Nitrogen Management to Increase Fertilizer Efficiency and Reduce Losses

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Photo by K. Olson-Rutz

Goal: Present N management practices that increase fertilizer use efficiency, minimize soil degradation, and decrease losses.

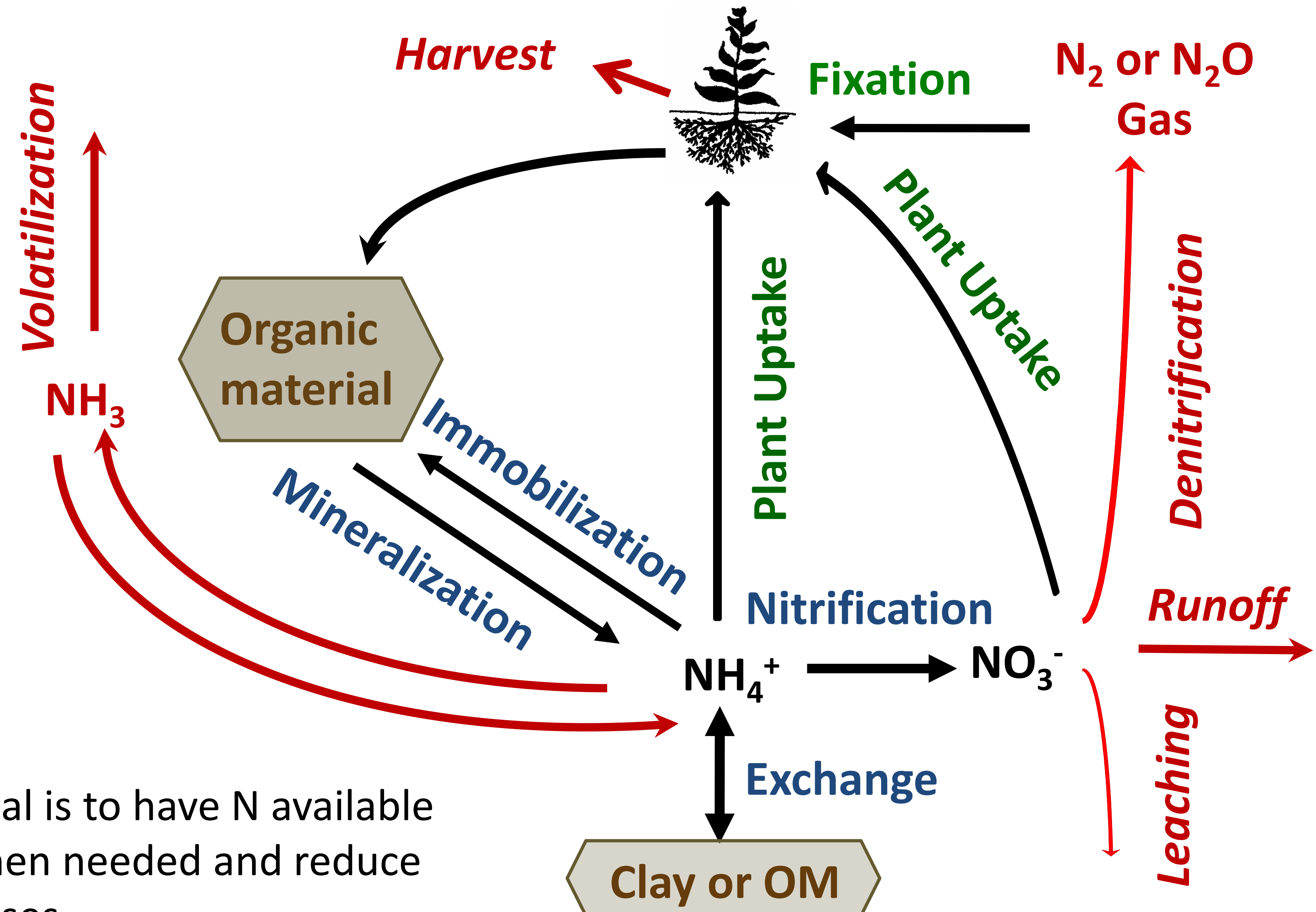
N concerns:

- Leaching/runoff
- Volatilization
- Denitrification to N gas
- Soil acidification
- Expense in era of low commodity prices

Management tools:

- Soil testing
- N rate
- N source, credits
- Timing
- Placement
- Rotations for N and to ‘catch and release’ N
- Tillage
- Irrigation, but won’t discuss
- Tools and technology, e.g. online N calculators, chlorophyll meters, Nutrient Tracking Tool

N cycles through the soil, plants, and air



Goal is to have N available when needed and reduce losses

Soil tests for N

- Traditional soil test for nitrate-N (nitrate-N), best done in spring to depth determined by region (2 or more feet).
- Illinois N soil test – INST.
  - A measure of soil's ability to provide N during the growing season.
  - In some areas there is no correlation between INST and economic optimum N rate, check with local Extension
- New tests are being developed to predict N available through mineralization.

Fall soil tests can lead to over or under-fertilized fields

High N crop residue and/or high O.M.

Mineralization (Residue decomposition)

Over fertilized

Over winter

High Precip

High N on shallow or coarse soil

Under fertilized

N leaching or N_2 gas losses

Compare fall with spring a few times to see patterns of loss or gain for given pastures/rotation.

Calculating N rates. Many but not all regions use yield goal in their calculations.

Realistic yield goals

- Use variety selection tools
- Past yields indication of future performance
- Having ability for in-season N application allows conservative yield estimate for pre-plant rate

Because it’s not that simple: N rate calculators

- Example inputs
  - N fertilizer cost, grain price, plump and protein cutoff
  - Yield goal
  - Residual soil N
  - Soil organic matter (SOM)
  - Prior crop
  - N credit from legumes
  - Stubble residue
  - Tillage
- Look for calculators supported by research in your region. Examples

Montana State University Economic N Rate
 http://www.msuextension.org/econtools/nitrogen/index.html
ND Wheat N Calculator https://www.ndsu.edu/pubweb/soils/wheat/
IA State University Corn N Rate http://cnrc.agron.iastate.edu/

See Morris et al. 2018 Agron. J. for a review of N rate calculators for corn

Example N rate adjustments

- Fall vs. spring soil test
- Stubble: small grains stubble high carbon to N (C:N).

  MT example: add 10 lb N/1000 lb stubble up to 40 lb N

- Fallow: assume ½ of stubble has decomposed over previous year when adjusting
- After legume rotation: Legumes credit (add) N. Amount depends on region, legume crop, # times grown

Montana example	
Crop	N credit (lb N/acre)
Alfalfa	40
Annual legume 1 x	~10
Annual legume >3 x	~20

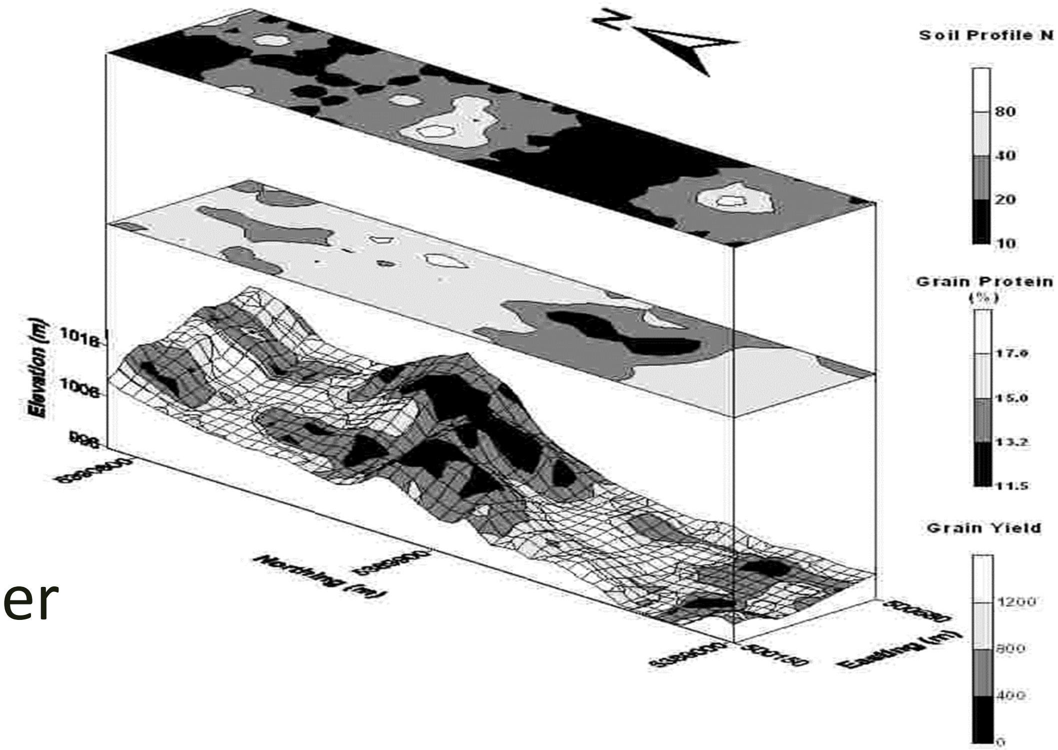
Soil acidification: a N rate adjustment factor?

- Soil acidification from ammonia based N fertilizer at seeding depth is leading to lower yield → crop failure in traditionally calcareous soils
- MT study found 1 pH drop in 14 yrs at recommended N rates = 0.044 pH drop for every 100 lb N/ac applied.
  - At pH < 6.0, poor legume nodulation
  - At pH < 5.0, aluminum toxicity
- Consider cost of liming in calculation of N rate?

Photo courtesy R. Engel

Variable rate N application
(Zone or site specific farming)

- Economic advantage
  - Inconsistent where water limits yield as much or more than N
  - Proven where N, not water, limits yields
- At simplest, divide field into zones of low, med, high productivity = yield potential



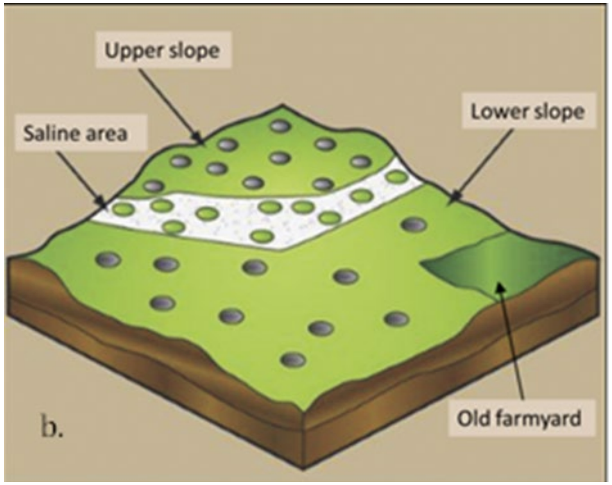


Image adapted from IPNI 2012

On to *Sources*

Different N sources have different volatilization and leaching loss potential

	POTENTIAL **loss compared to urea**	
Source	Volatilization	Leaching
Conventional		
Ammonium nitrate, CAN, ammonium sulfate	less	≈
UAN (solution 28 or 32)	less	≈
Enhanced Efficiency Fertilizers		
Urease inhibitors (Agrotain, N-Fixx, Arborite® AG)	less	≈
Nitrification inhibitors (DCD, N-Source, N-Serve, Instinct)	≈	less
Combinations (SuperU)	less	less
Controlled release polymer coated (ESN)	less	less
Slow release (Nitamin, N-Sure, N-Demand)	≈	less?

