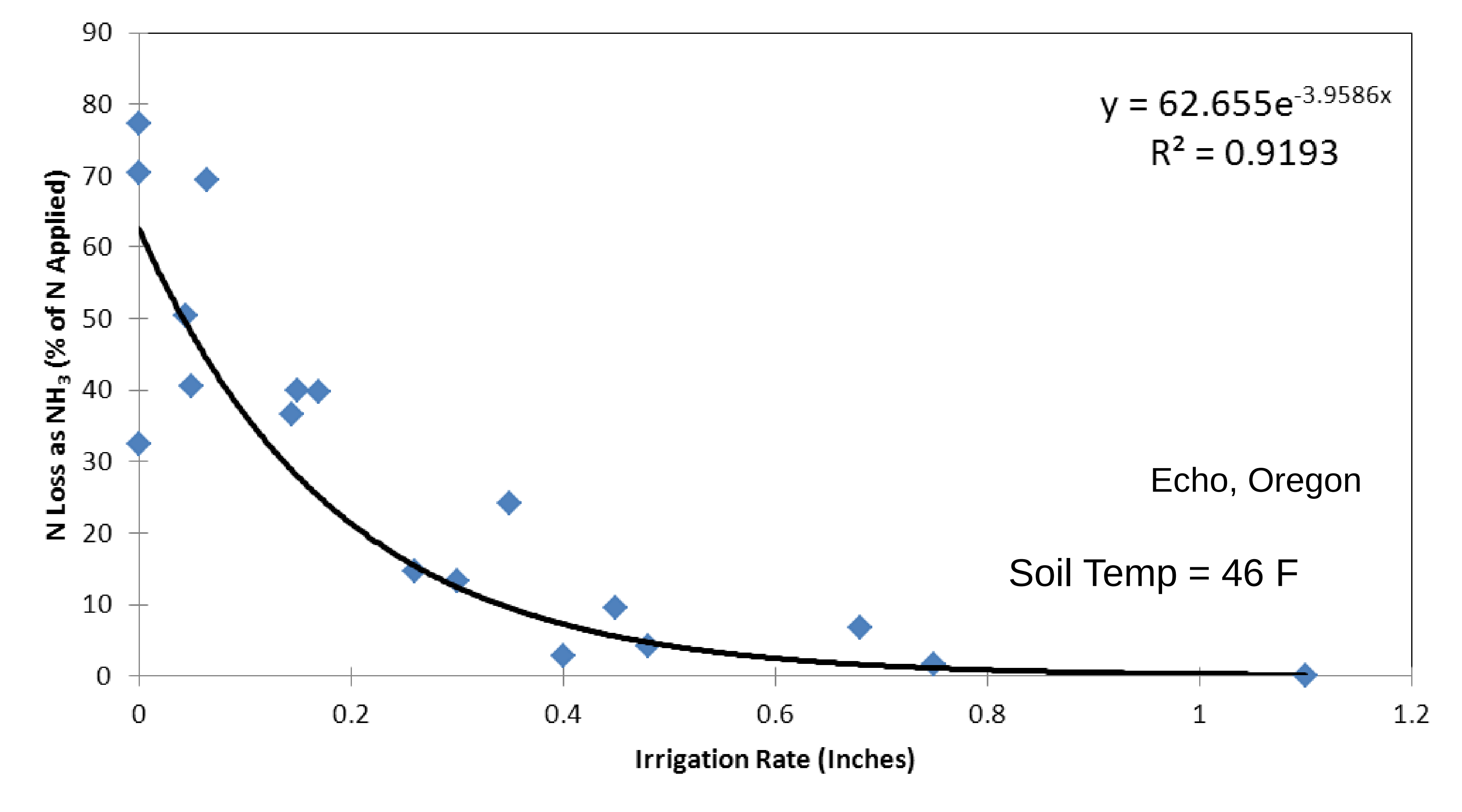
Angvick et al. unpub data


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)

