N Fertilizer Rates and Soil Acidification

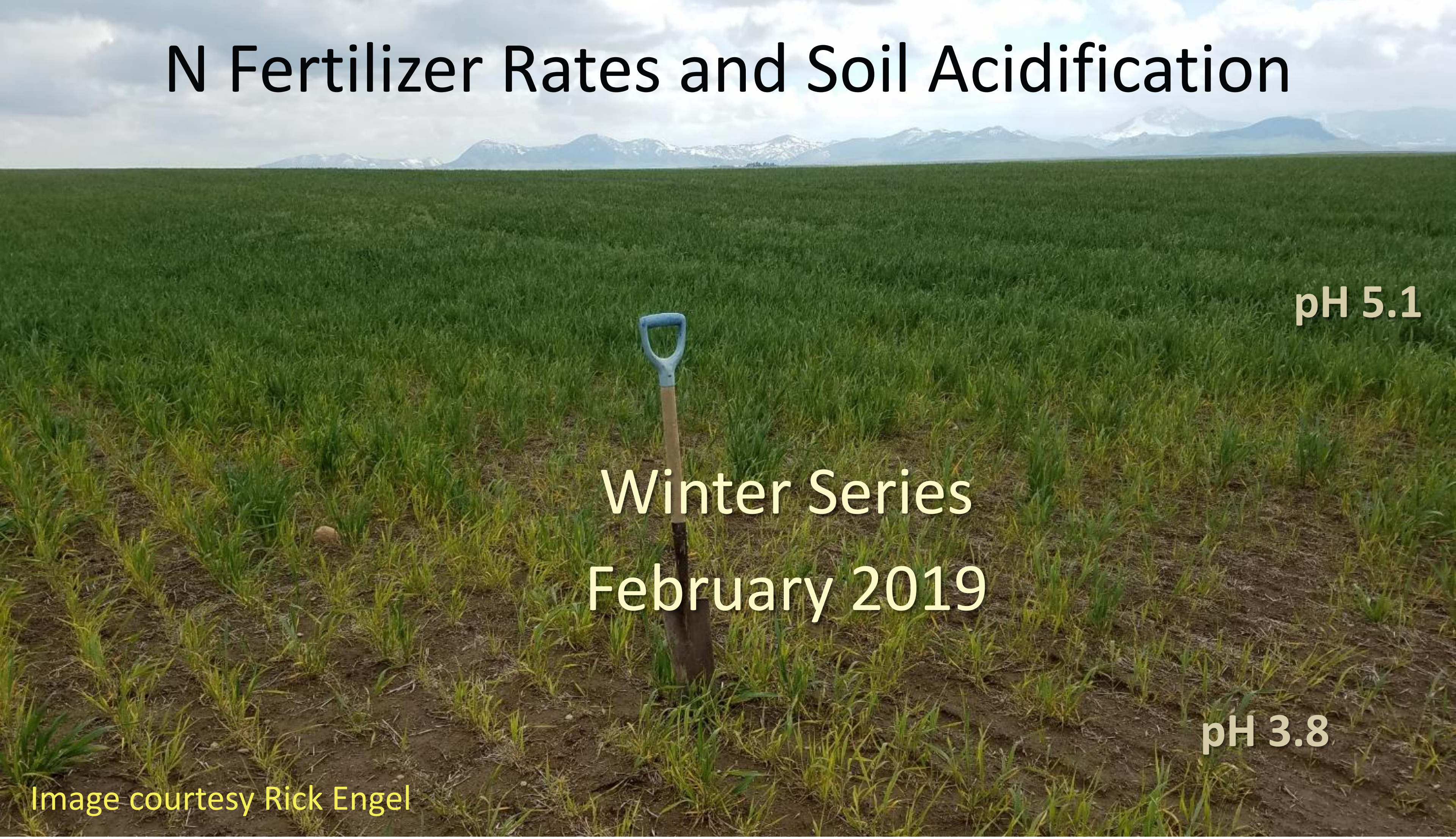

Image courtesy Rick Engel

Winter Series

February 2019

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MONTANA STATE UNIVERSITY

MSU Soil Fertility Extension

Objectives

1. Explain how to determine N fertilizer rates
2. Demonstrate the MSU N rate calculator, and adjustments to calculated N rates
3. Show impact of N fertilization and other factors on soil pH
4. Present ways to identify low soil pH
5. Discuss steps to prevent or reverse acidification

The Montana Fertilizer Check-Off and the Western Sustainable Agriculture Research and Education Program help fund our studies.

How much N fertilizer do I need to apply? Soil test

Soil nitrate-N: can vary greatly by year due to e.g. plant residue decomposition, leaching loss.