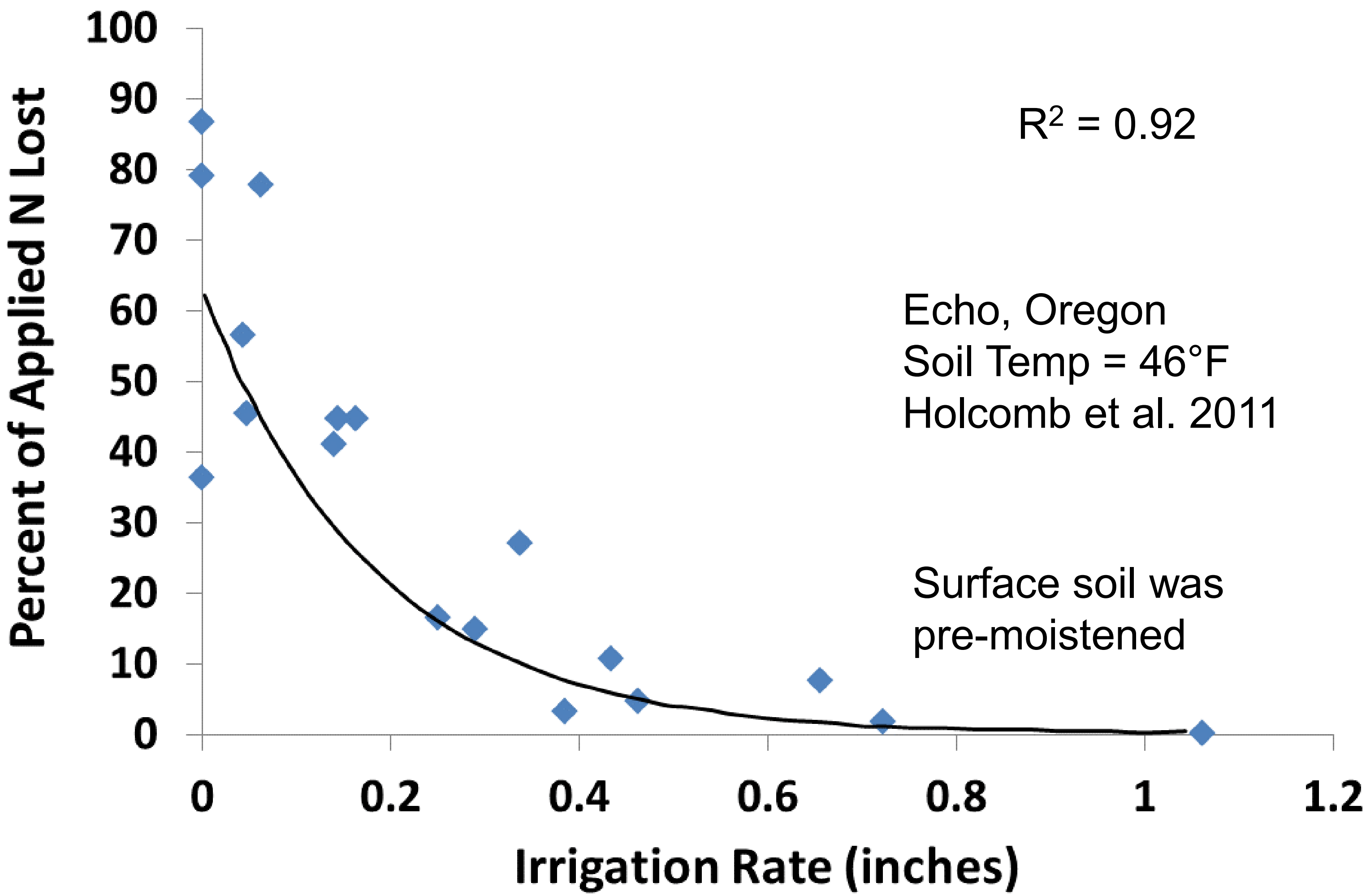
High risk conditions for urea and UAN volatilization (Engel et al. 2011, MSU Fertilizer Facts FF59 & 60)

In MT's cool dry environment, 0-44% of fall/winter broadcast urea N can be lost to volatilization. Worse with:

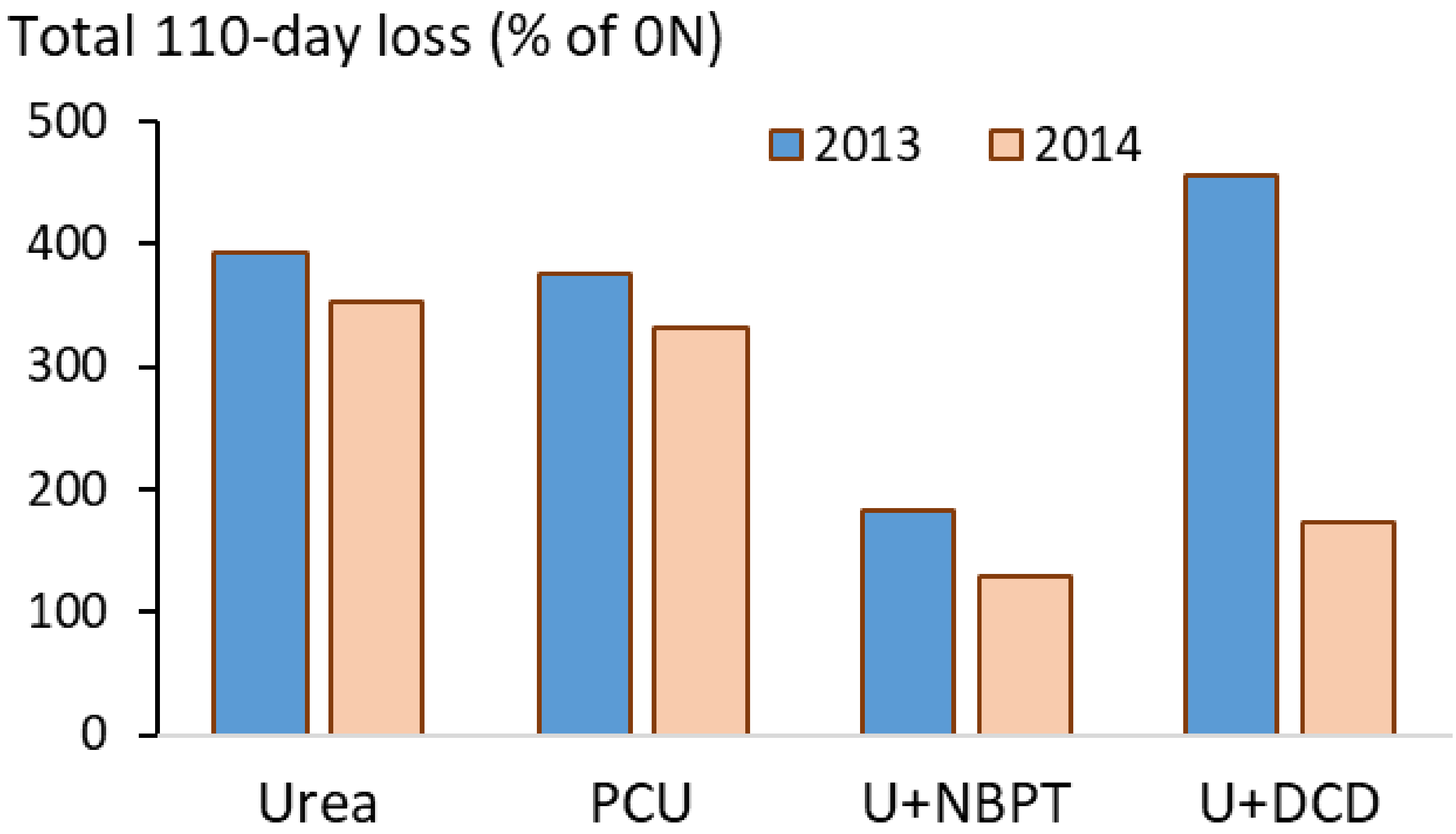
- Moist soil or heavy dew
- Time between application and incorporation by water or tillage
- High soil pH (>7.0)
- High soil temperature (>50°F) or frozen soil
- Crop residue, perennial thatch or sod
- Low cation exchange capacity soil (sandy)
- Poorly buffered soils (low soil organic matter, low bicarbonate content) because urea increases pH around prill, increasing loss.

The risk of loss increases as the number of high risk conditions increase, with soil moisture and incorporation likely being the most important.

Urea requires 2” incorporation with water or tillage to protect from volatilization