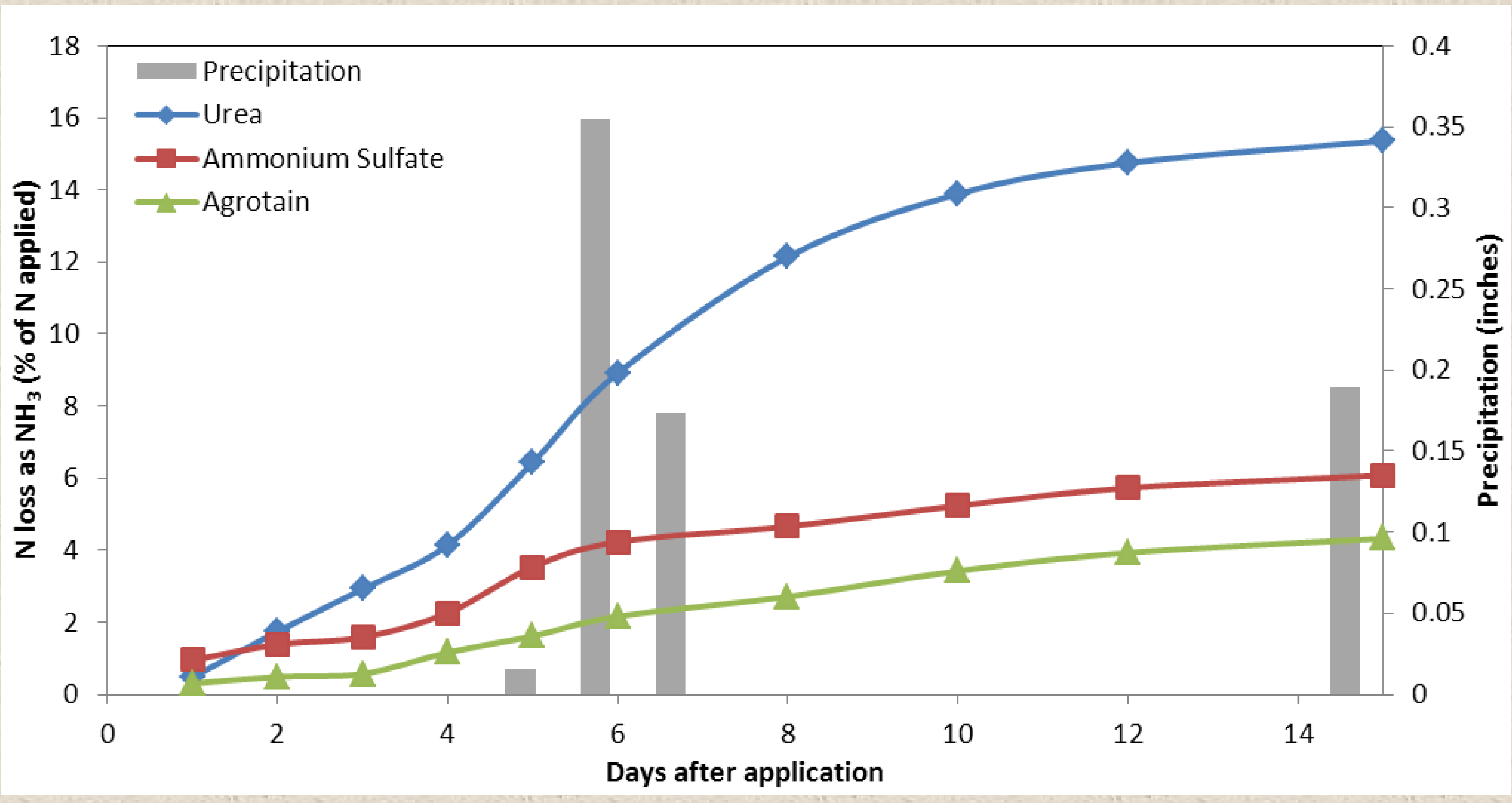
0.5 inches


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

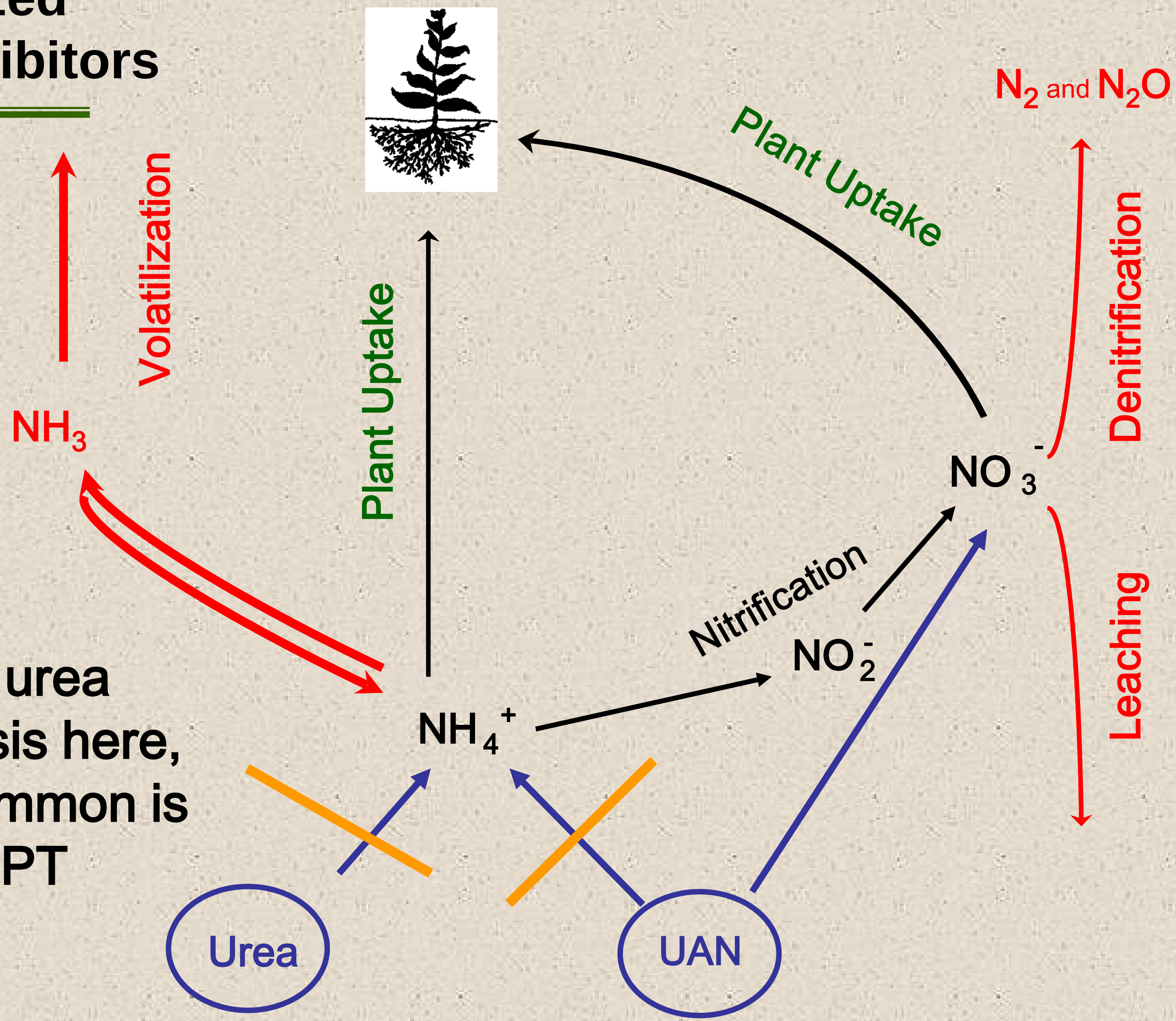
What should you do to minimize volatilization?

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 or a wide opener.
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.

Enhanced Efficiency Fertilizers EEFs

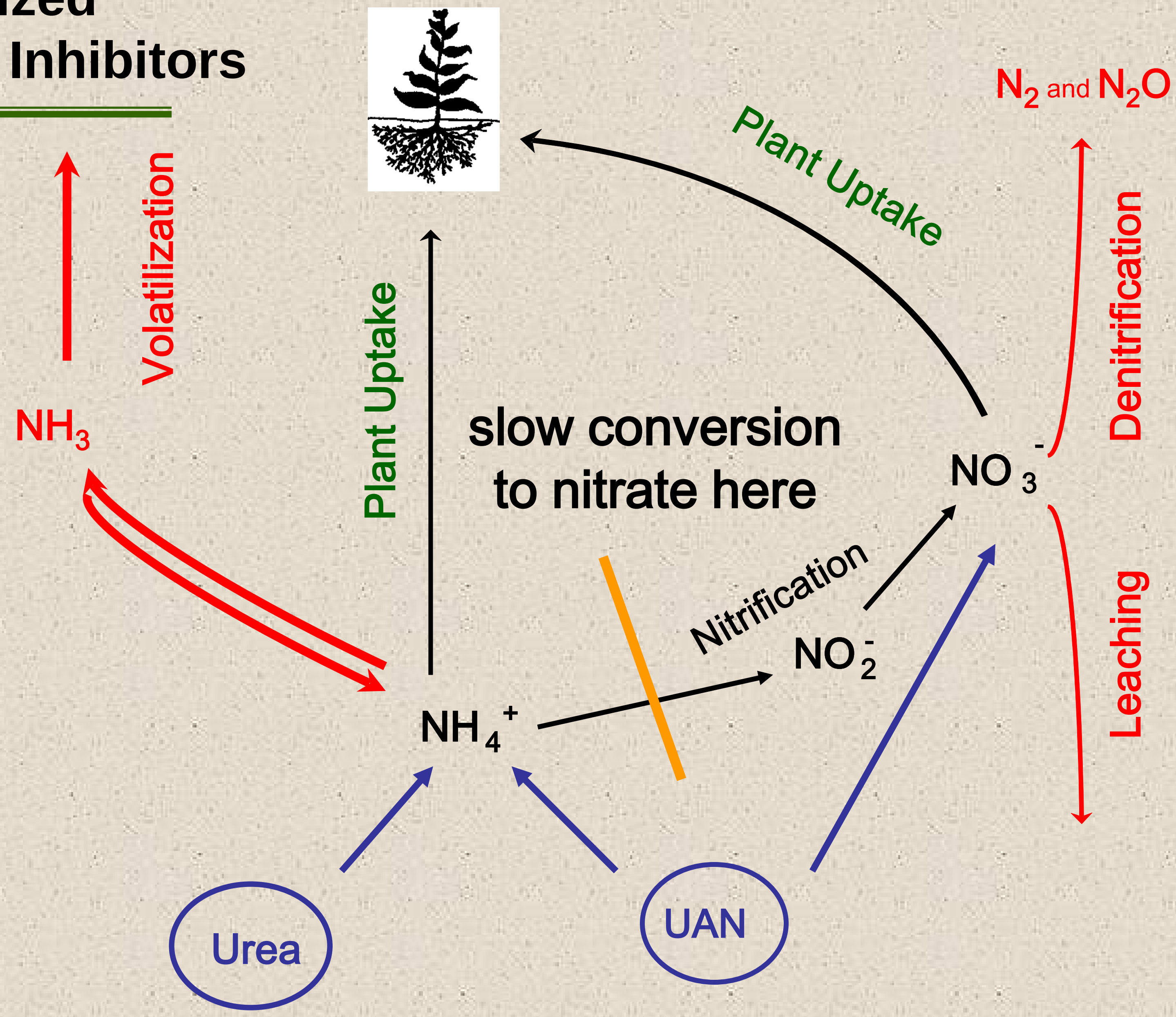
- Any fertilizer designed to:
  - Increase fertilizer availability
  - Decrease fertilizer losses
- 3 major methods of action
  - Stabilized - alter soil microbial or enzymatic reactions
  - Slow release - have additives which require chemical or biological decomposition to release nutrients
  - Controlled release - a semipermeable coating, usually a polymer, regulates release