Fertilizer rate based on soil test results:

- Soil test ideally 2-3 ft.
- Best done in early spring, but not when soil is wet, therefore in our climate perhaps best done in late fall
- See MT200702AG and MT200803AG for details on 'how-to'

Calculating N rates

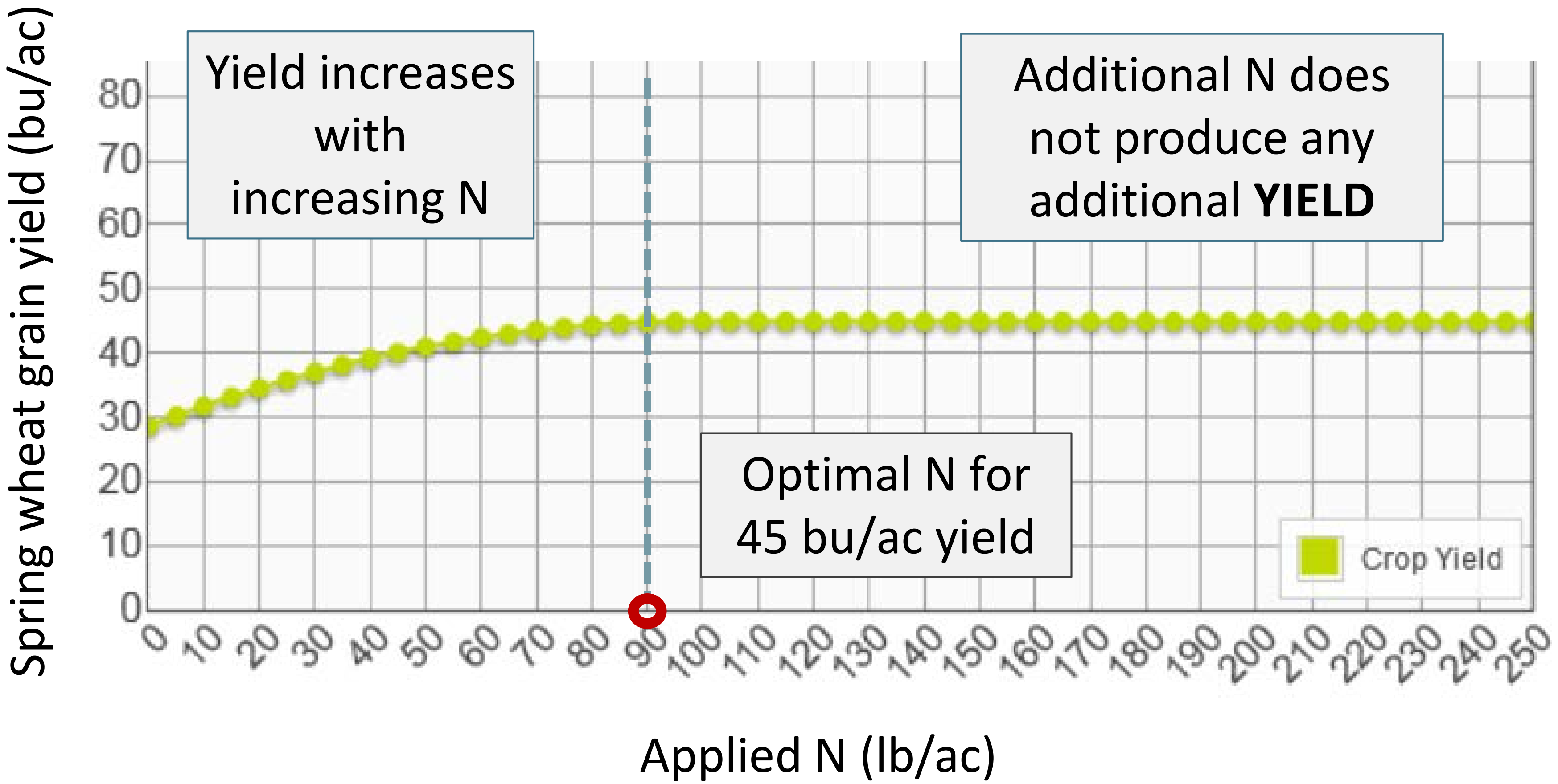
Rates are based on soil test results and reasonable yield goal

- Provided by lab (check if they use MT rate guidelines)
- Guidelines & calculations in MSU MontGuides and crop specific bulletins