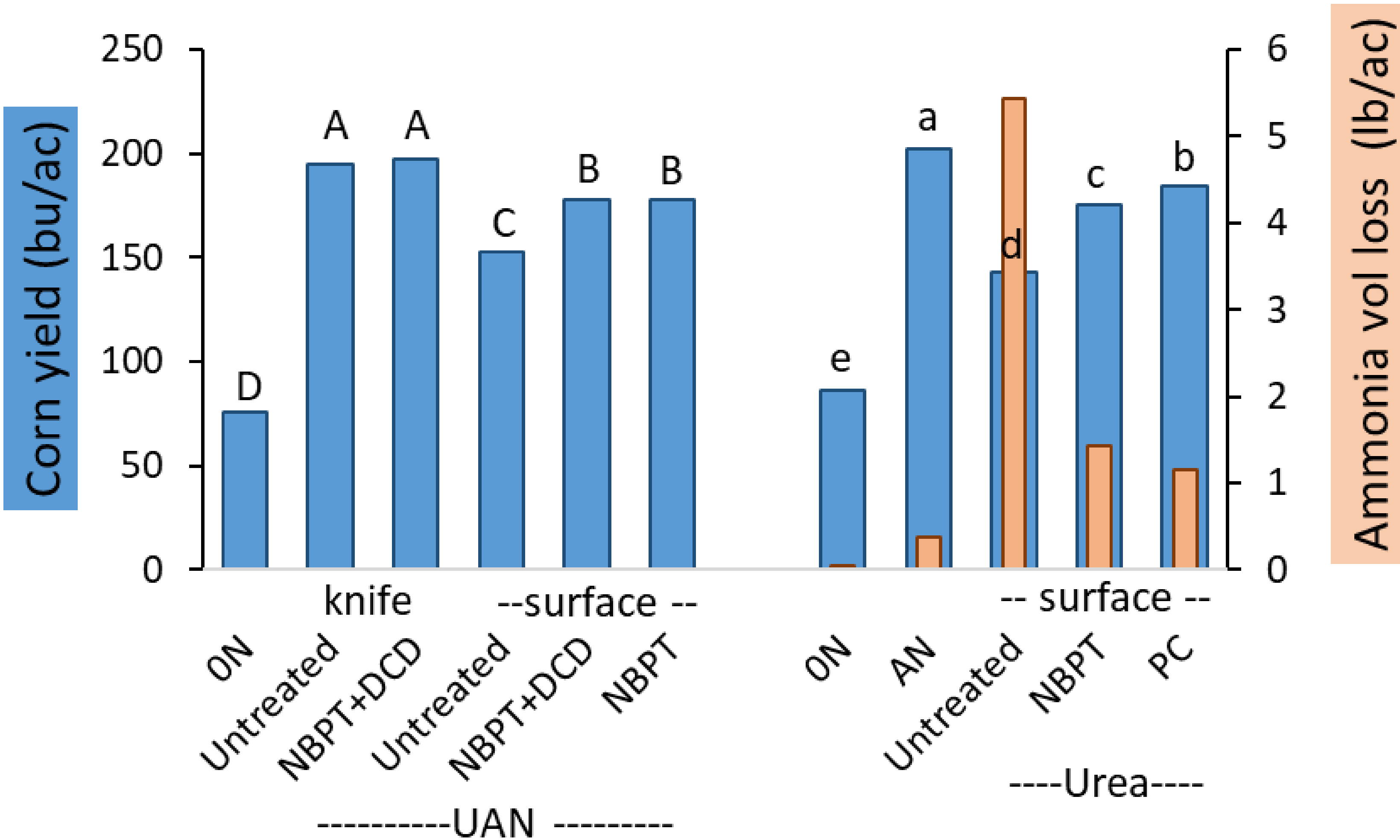
Effect of N source on volatilization



Tian et al 2015, LA

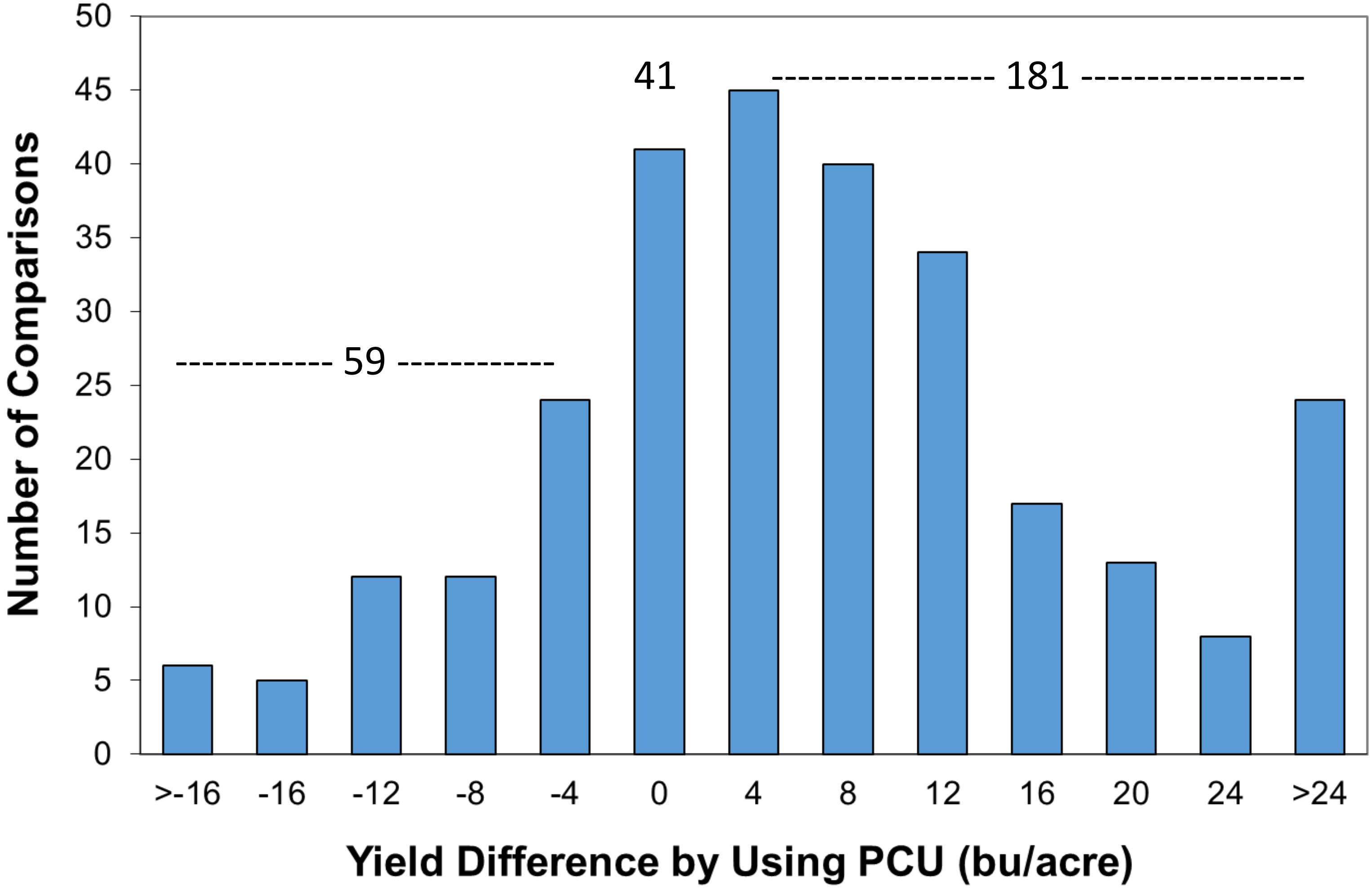
100 lb N/ac side-dress on reduced till cotton

No till corn yields increase when surface applied UAN and urea are treated with NBPT or polymer coating (PC)



Liu et al., 2019, TN, notill corn
averaged across N rates of 110 to 180 lb N/ac applied at seeding

Frequency of corn yield response between pre-plant PCU (ESN®)and conventional N at equal rates (US corn-belt (2000-2004)



Blaylock et al, 2006

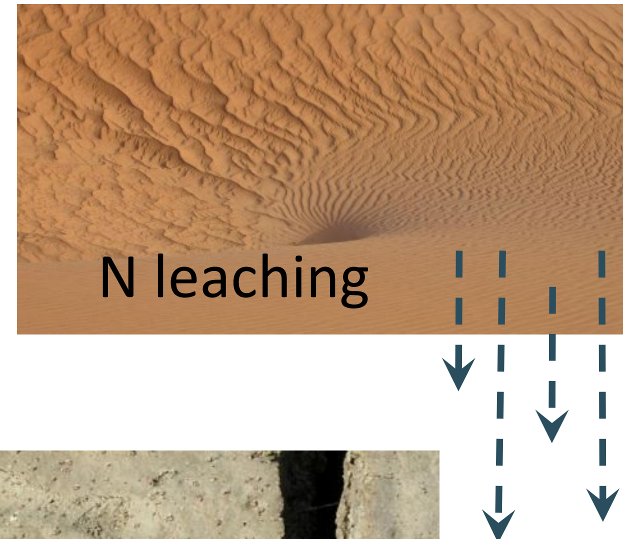
Slow- and controlled-release

Photo courtesy Agrium

- Benefit depends on climate/weather
- Consider in areas with high leaching or denitrification potential
- Release of polymer coated urea depends on warmth and moisture, can be too slow with late winter/early-spring application in cool/dry environments
- If fall application to reduce spring workload is important, then extra cost might be worth it
- May benefit protein more than yield, and protect water quality

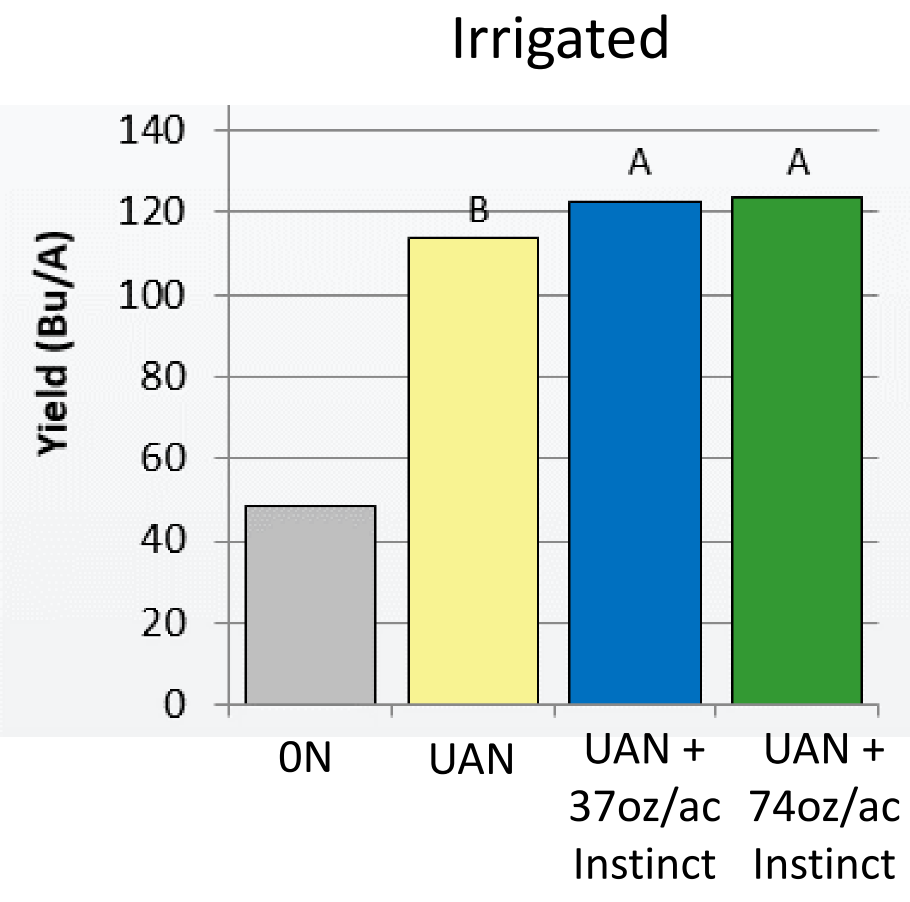
Nitrification inhibitors (e.g. DCD): delay ammonia (NH_4^+) to nitrate (NO_3^-) conversion

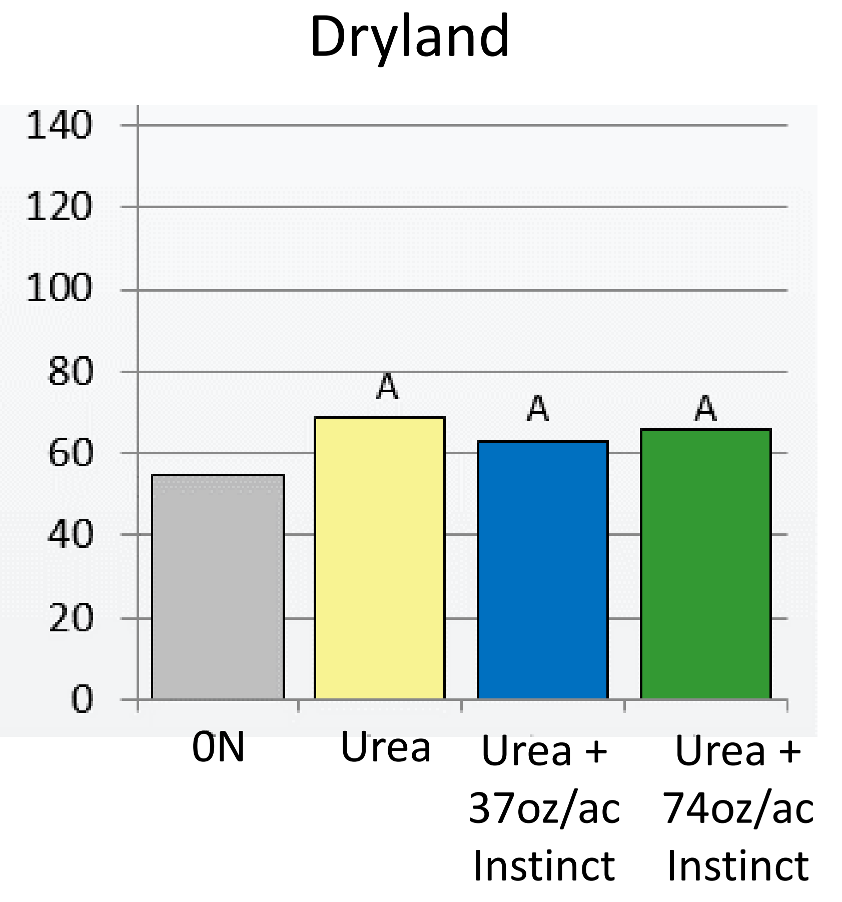
- Reduces leaching and N_2 gas loss
- Potential benefit with fall-banded urea where:
  - high precip with leaching in sandy soils
  - denitrification (nitrate → N_2 gas) in water logged/clay soils



- Benefits less likely in dry or well drained soils
- DCD sprayed before fall plow-down can slow decomposition and leaching loss (Francis 1995)

Instinct II® (nitrification inhibitor) increased winter wheat grain yield under irrigation but not dryland





Scherder et al., 2015, inland Pacific NW
UAN sidedress dribble stream bar, urea preplant incorporated