Stabilized Urease Inhibitors

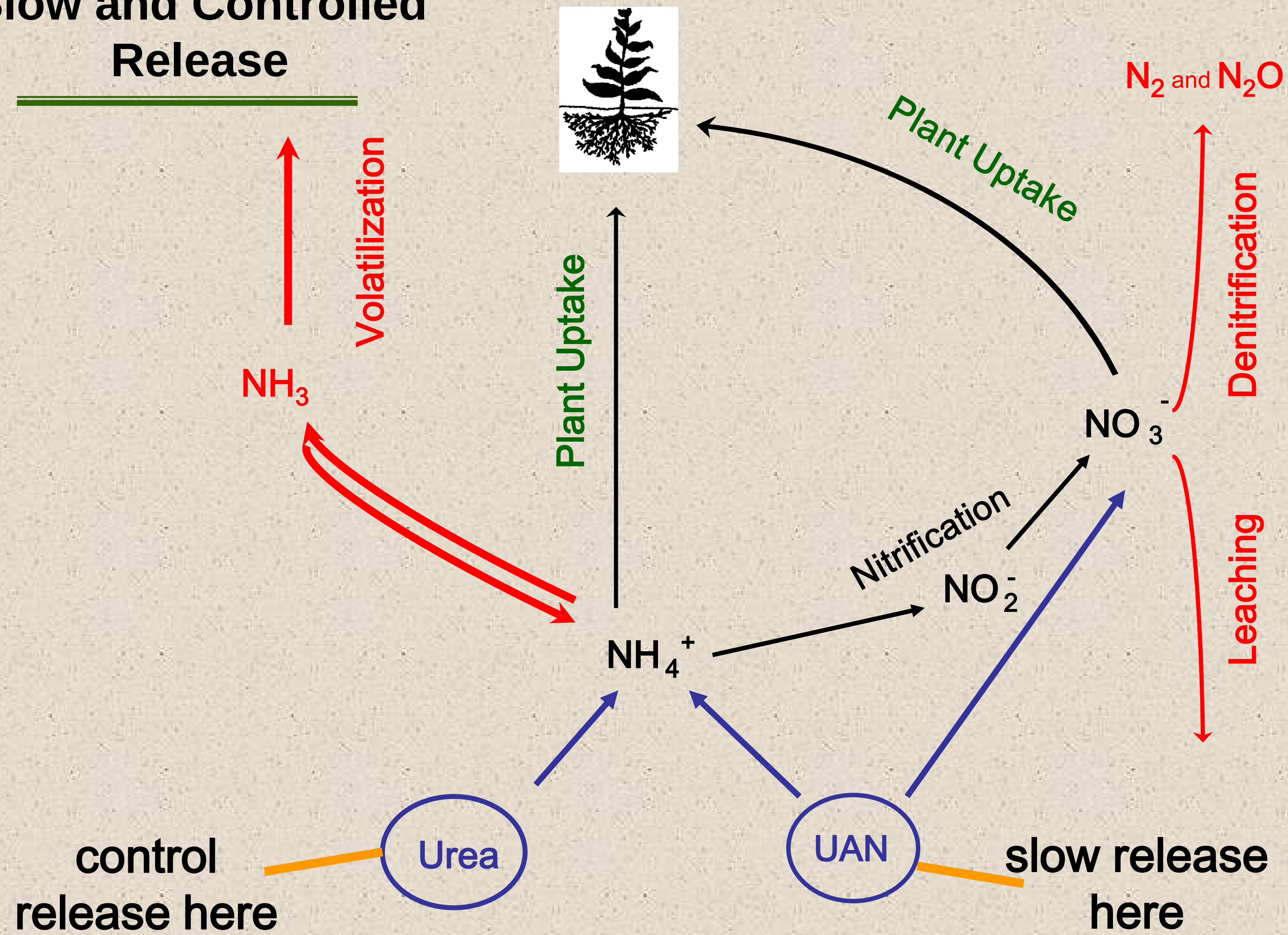


slow urea hydrolysis here, most common is NBPT

Stabilized Nitrification Inhibitors



Slow and Controlled Release



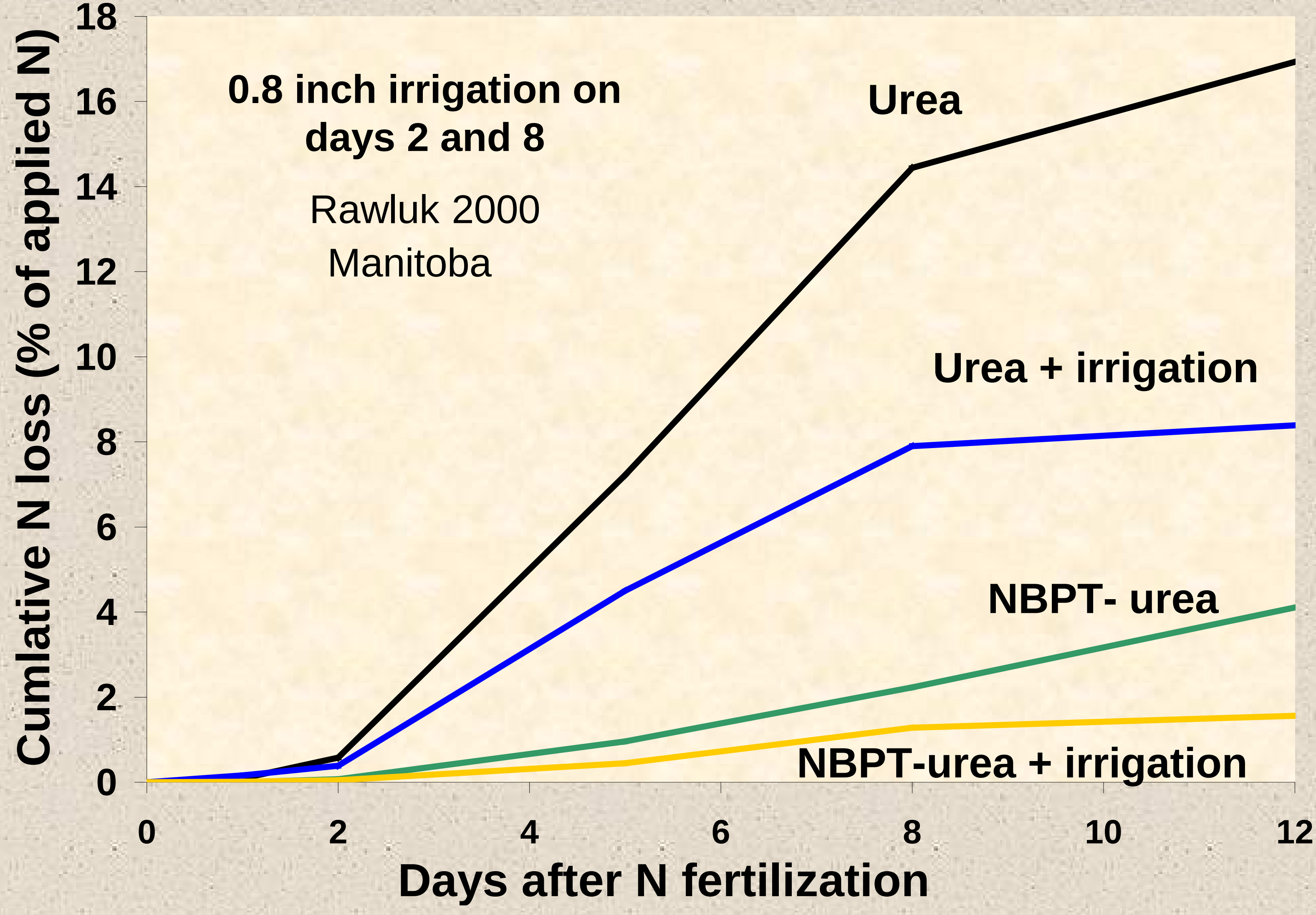
Questions?