http://landresources.montana.edu/soilfertility/publications.html

- MSU soil test calculator
  http://www.sarc.montana.edu/php/soiltest/

More ≠ better: Law of diminishing returns



Soil N = 10 lb/acre, SOM = 2%

http://econtools.msuextension.org/nitrogen/

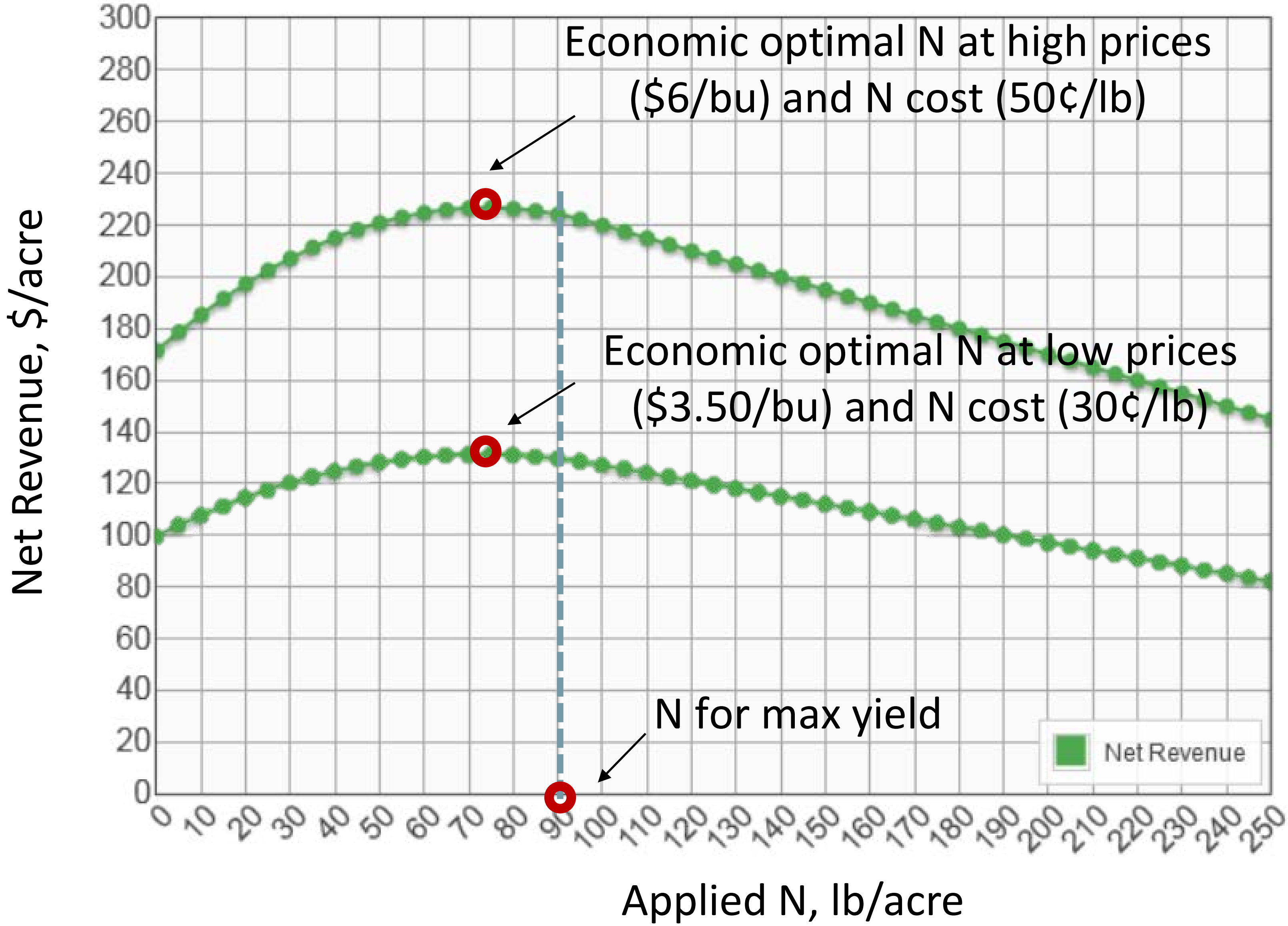
Because it’s not that simple: MSU N Rate Econ Calculator

- Inputs
  - N fertilizer cost, grain price, protein discount/premiums
  - Yield goal
  - These help calculate **TOTAL** available N for max net return
  - Residual soil N
  - SOM

Calculators online for barley, SW, and WW after fallow (and hopefully for recrop soon)

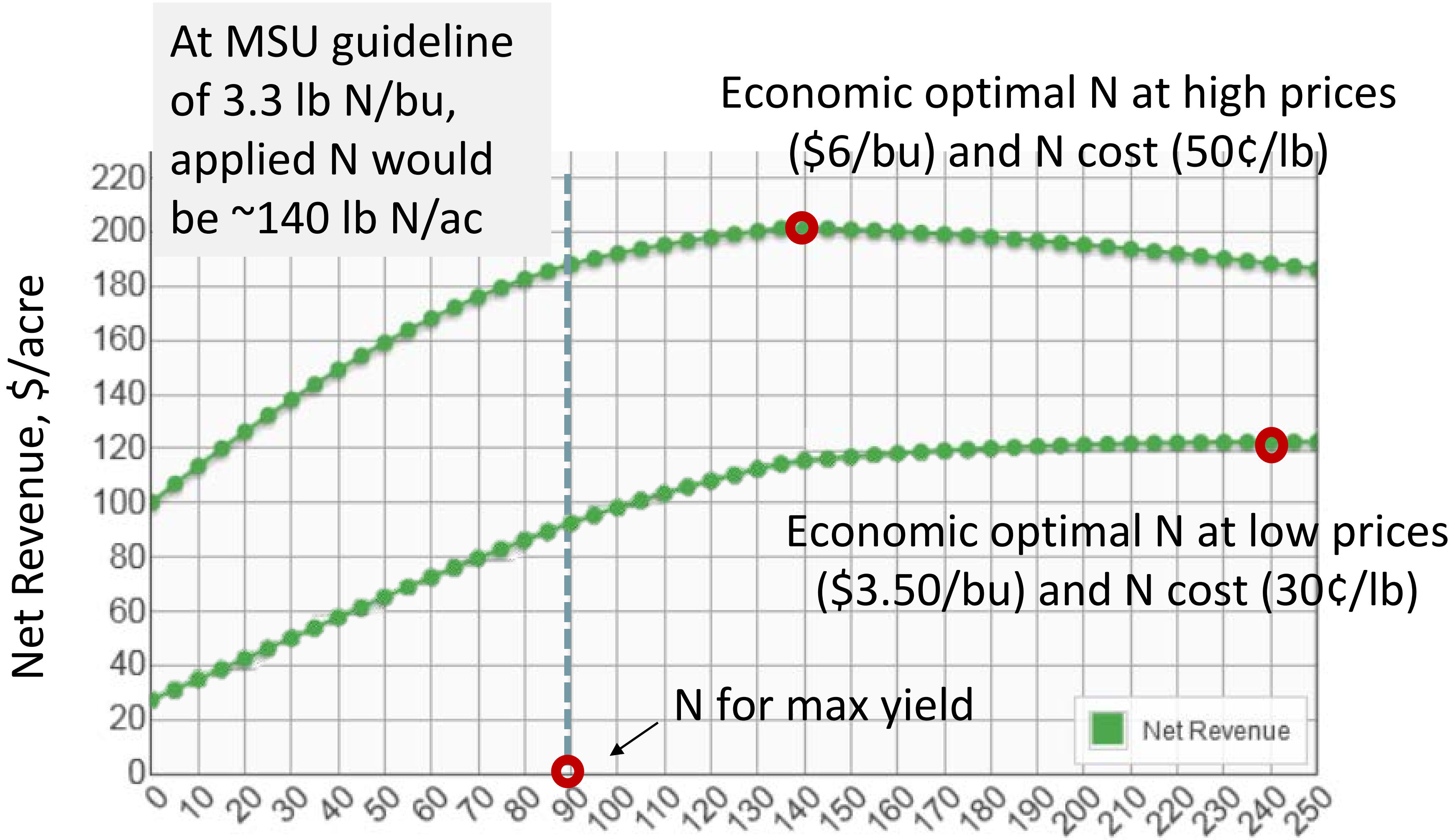
http://www.msuextension.org/econtools/nitrogen/