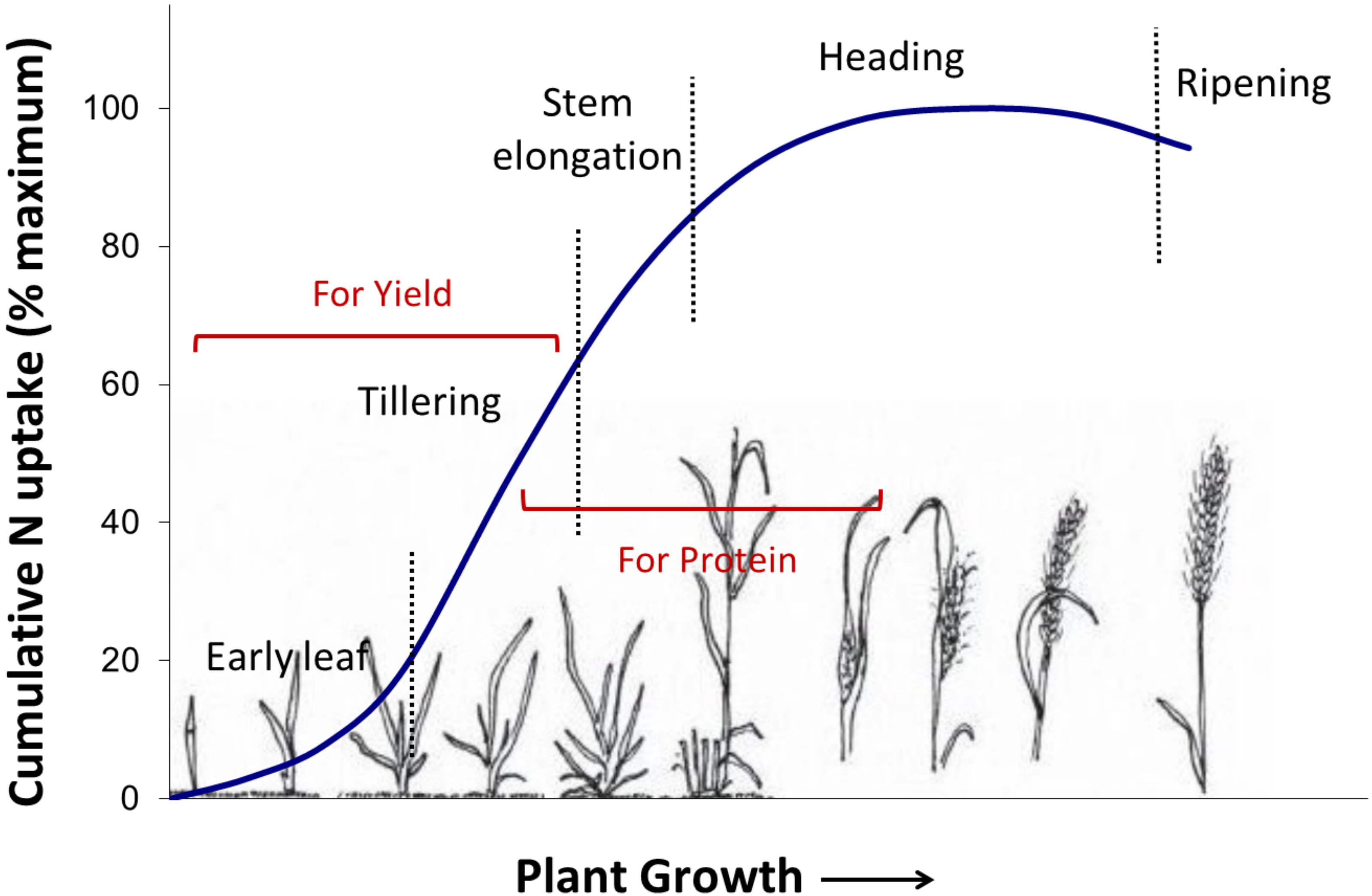
On to *Timing*

Time application to supply when needed and protect from losses

N source

- Readily available [urea (46–0–0), urea ammonium nitrate (28–0–0)]
  - shortly before seeding up to mid-tillering
- Slowly available (manure, slow-release N)
  - take time to become available
  - apply before needed – e.g., fall in semi-arid conditions

Uptake depends on growth stage NOT calendar day.
N available before stem elongation goes to wheat yield,
N after goes to grain protein

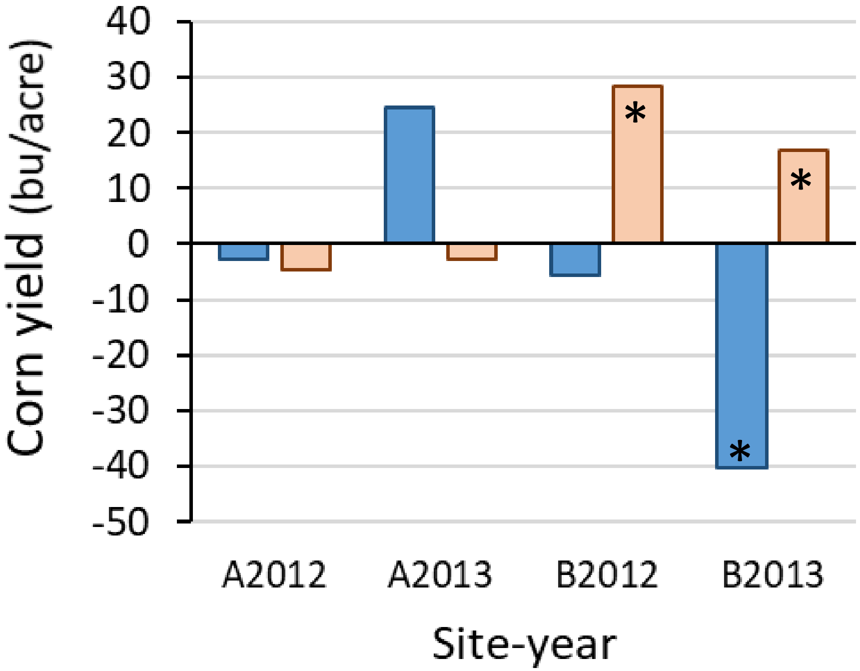


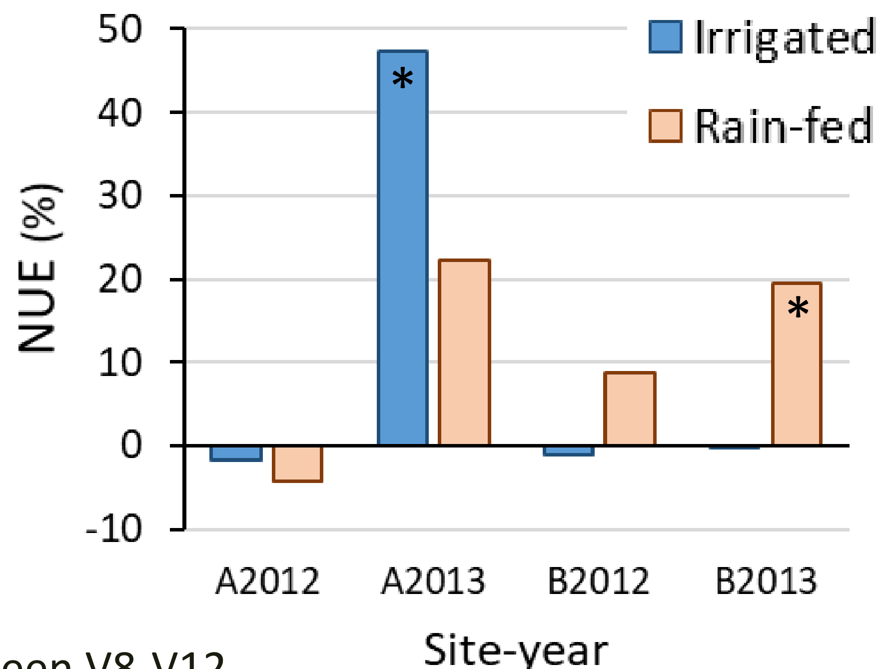
For assorted crop uptake curves see
http://landresources.montana.edu/soilfertility/nutuptake.html

In-season split application allows N rate adjustment based on:

- The crop's potential need
- The soil's ability to supply N
- These depend on the growing season which is why there is no definite clear benefit on yield of split (or side-dress) app over preplant.

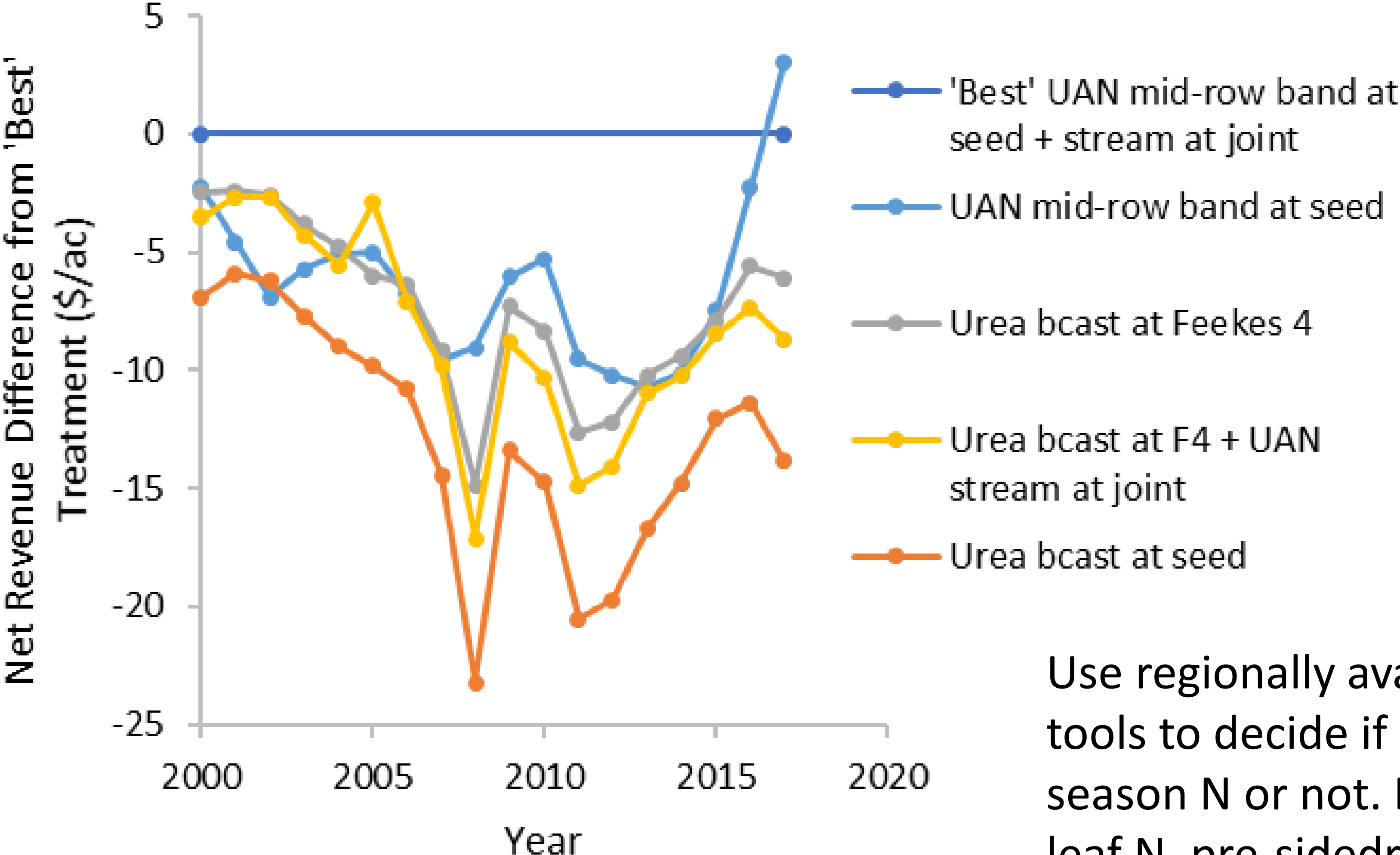
Benefit of split application over preplant (split app minus preplant)