Under what growing conditions would you expect EEFs to work better?

- High potential volatilization loss
  - **coarse soils**
  - **moist surface**
  - **warm temps**
  - **long time between application and incorporation**

- High potential leaching
  - **coarse soils**
  - **high moisture content/irrigation/rainfall**

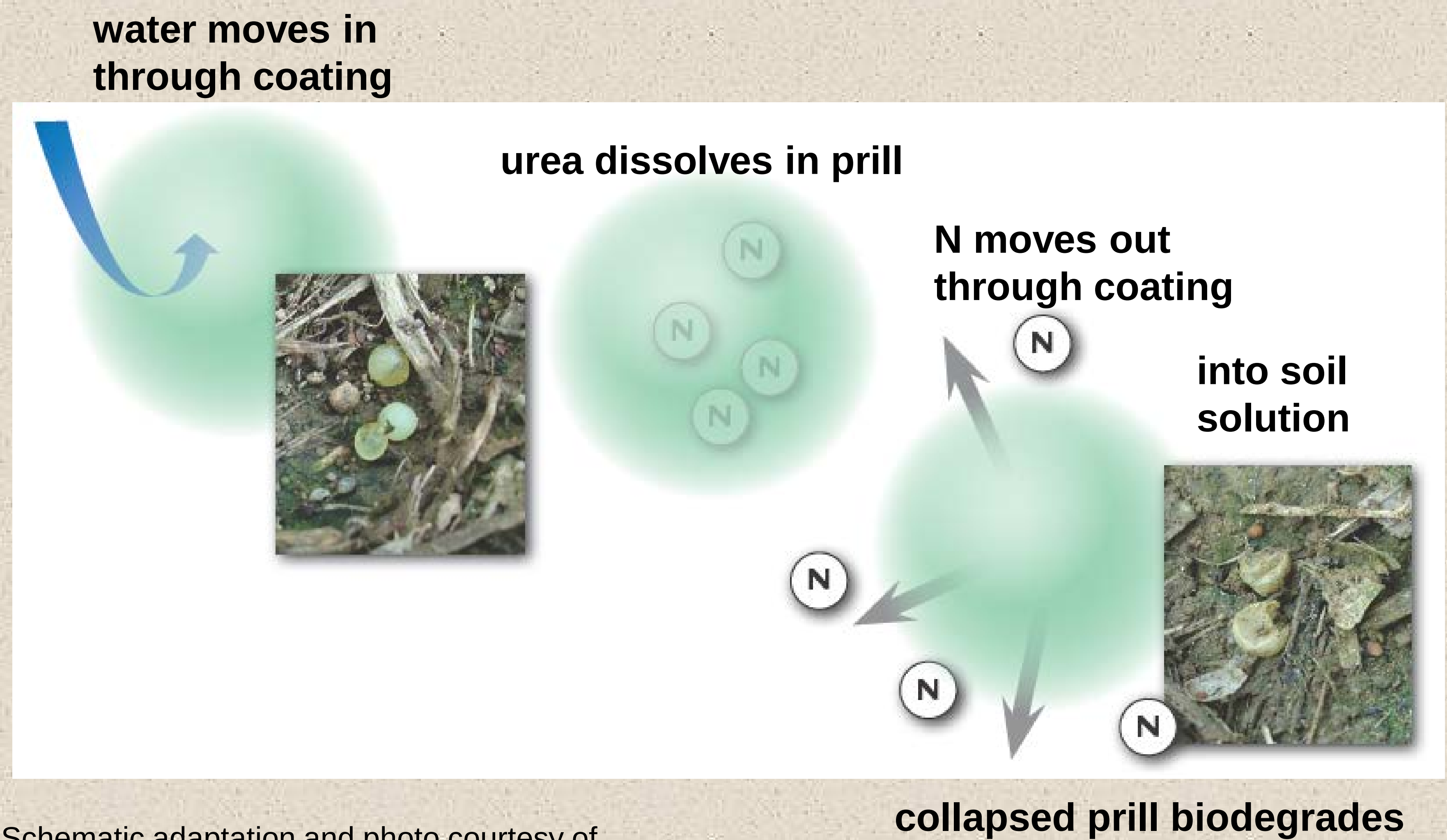
Effect of irrigation and NBPT on volatilization



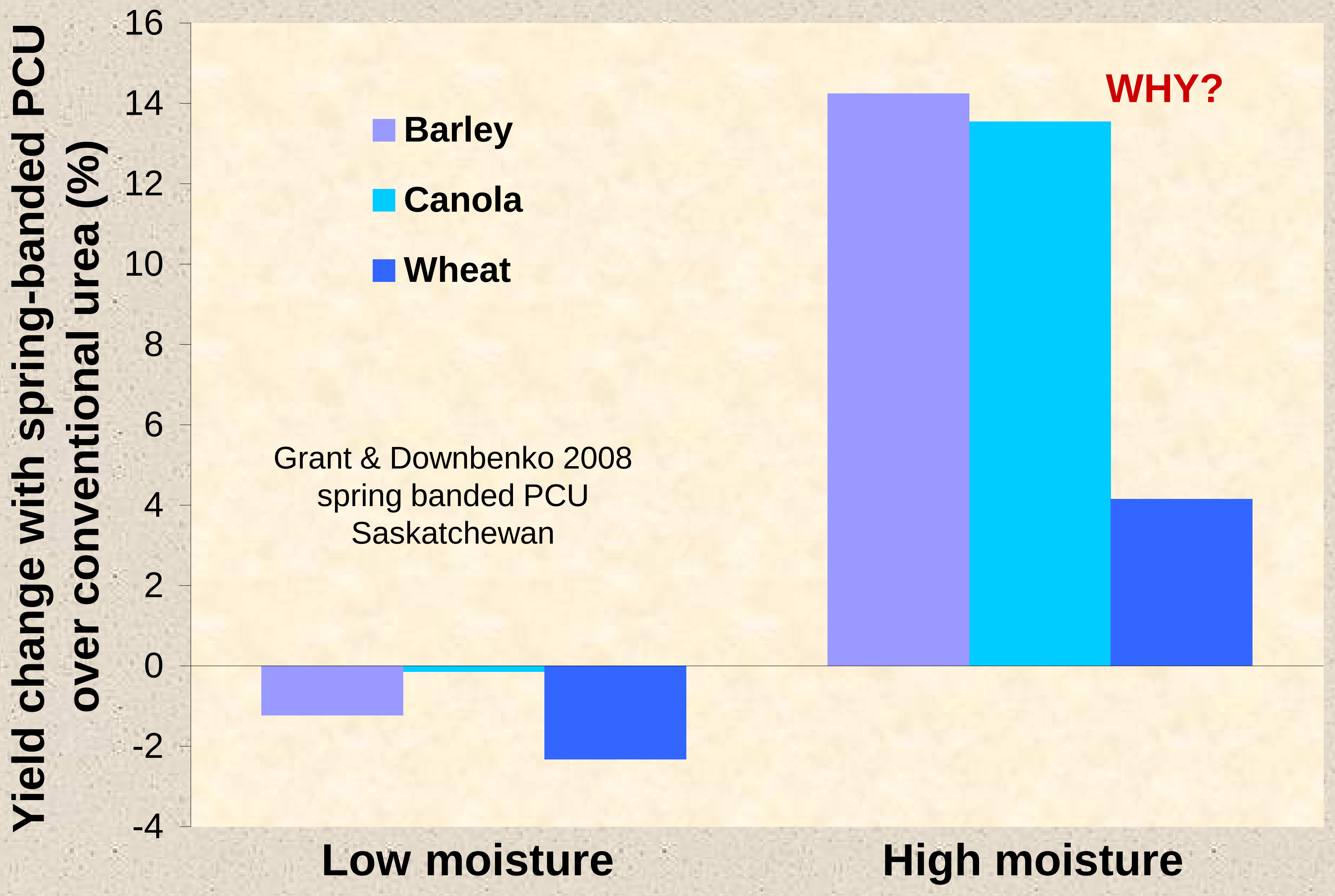
NBPT uses

- Can minimize urea volatilization for several weeks
- ‘Buys’ time for rainfall, irrigation or mechanical incorporation to protect urea
- Warm weather top-dressing
- Cool weather broadcast