Economically optimal N (e.g. SW with 0 discounts/premiums)



Soil N = 10 lb/acre, SOM = 2%, 45 bu/ac

Economically optimal N when discounts are high: protein discounts (15¢/0.25%) & premiums (10¢/0.25%)



Soil N = 10 lb/acre, SOM = 2%, 45 bu/ac

N rate adjustment: Fall soil tests can lead to over or under-fertilized fields

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

Mineralization

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

N rate adjustments: prior crop

- Stubble: small grains stubble high carbon to N (C:N). Adjust fertilizer N up or down?

  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:

  Adjust fert up or down?

  Legumes credit (add) N

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

Variable rate N application: Zone or site specific farming

- At this time economic advantage is inconsistent (and hard to study)
- At simplest, divide field into zones of low, med, high productivity
- NDSU has bulletin series on Zone farming SF1176 series at [www.ag.ndsu. edu/publications](www.ag.ndsu.edu/publications)

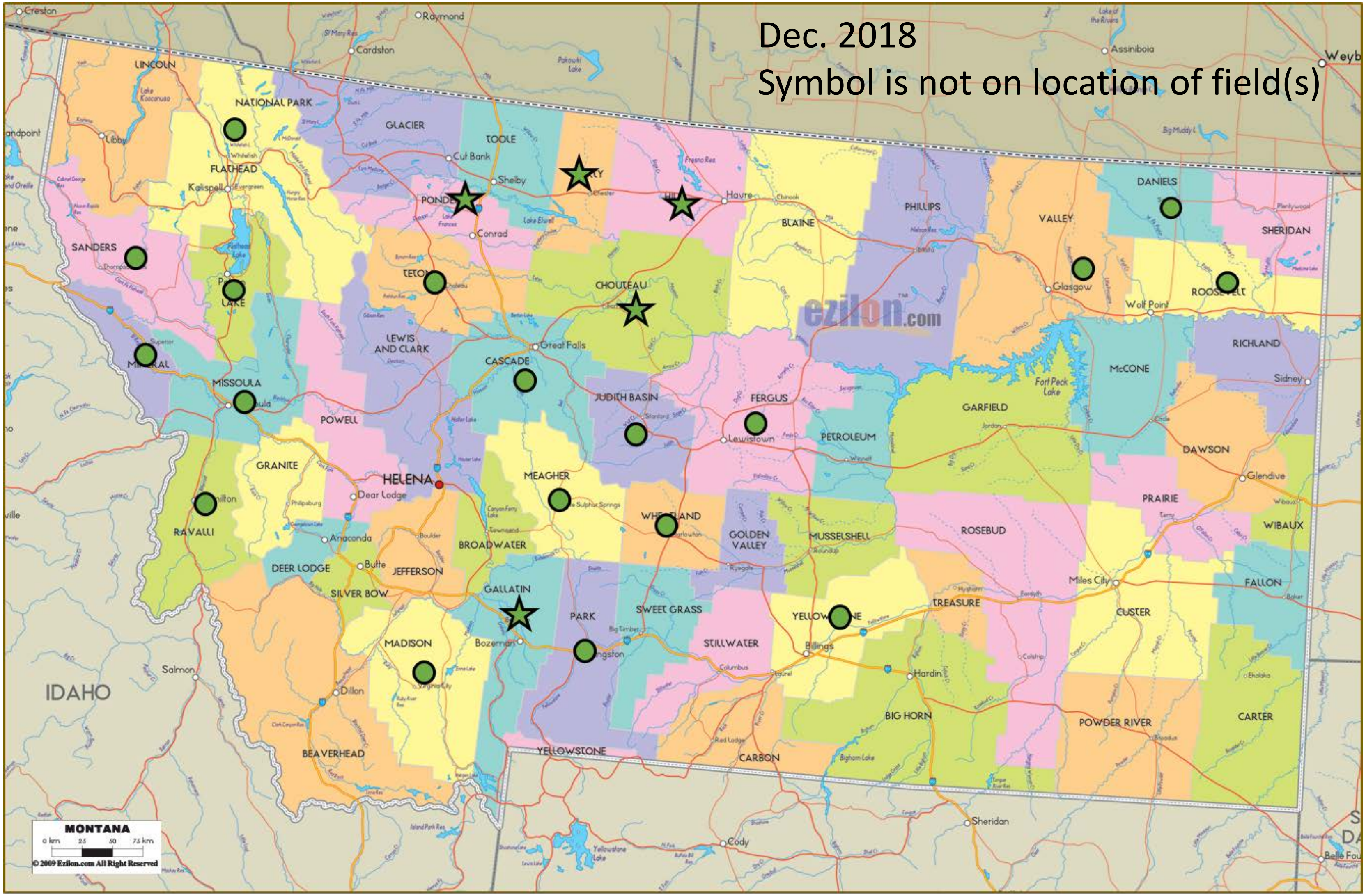
53B silt loam 0-4% slope
155F cobbly loam 15-60% slope
451C silt loam 4-8% slope