Bushong et al, 2016, OK, UAN preplant and between V8-V12

Split-application increases options and maybe net returns



Yield bu/ac
56.5
54.1
56.1
56.5
55.9

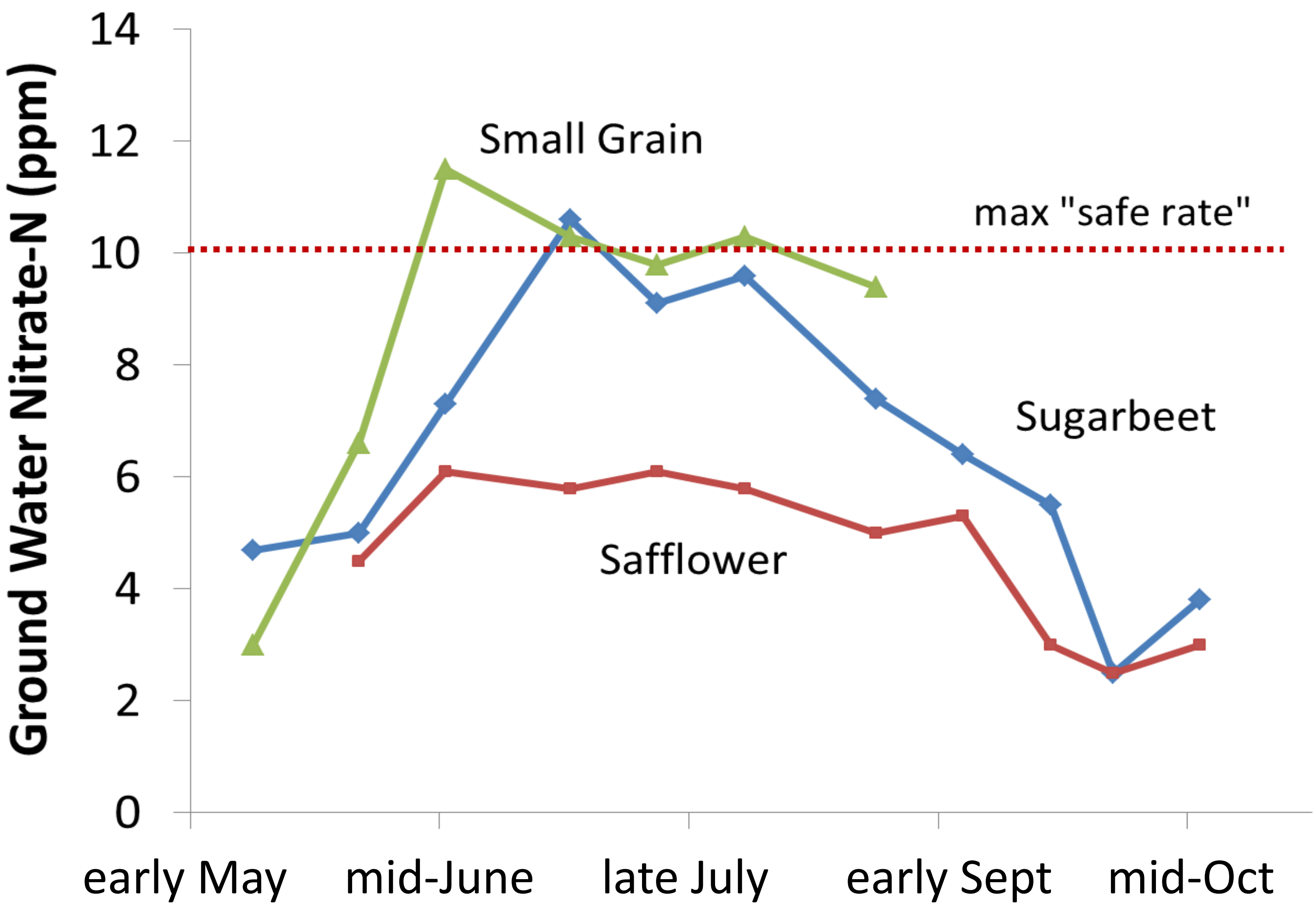
Use regionally available tools to decide if late-season N or not. Ex. flag leaf N, pre-sidedress N test, chlorophyll readings

8 lb N/ac applied with seed, total fertilizer 67 lb N/ac

Graham and Stockton 2019, SD, dryland winter wheat

On to *Crop rotations to catch residual N and reduce loss from system*

Deep rooted crops dig deep for N and help keep nitrate out of groundwater

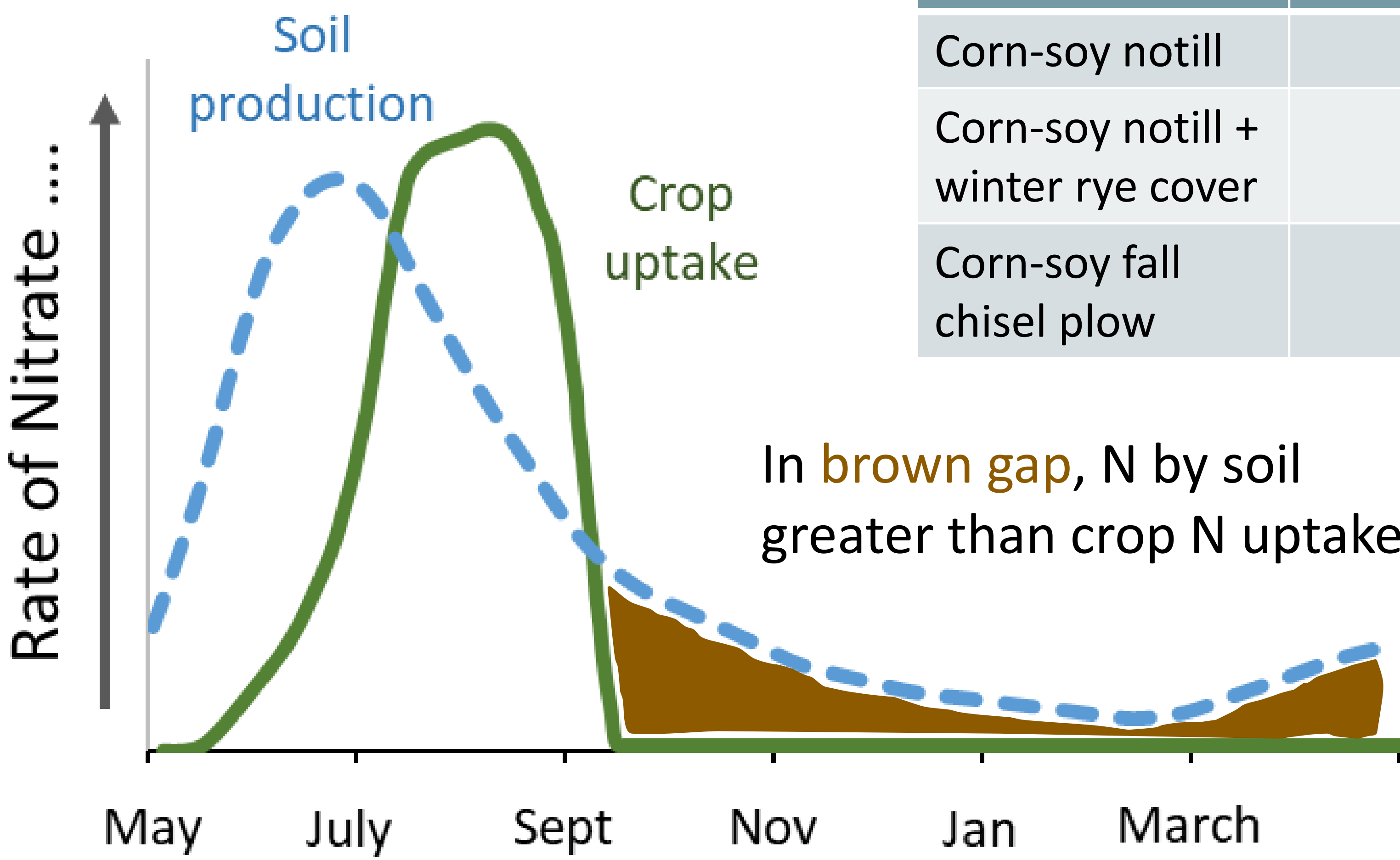


6-yr average, Sidney, MT, MSU Fertilizer Fact 9

Poor match between uptake timing and availability

Reduce the 'brown gap' by catching the losses with overwinter cover crops.

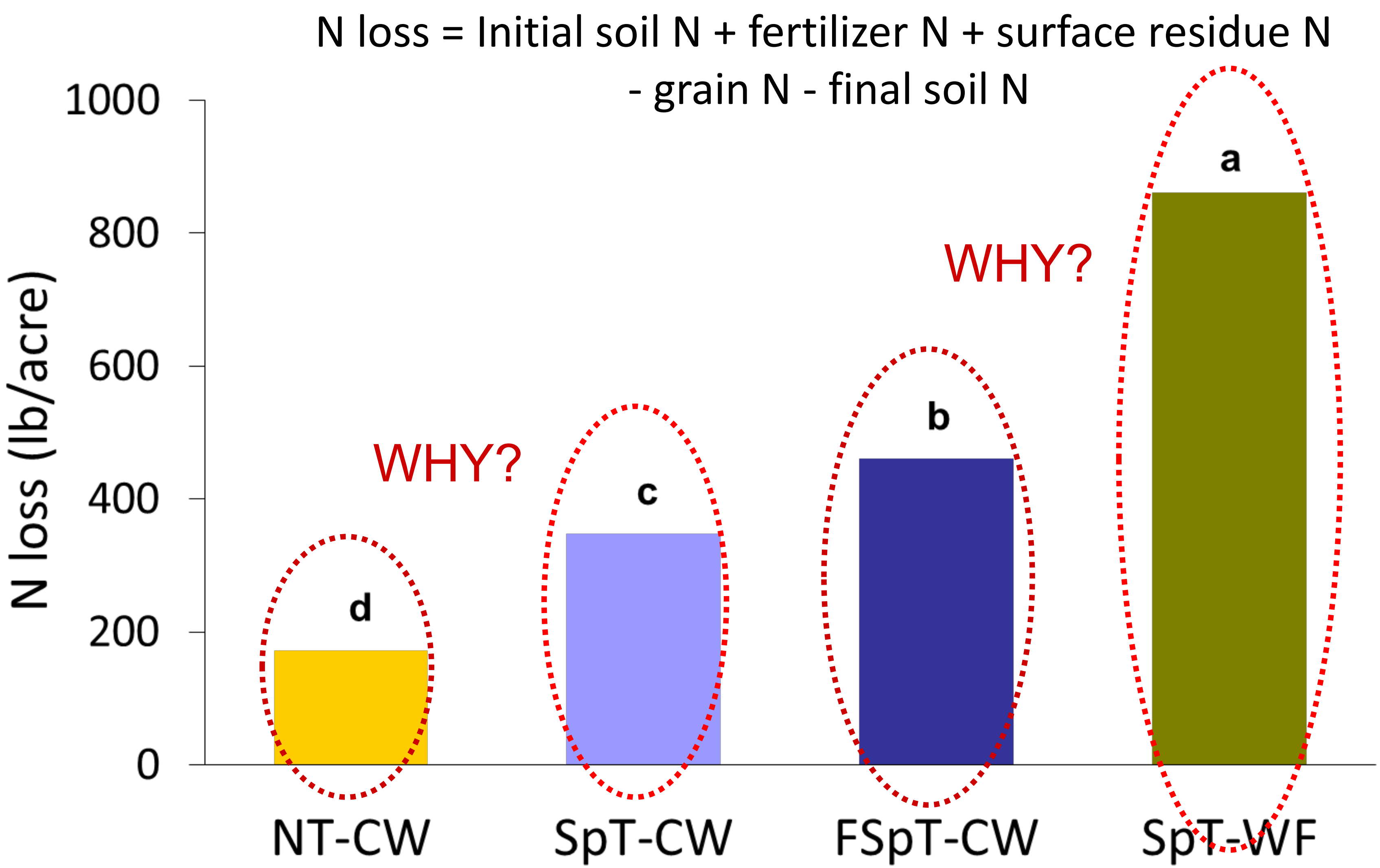
4-yr total N lost in drainage	lb nitrate-N/ac
Corn-soy notill	90
Corn-soy notill + winter rye cover	29
Corn-soy fall chisel plow	78