N release by polymer-coated (controlled release) fertilizers



Effects of over-winter moisture conditions on effectiveness of PCU

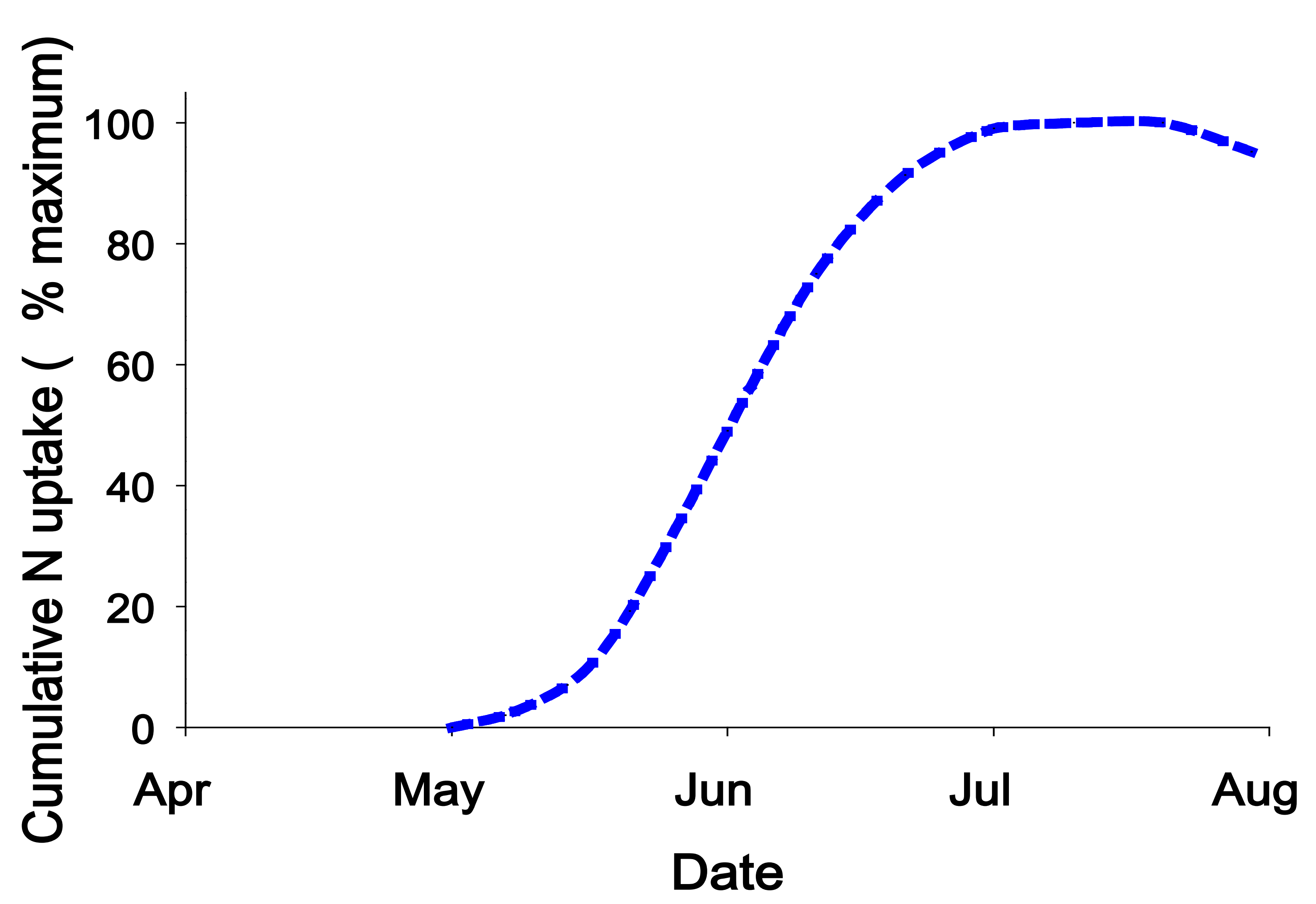


What type of crops would you expect slow release to work better?