https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Questions?

What are consequences of over fertilization?

Low soil pH: MT counties with at least one field with pH < 5.5



☆ Measured by MSU ● Reported by CCA, Ext. Agent, or producer

40% of 20 random locations in Chouteau County have pH < 5.5 in top 2”

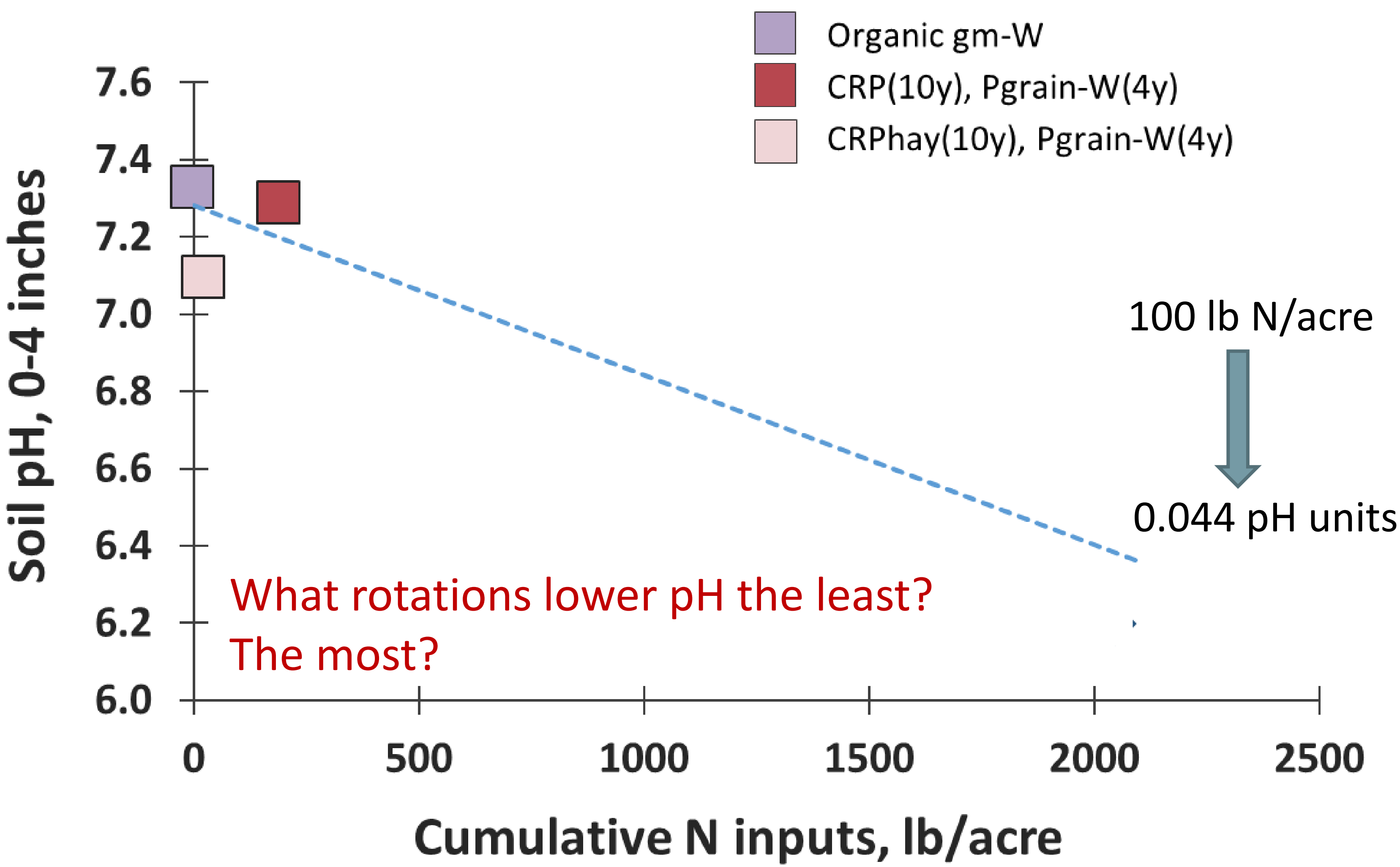
Agronomic reasons for low soil pH

- Ammonium-based N fertilizer above plant needs due to nitrification:

ammonium or urea fertilizer + air + $H_2O \rightarrow$ *nitrate* (NO_3^-) *+ acid* (H^+)