Kaspar et al, 2017 USDA-ARS National Conference on Ccrop and Soil Health

20-yr cropping systems with tillage and fallow have greatest estimated N loss

Sainju et al. 2009, Culbertson, MT

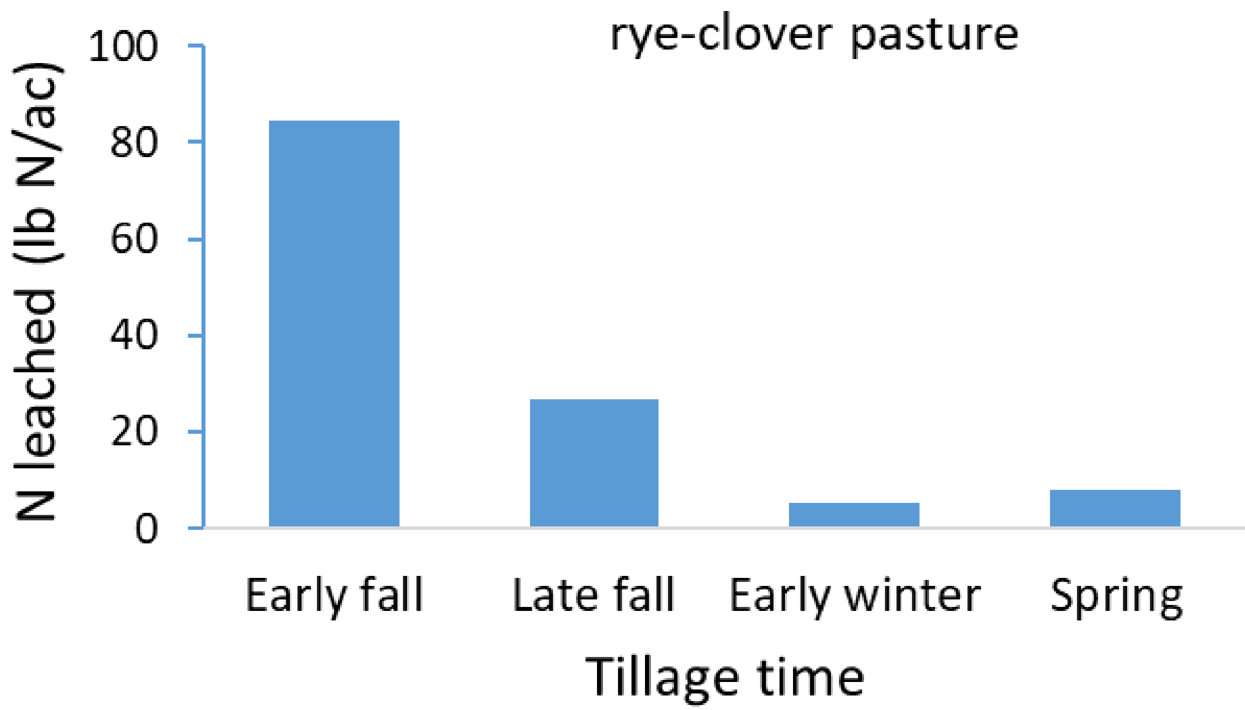


NT notill; SpT spring till; FSpT fall spring till; CW continuous wheat; WF wheat fallow

Tillage

- Increases mineralization rate, creates a flush of N. Have a crop in place to ‘catch’ it.

- Delay until late in fall or spring to reduce leaching loss (Francis et al. 1995, Australia)

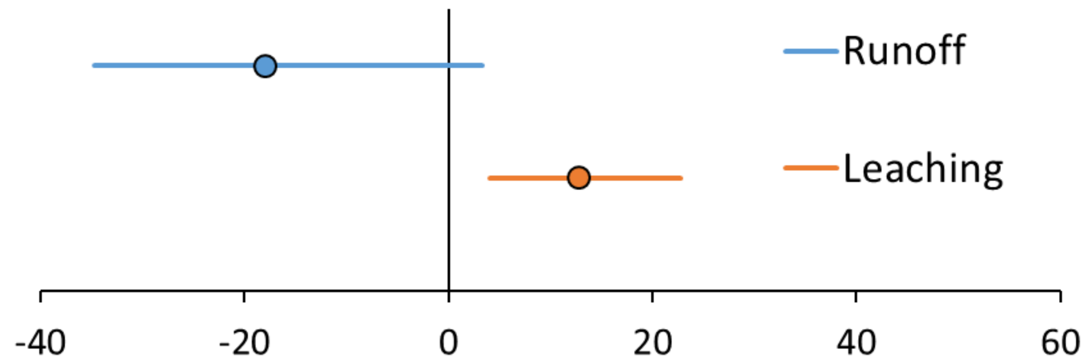


No-till

- Moderates temperature
- Increases water infiltration and storage

The % change of nitrate runoff and leaching with no-till compared to tilled

With 95% confidence intervals, (Daryanto et al 2017, review paper)



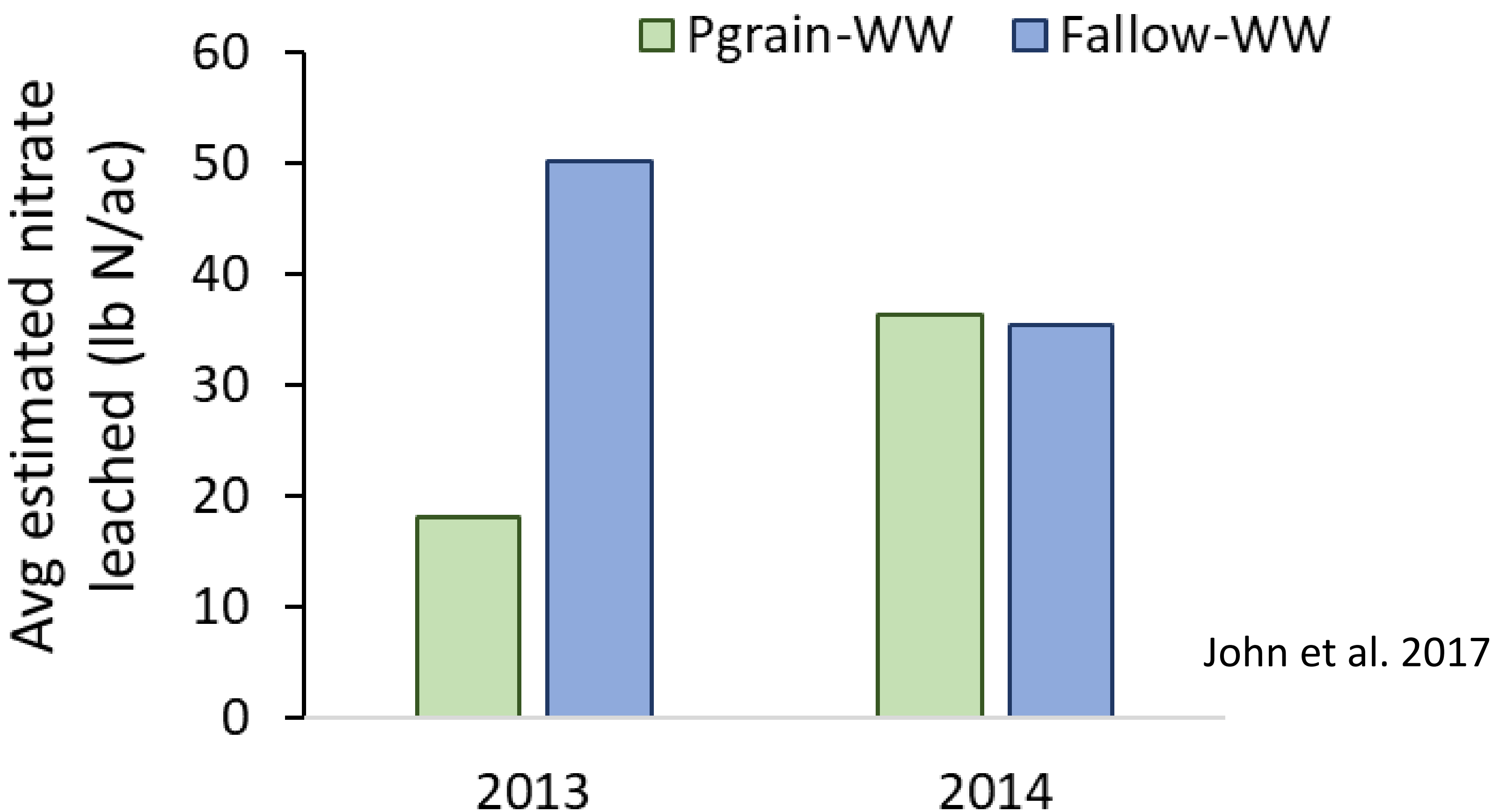
- Pattern holds for both organic and inorganic fertilizers
- Runoff increases with NT after 10 yrs duration
- Leaching on NT is greater than on CT in wheat and corn, but the same on soy

Adjust management to reduce NT leaching.

- Reduce N rates where possible
- Cover crop
- Split N applications
- Light tillage every 10 yrs to alter the causes of nitrate losses (e.g. disrupt macropores that enhance leaching).

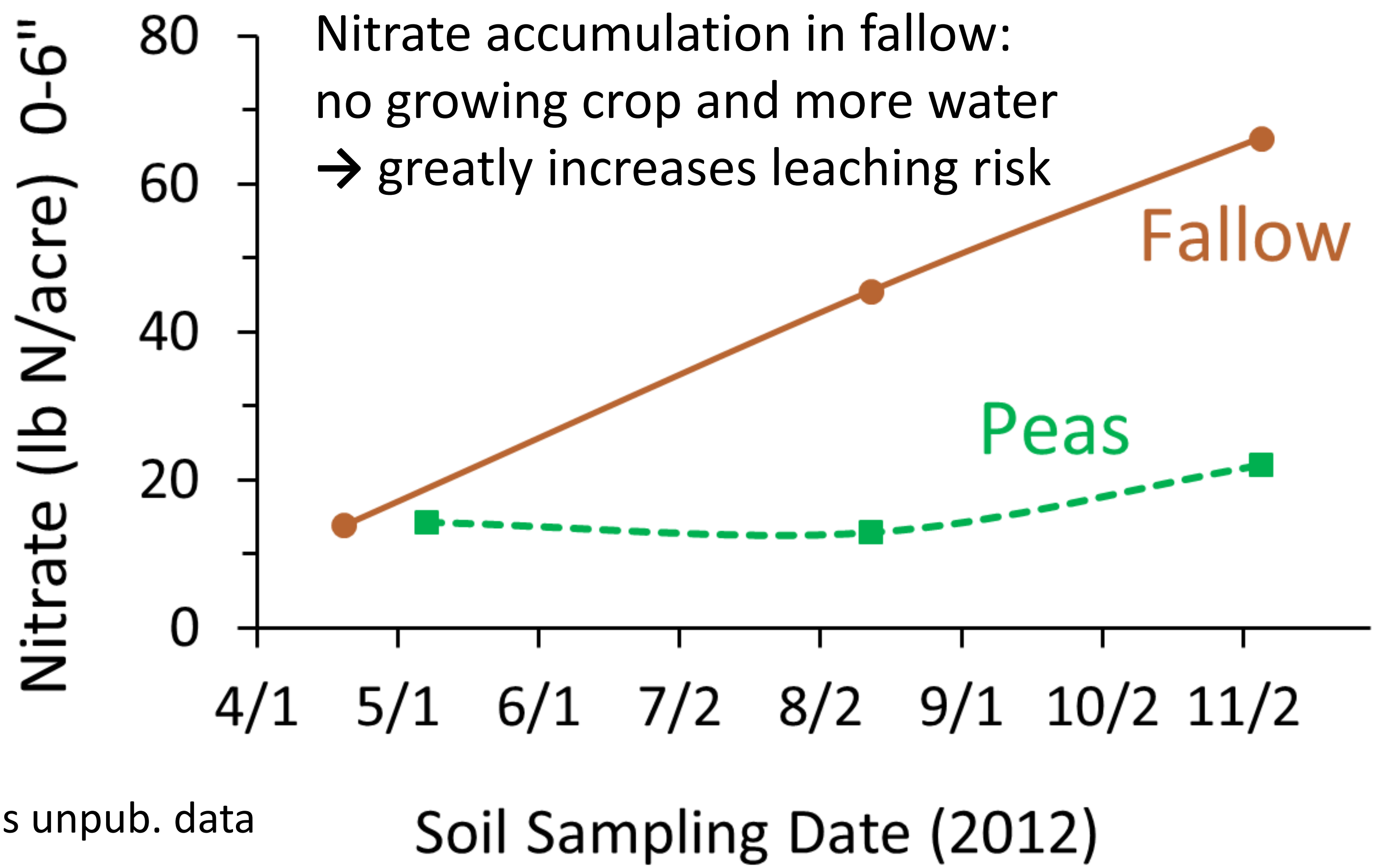
Judith Basin Nitrogen Project

Farmer's used alternative vs 'standard' practices for 2 growing seasons.