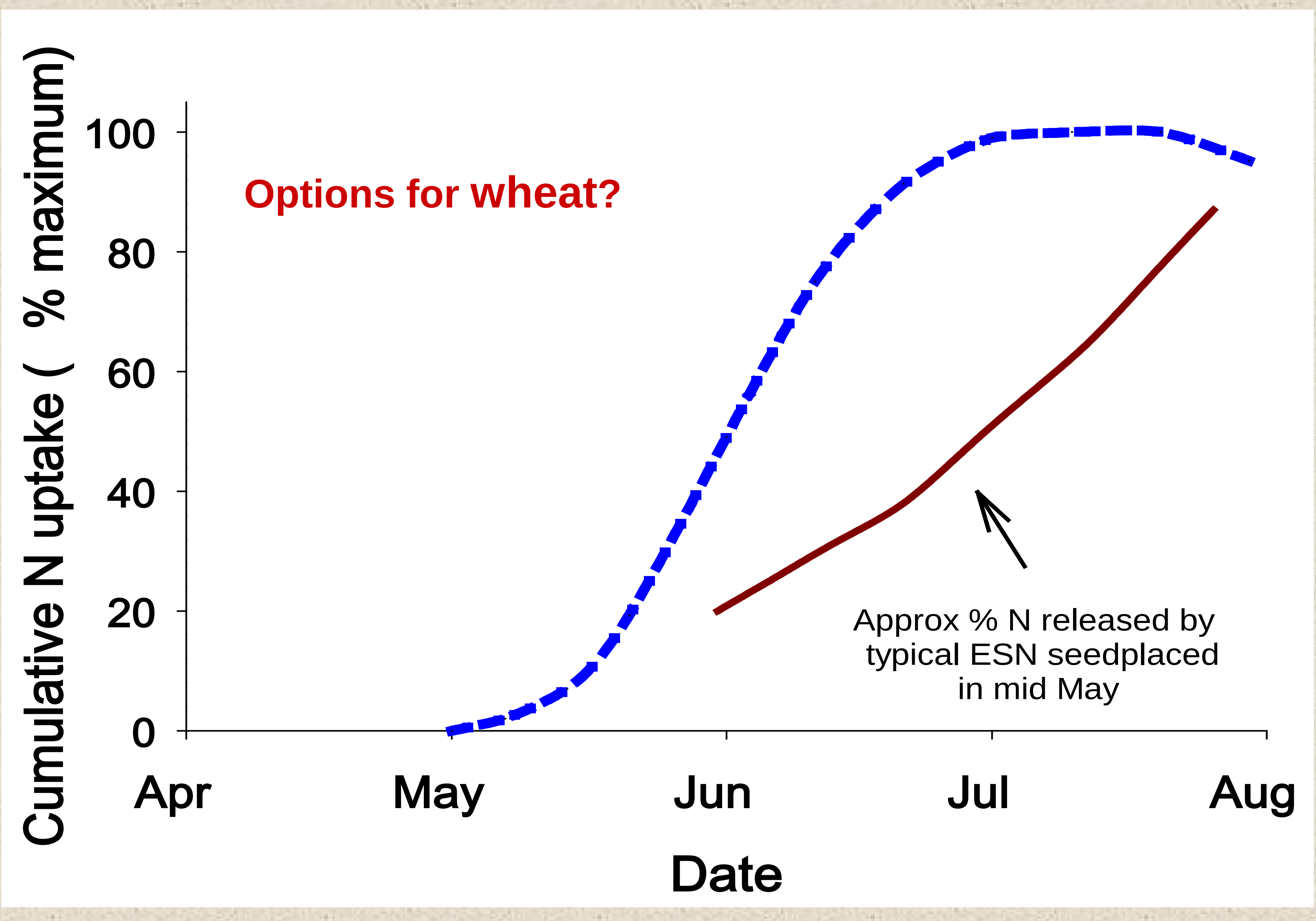
- Irrigated
- Warm season

What about dryland cool season crops?

Timing of N uptake by wheat



Timing of N uptake by wheat and ESN® N release



How does PCU work for small grains?

- Fall/winter pre-plant works well. PCU is in soil long enough to dissolve in time for plant need.
- Late winter/spring broadcast PCU does not - may dry out, release is too slow.
- Incorporation is important, especially late winter/spring.
- Blending is recommended with late winter/spring surface applied PCU.

Effect of EEF source and application method on winter wheat yield

Location: Beiseker, Alberta

Soil: silt loam, 4.5% organic matter

Precipitation: 13.5 in. seeding to harvest

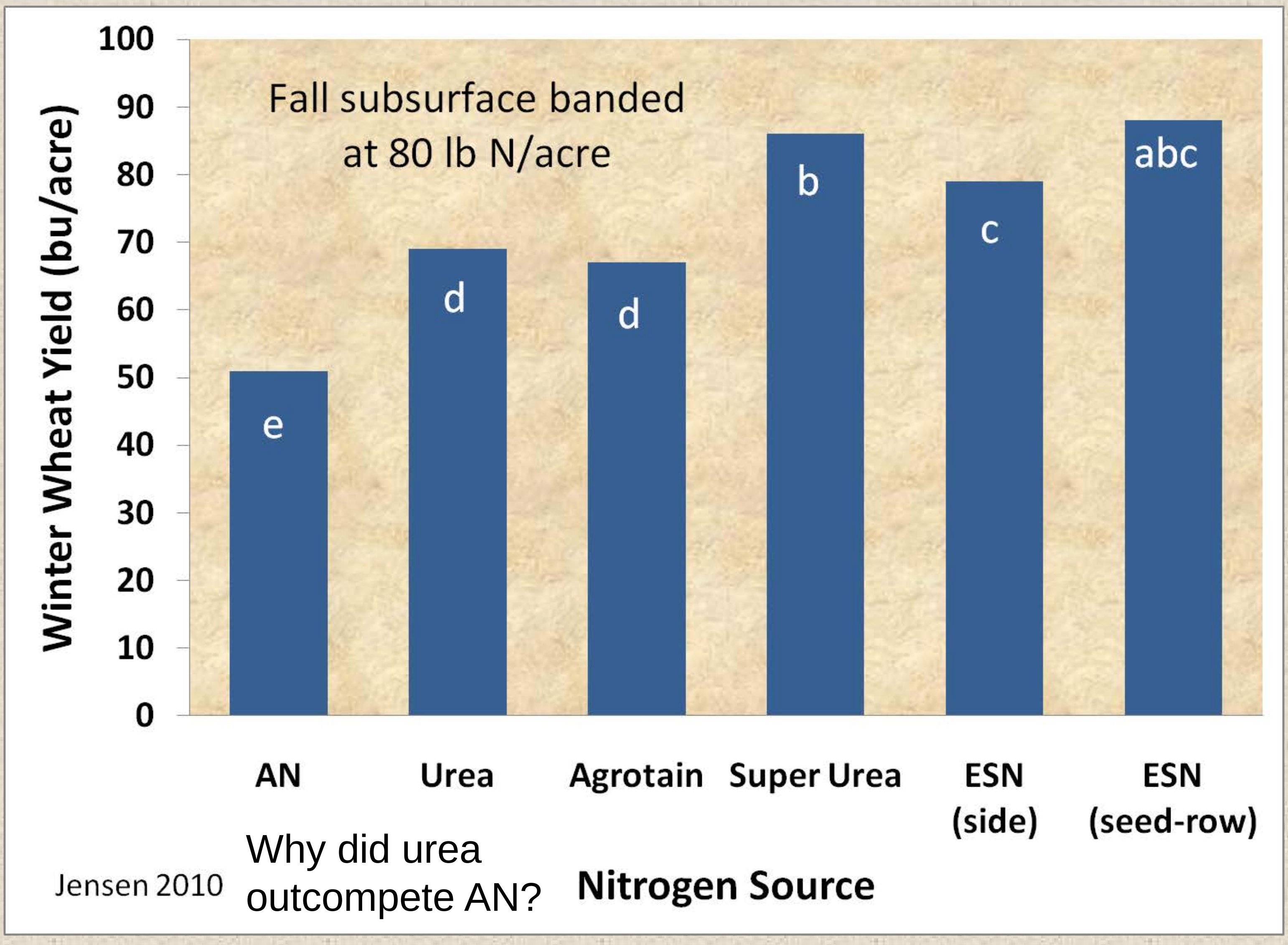
5 N sources:

- AN – ammonium nitrate
- Urea
- Agrotain® treated urea – urease inhibitor
- Super Urea® – urease and nitrification inhibitor
- ESN® – polymer coated urea