- Leaching loss of nitrate: less nitrate to take up = less root release of basic anions (OH^- and HCO_3^-)
- Crop residue removal: removes Ca, Mg, K ('base' cations).
- Lack of deep tillage concentrates acidity where N fertilizer applied
- Legumes acidify their rooting zone through N-fixation. Perennial legumes (e.g., alfalfa) more so than annuals (e.g., pea). Yet apparently much less than fertilization of wheat.

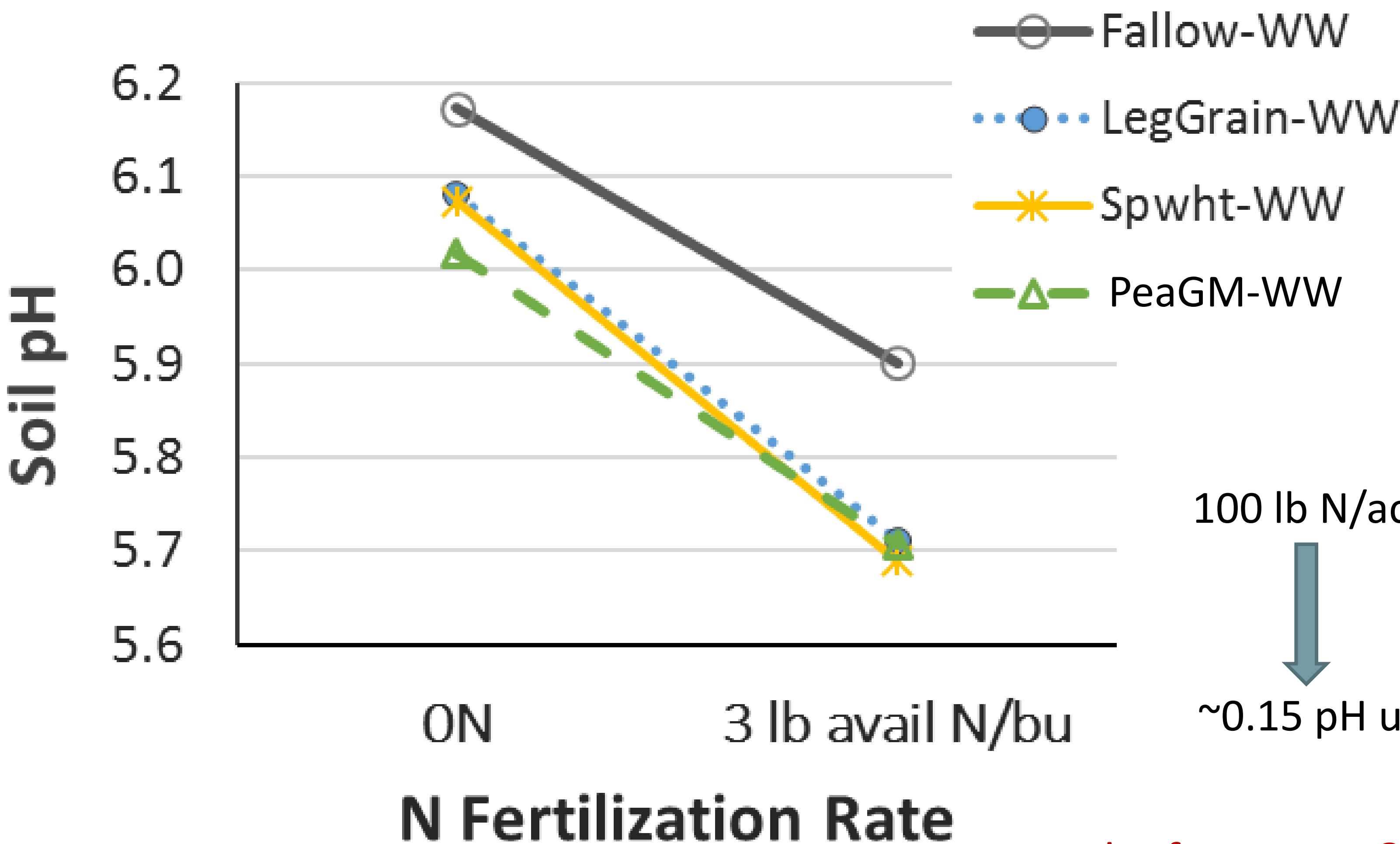
14-yr of N fertilization reduce top 4” pH on dryland cropping west of Bozeman up to 1 pH