Pea grain-wheat leached less one year than fallow-wheat, equal NR.
Leaching no diff between rotations in 2nd year, NR greater with pea-wheat.

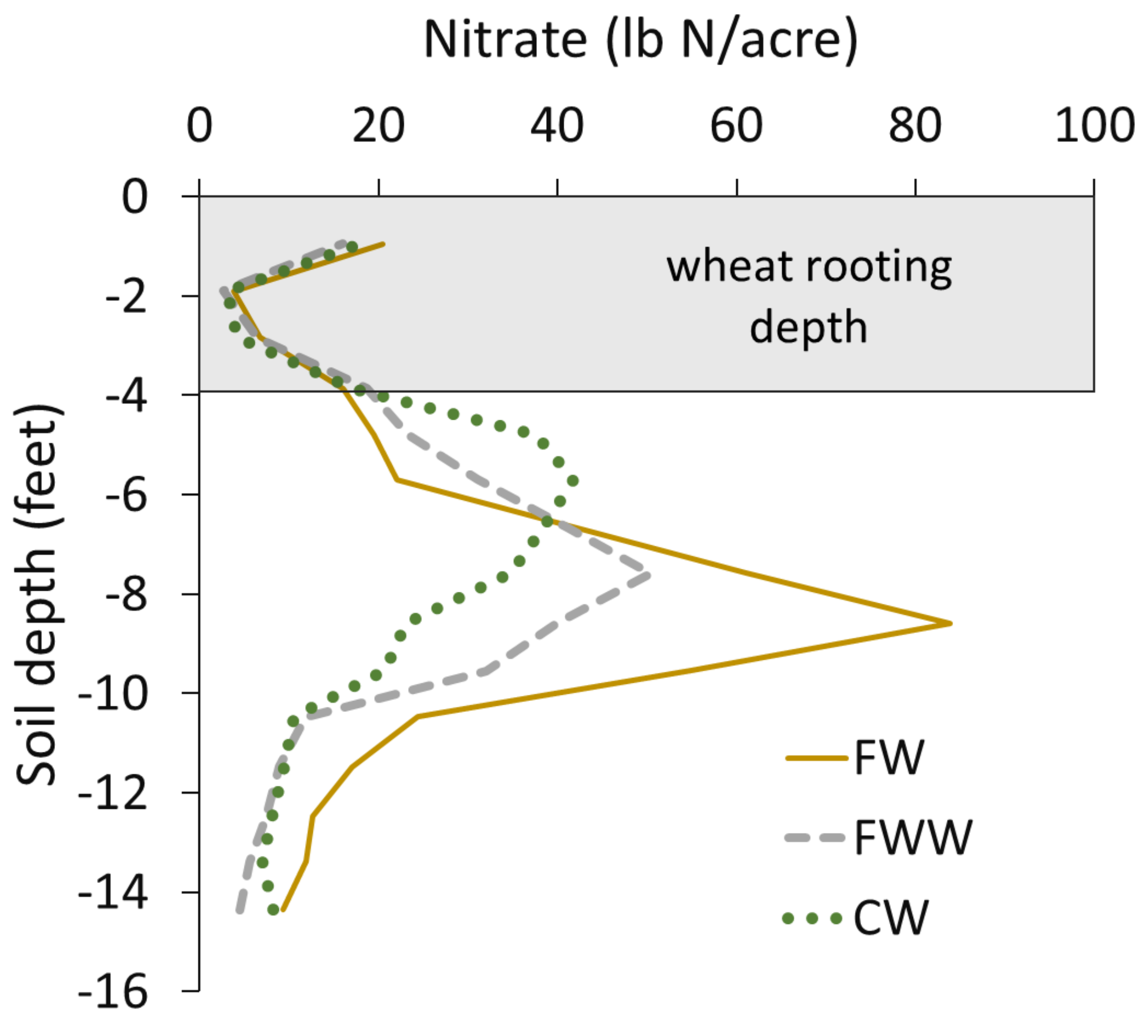
Nitrate Source:
Organic matter mineralization mainly during fallow



Jones unpub. data

Mineralization of organic matter is 30-60 lb/acre in the top 6 inches; this is on par with annual fertilizer rates in this MT semi-arid region.

Continuous cropping leaves less nitrate in soil to leach



37 years of each dryland cropping system with spring wheat

Campbell et al, 2006
Swift Current, SK

N management factors to decrease N leaching

- Apply N based on spring soil test
- Split N application to match plant needs
- Avoid fall application on shallow and/or coarse soils
- Consider applying less N in areas that yield less or have shallow soils (variable rate application)
- Use an enhanced efficiency fertilizer to reduce leaching (and denitrification) losses

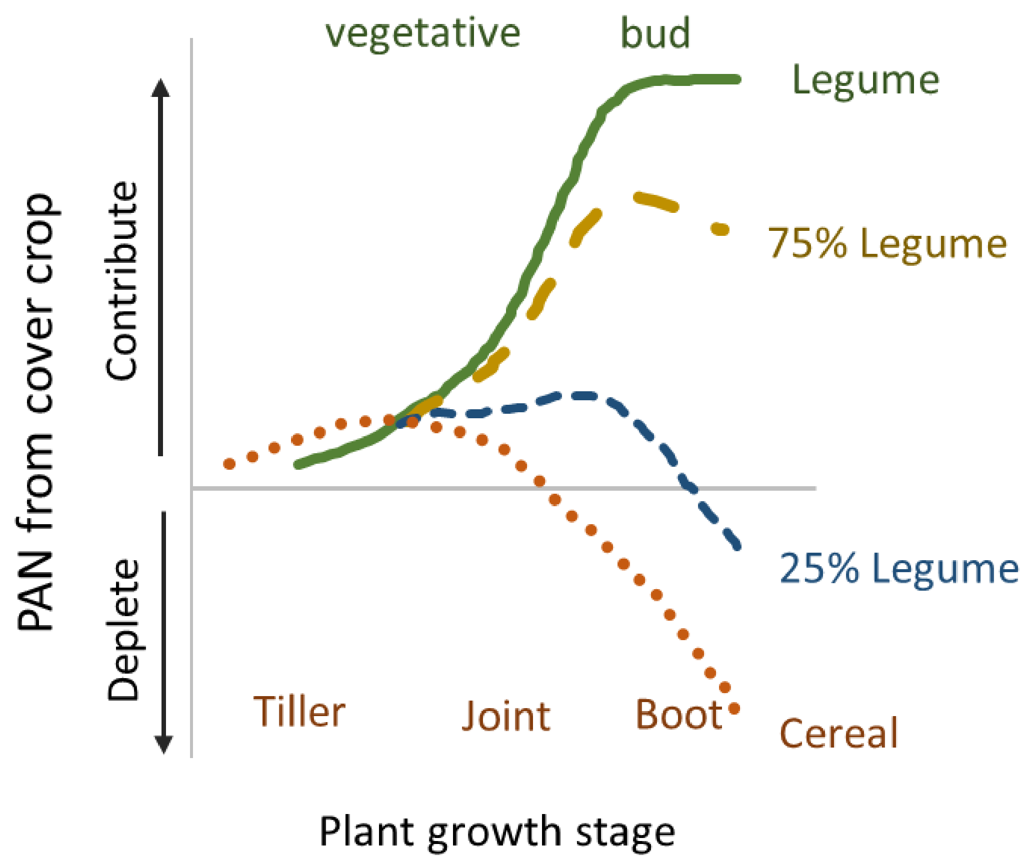
On to

Crop Rotations to Supply N

N from legumes

- Legume cover crops release more N more quickly than legume grain (pulse).
- N benefit depends on the legume species, how long grown (cover crop vs grain), how often grown, growing and decomposing conditions.

- Legumes should be 50% of ccrop to provide plant available N (PAN), especially if terminated late

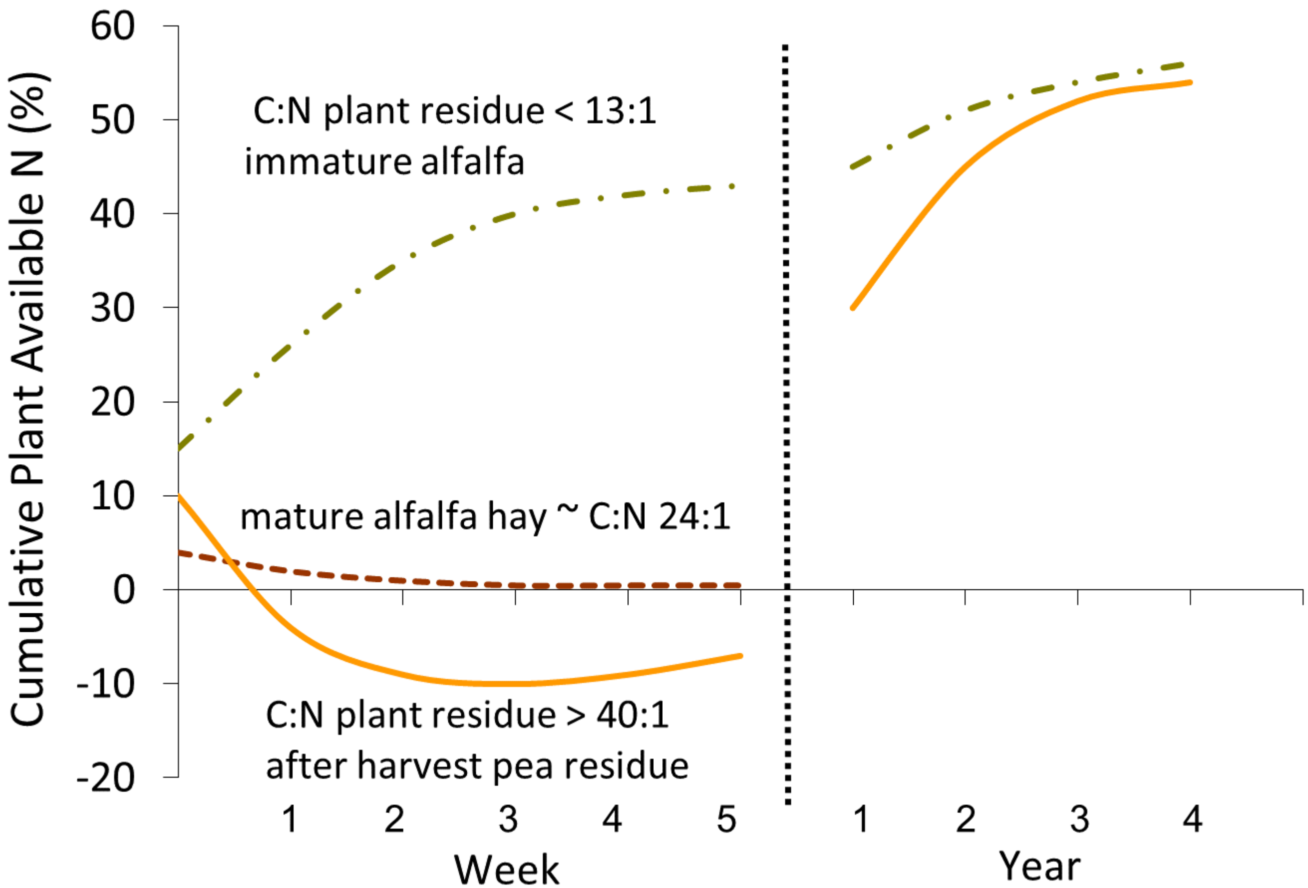


Sullivan and Andrews, 2012, OR

Plant available N from plant residue

Depends on C:N.