Rate: 80 lb N/ac

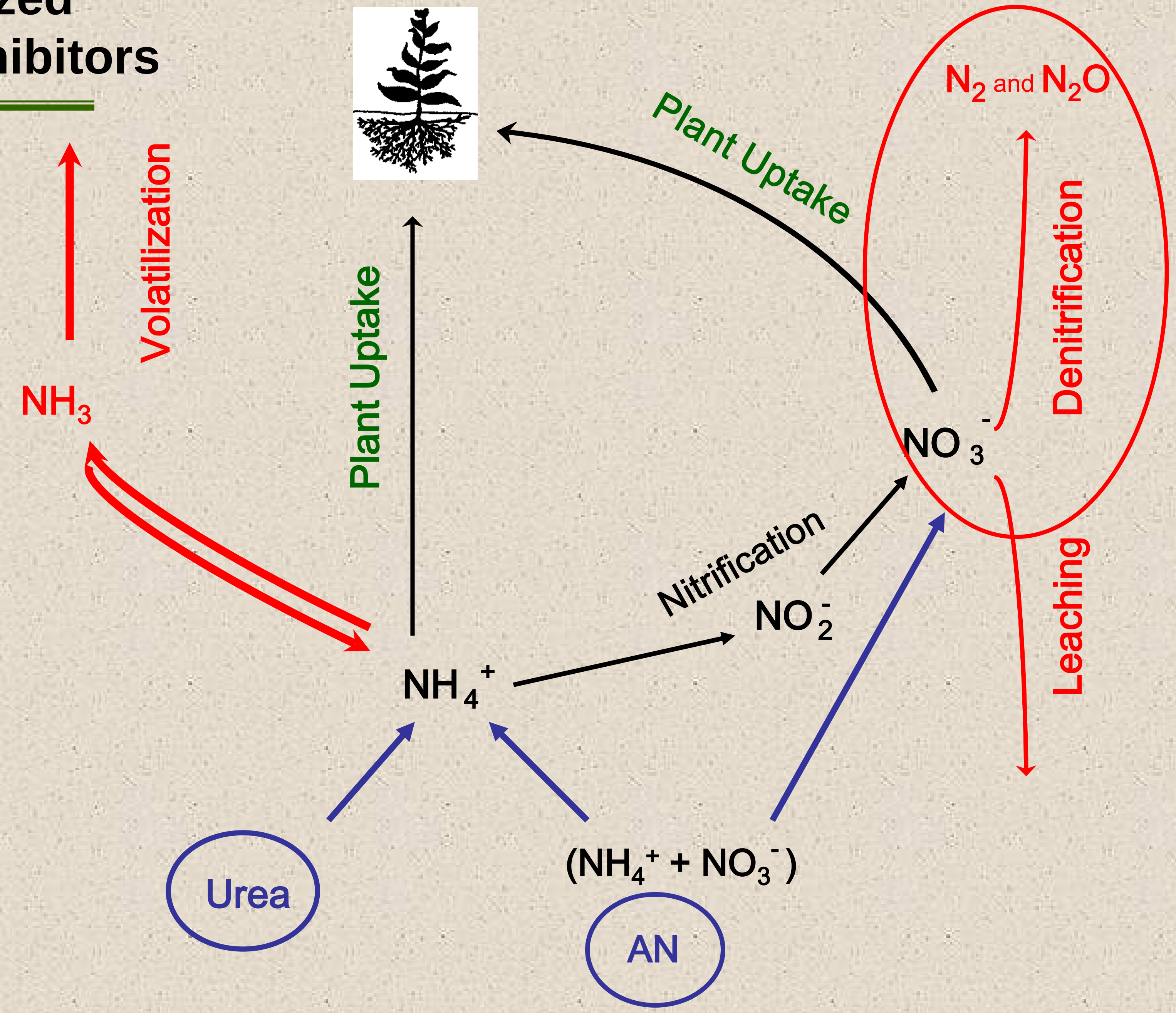
Subsurface side-banded (1.2” below and 1” side of seed) at seeding or broadcast in spring

Yield with N fall subsurface side-banded

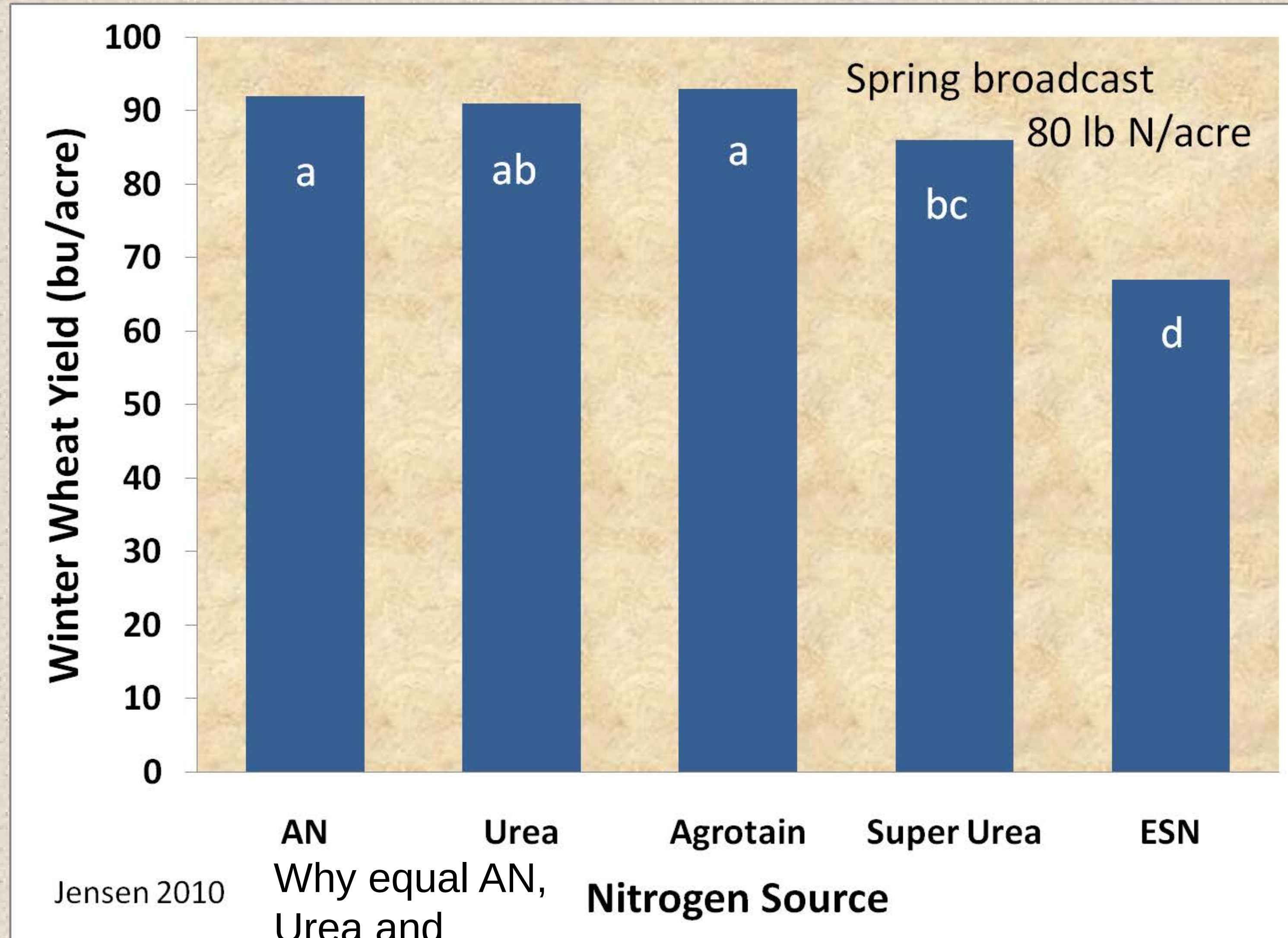


Why did urea outcompete AN?

Stabilized Urease Inhibitors



Yield with N spring broadcast



Why equal AN, Urea and Agrotain yields?

Alberta Study Summary

Each form of N is suitable – if used properly

- Urea and Agrotain®-urea best used in spring
- Super Urea® best fall banded
- ESN® best side- or seed-row banded in fall – advantage likely less in MT. Why?
- Blend urea with ESN® to ensure early N availability (50/50?)