Silt loam, 2% OM

Engel, Ewing, Miller, unpub data

6-yr N fertilization reduce soil pH (0-3”) west of Big Sandy



100 lb N/acre

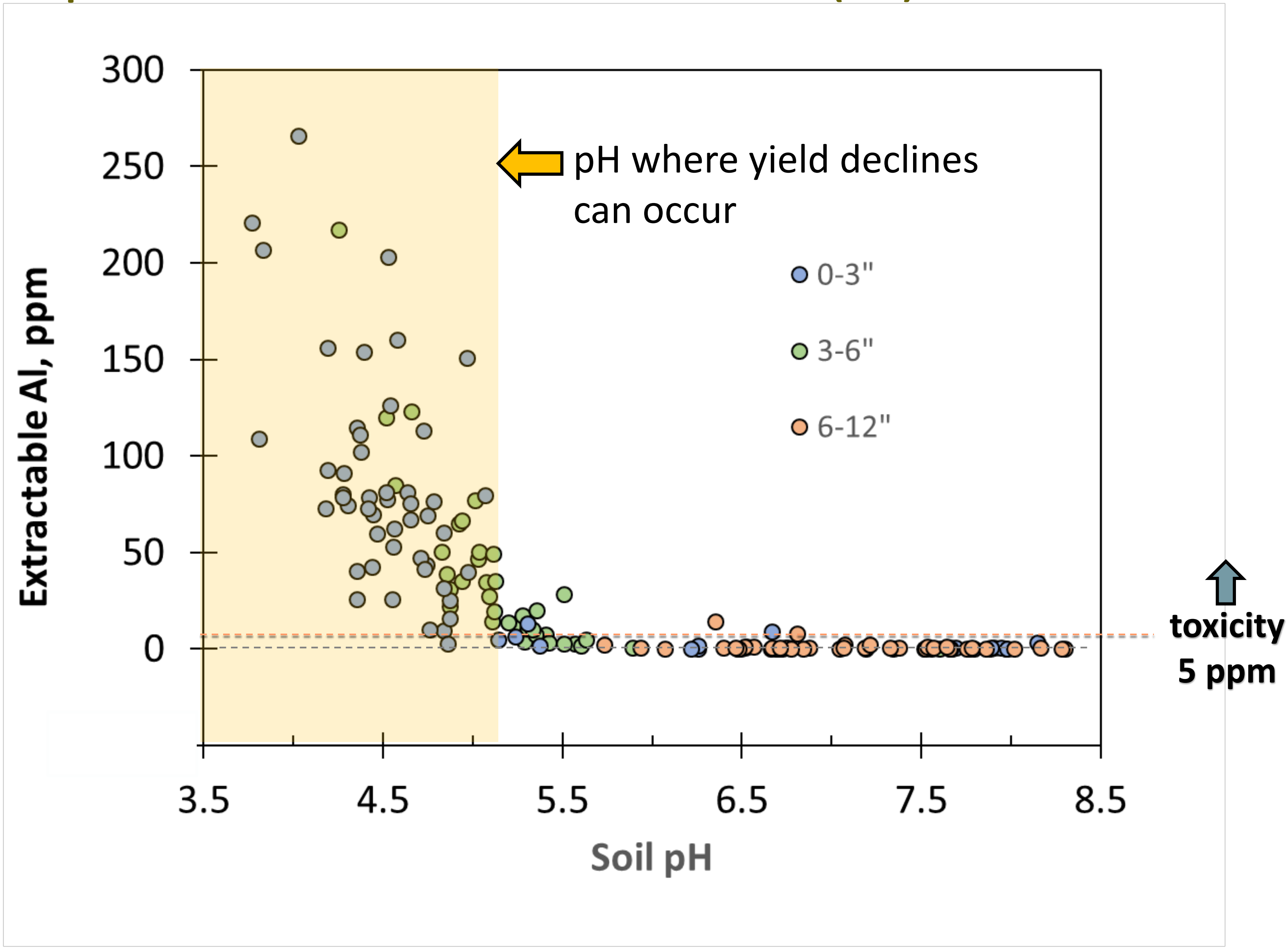
~0.15 pH units

why faster rate?

sandy clay loam, 1.1% OM

Alternate year was always winter wheat; Jones and Miller unpub data

Low pH increases soil aluminum (Al) to toxic levels



Engel unpub. data, 2016, 5 farms near Highwood, MT

At pH < 4.8 → Al toxicity

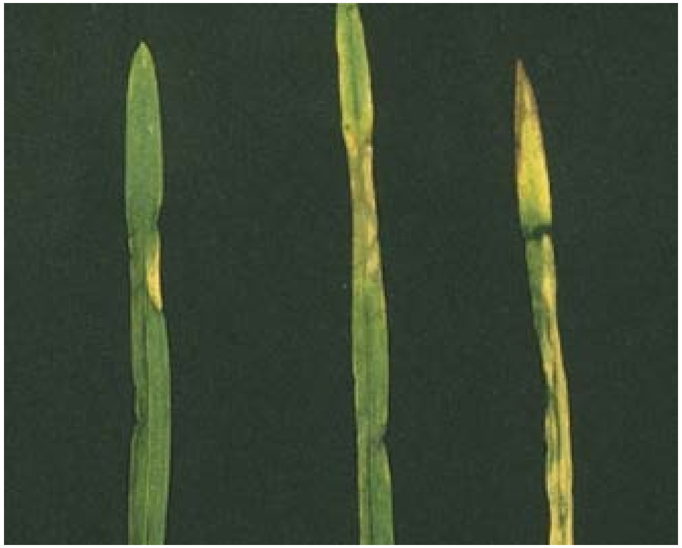
- Unexplained poor health in low or mid-slope areas
- **Al** toxicity
  - stubby club roots, no fine branching (similar to nematode damage)