- Leafy green lower in C:N = more N available to next crop
- Mature plant higher in C:N, at > 24:1 microbes tie up N

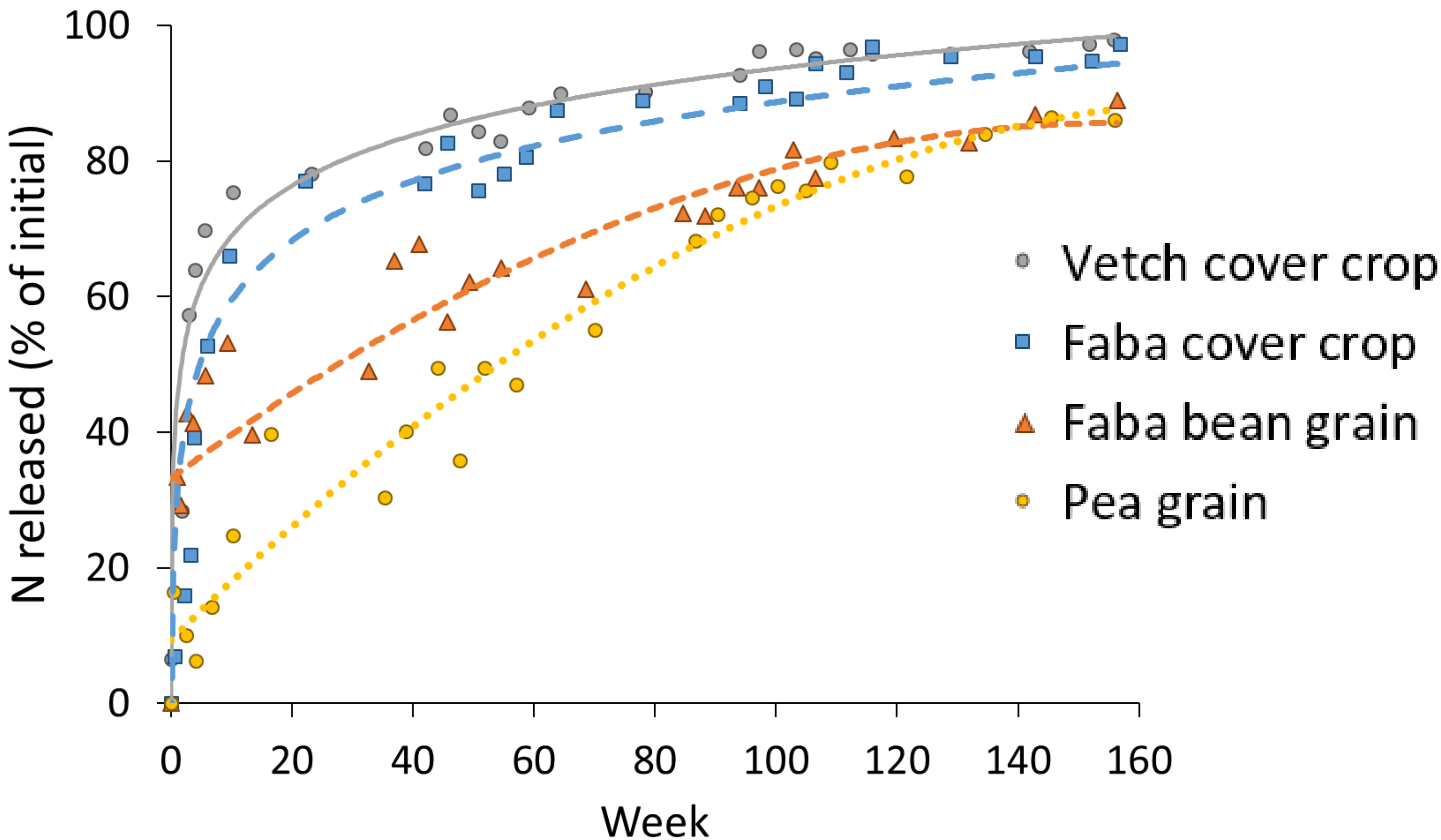


Balance C:N by:

- Termination timing
- Mix species planting
- Sequential high N, low N rotations
- Look for regional PAN calculators

Montana State University Extension bulletin EB0200

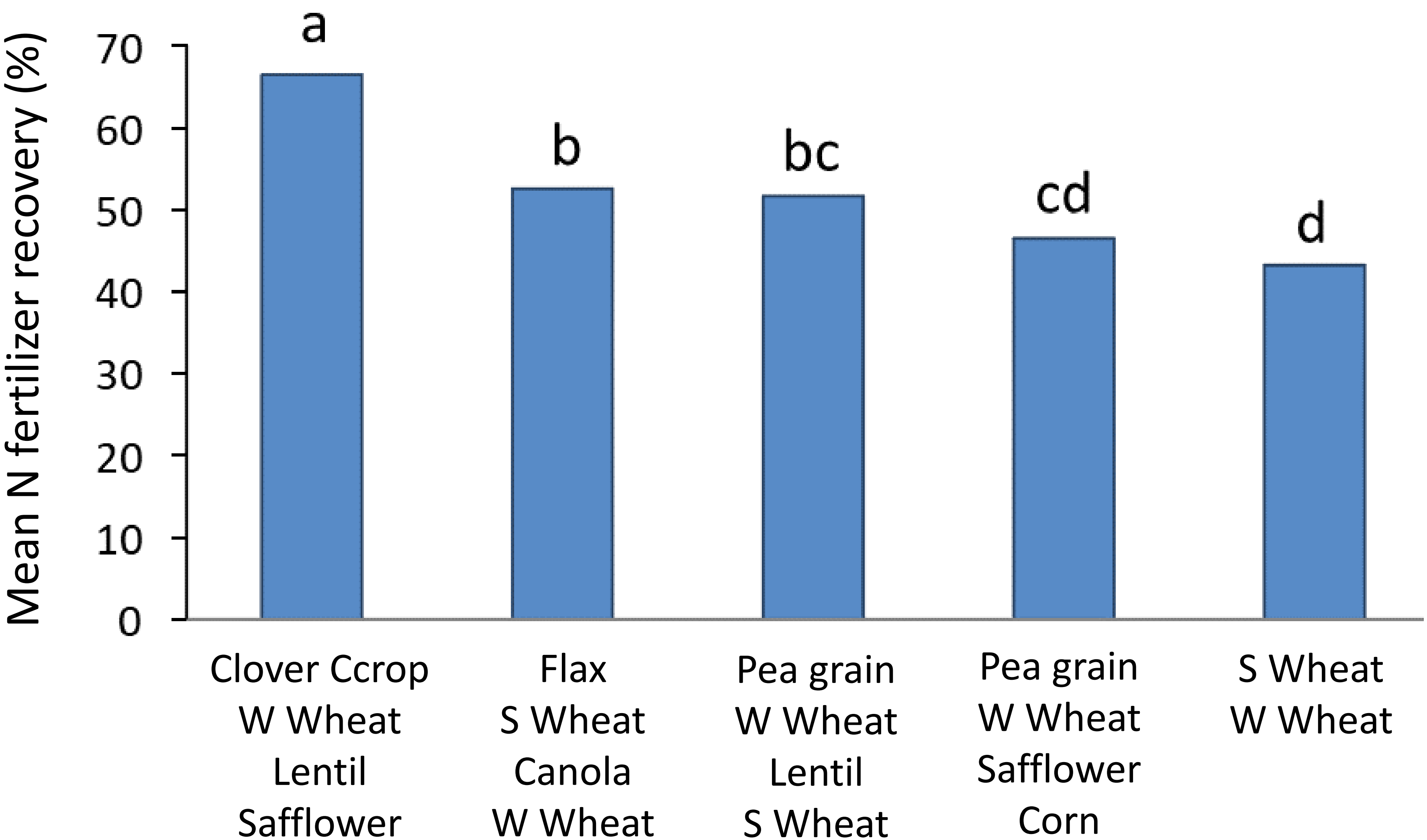
Legumes are the ultimate slow release N, after the initial burst of N release, especially when grown to grain



A pulse rotation can still provide N for grain planted three years after the pulse crop.

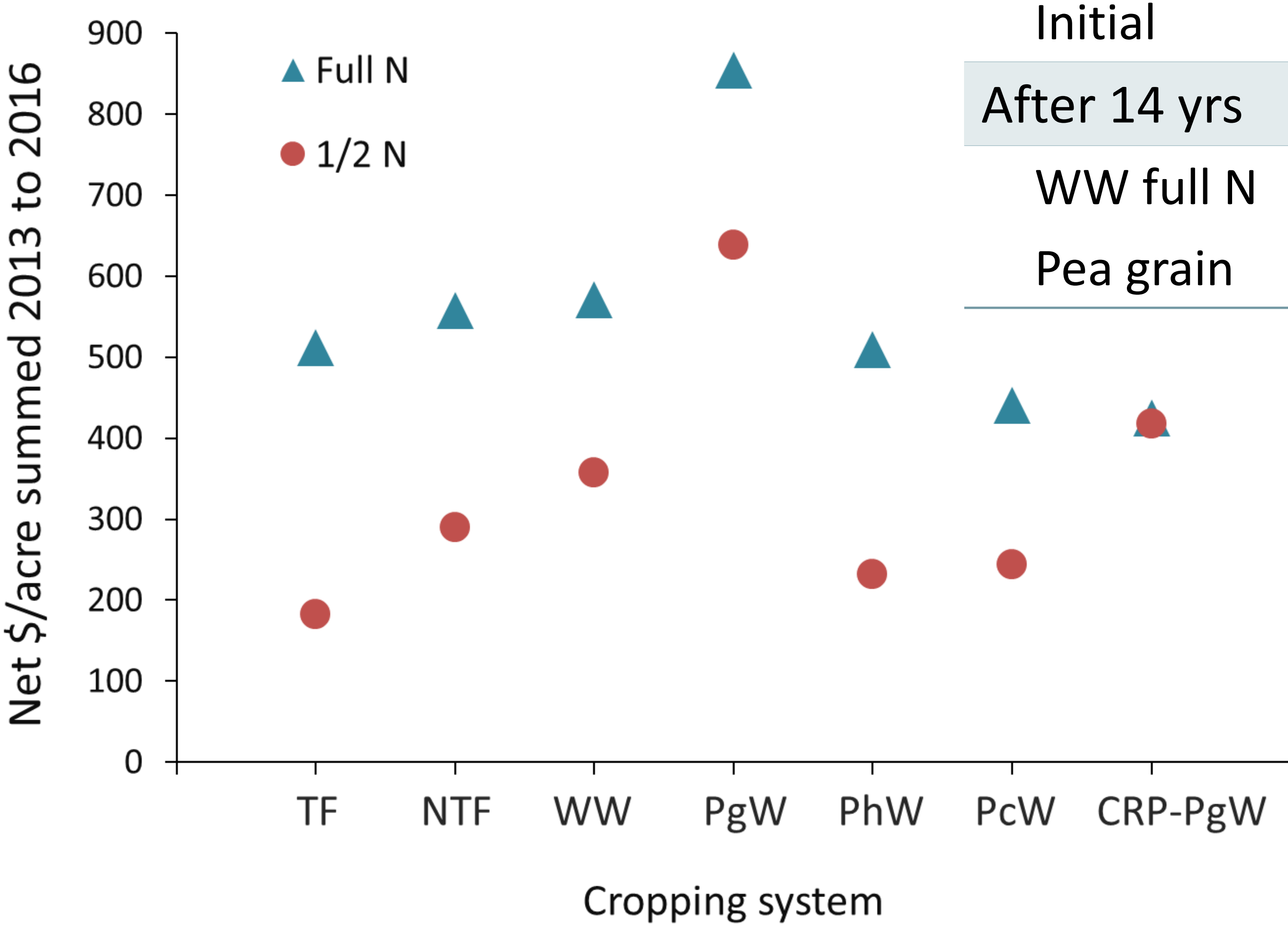
Lupwayi and Soon 2015, AB, 10.7” growing season precip

Diverse rotations generally have greater N fertilizer recovery, when legume N credit is included in N fertilizer rates



Rick et al. 2015, MT dryland-yrs no till, avg. from years 10 to 13 of rotations

Pea grown for grain more profitable than as hay or cover



Rotation at full N	pH
Initial	7.4
After 14 yrs	
WW full N	6.2b
Pea grain	7.3a

Miller et al. 2017, MSU Fertilizer eFact # 72

Summary

- A combination of management changes is likely needed to substantially increase NUE
- Manage N with the N-cycle in mind to supply N when needed, reduce N losses, and protect soil, water, and air quality and client's pocket book
- Each growing region will have unique best management practices to increase NUE – look for local information
- Research can't test all possible conditions – do strip trials with willing producers

QUESTIONS?

This presentation and additional information on soil fertility topics are available at http://landresources.montana.edu/soilfertility

Photo by Andrew John