Winter wheat with Nutrisphere-N® (NSN) side-banded at seeding

Location: North of Conrad (WTARC)

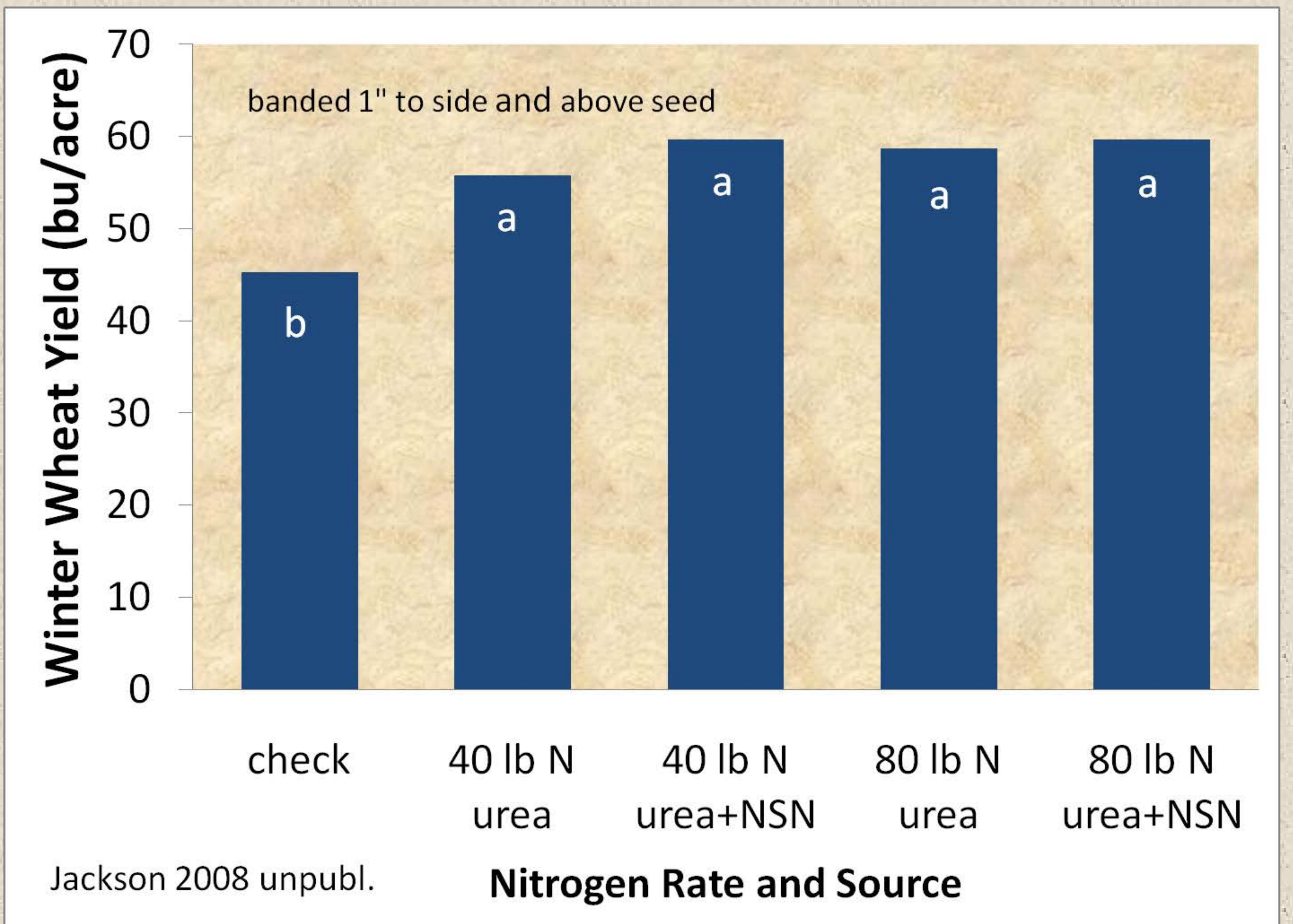
2 N sources:

- Urea
- Nutrisphere-N® – urease and nitrification inhibitor

Rate: 40 and 80 lb N/ac

Subsurface side-banded (1” above and to side of seed) at seeding

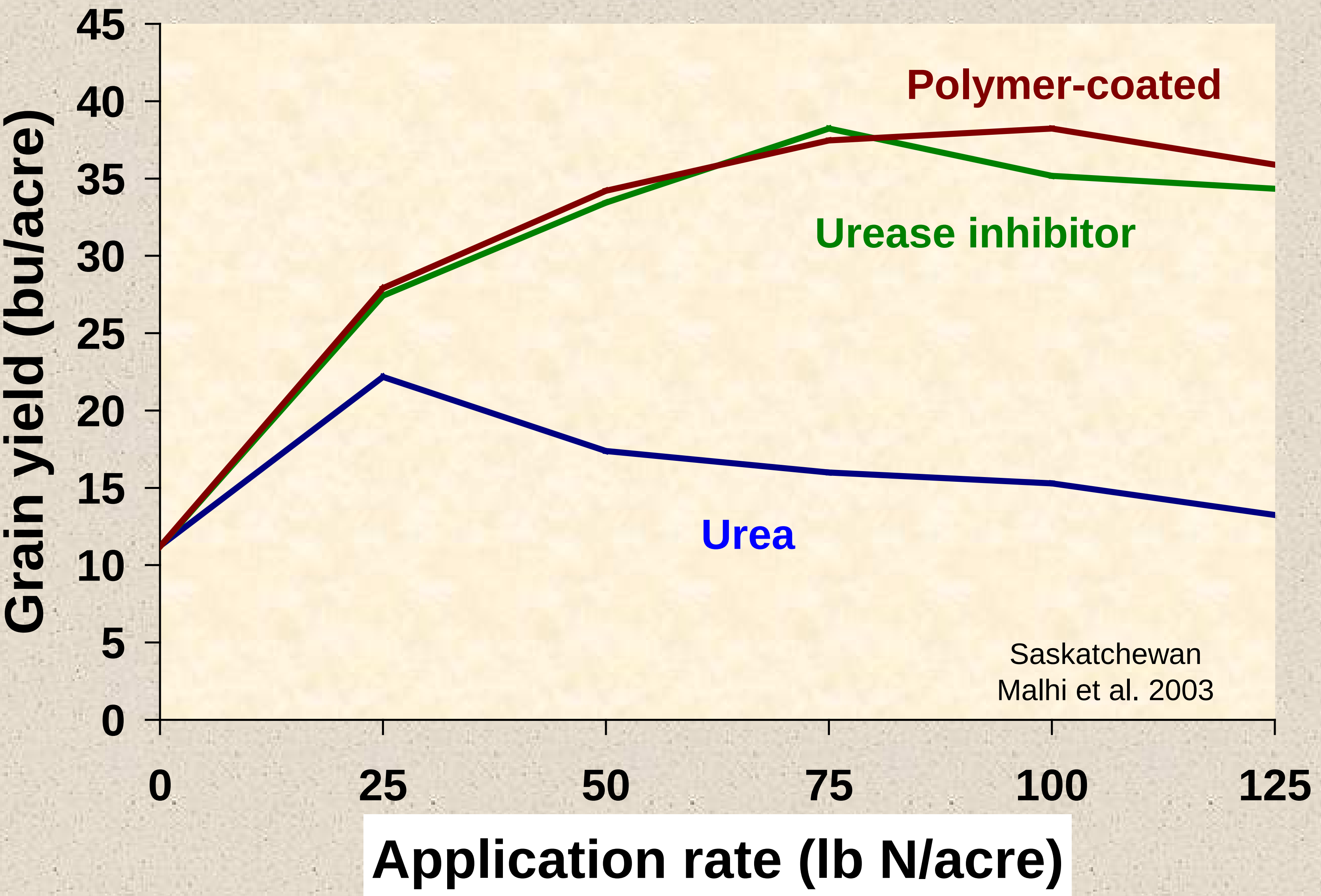
Yield with NSN treated urea side banded



Seed placing EEFs

- Can apply ~ 2 – 4x as much slow release product as urea directly with small grain seeds
- Saves on field passes – fuel, labor, soil disturbance

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



Conclusions

- Urea volatilization rates are highest when applied to moist soil surface w/o rain for at least 2 weeks following application.
- The best way to prevent volatilization is to place urea below the soil surface (> 1.5 inches is optimum)
- Agrotain decreases volatilization.

Conclusions

- Enhanced efficiency fertilizers can decrease N losses.
- Blending EEFs with conventional fertilizer may provide a good match between crop uptake and fertilizer availability.
- More EEF can be placed with the seed than conventional fertilizer, possibly saving a fertilizer pass and fuel costs.

Additional info in:

Enhanced Efficiency Fertilizers (EB0188)

http://landresources.montana.edu/soilfertility

Go to Fertilizer Information