A. Robson, https://agric.wa.gov.au/n/4487

photo sources: Engel

Above ground symptoms of Al toxicity

- small leaves, short thick internodes
- yellow along margin near tip on older leaves
- purple or brown lesions in chlorotic regions, indentations
- leaf withering and collapse in center



Courtesy CIMMYT.org

courtesy Engel

Acid soils have additional negative impacts

- N fixation hurt below ~ pH 6
- Increase in some fungal diseases (e.g., Cephalosporium stripe) and root rot
- Change efficacy and persistence of chems

May be first indicators of pH change

Image from *Wheat Disease ID*. MT Wht & Barley Co.

Canola: Gov. West. Australia

Diagnose: scout, soil test

Look at pH on prior soil tests from composited samples

- pH < 6 likely have spots with pH ≤ 5
- 6 < pH < 7.5 don’t assume no areas have low pH
- pH > 7.5, likely don’t have problem (yet).

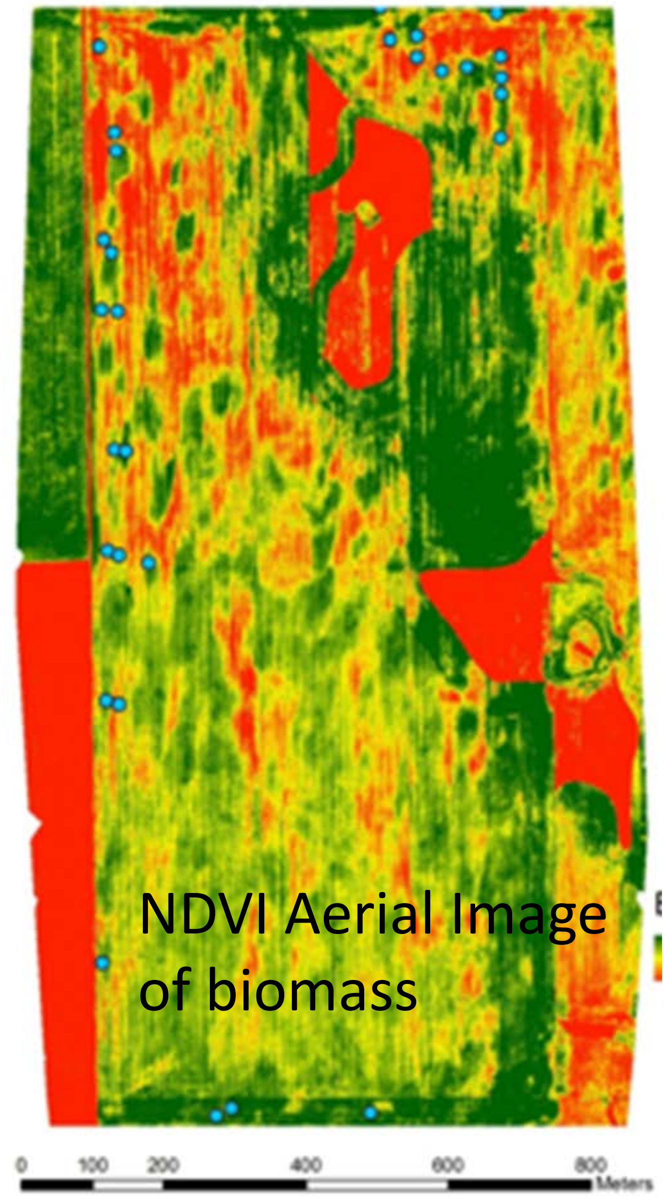
Image provided by Rick Engel

Safflower field, image by Scott Powell

Symptoms are not uniform across field landscapes

Soil test

1. Scout or use aerial maps to locate healthy and unhealthy areas
2. Field pH test, use soil/water slurry of top 3”. Why not the standard 6”?
3. Avoid compositing samples from different slope areas.
4. Send 0-3” depth sample to lab for pH (<5?). Test 3-6” if might till.
5. pH varies seasonally and annually, test from same area and time of year by same lab using same procedure to see trend
6. Veris can also sample for pH



Questions?

On to prevention

Management to prevent acidification:
Increase N fertilizer use efficiency

- Soil test close to application time. Make sure enough PKS
- Use conservative pre-plant rate, top-dress if adequate moisture
- Apply N close to peak crop uptake
- Use variable, site specific rates: Less N in low production areas limited by factors other than N (e.g., low pH, shallow soils)
- Reduce N rates especially when protein discounts low
- Takes steps to reduce N leaching (see our N Leaching Extension bulletin and MTGuide)

Management to prevent acidification: Change N source?

- Minimize use of ammonium fertilizers (MAP 11-52-0; AS 21-0-0-24). Consider gypsum for S source.
- Use calcium ammonium nitrate (27-0-0; $$) instead of urea or UAN (CAN shouldn't volatilize so can likely also lower rate)
- Include legume rotations, manure if available

Most acidifying

MAP = AS ≈ 2x urea

DAP (18-46-0)

Urea (46-0-0), UAN (28-0-0)

CAN ≈ 1/3x urea

Potassium nitrate (13-0-46)

Least acidifying

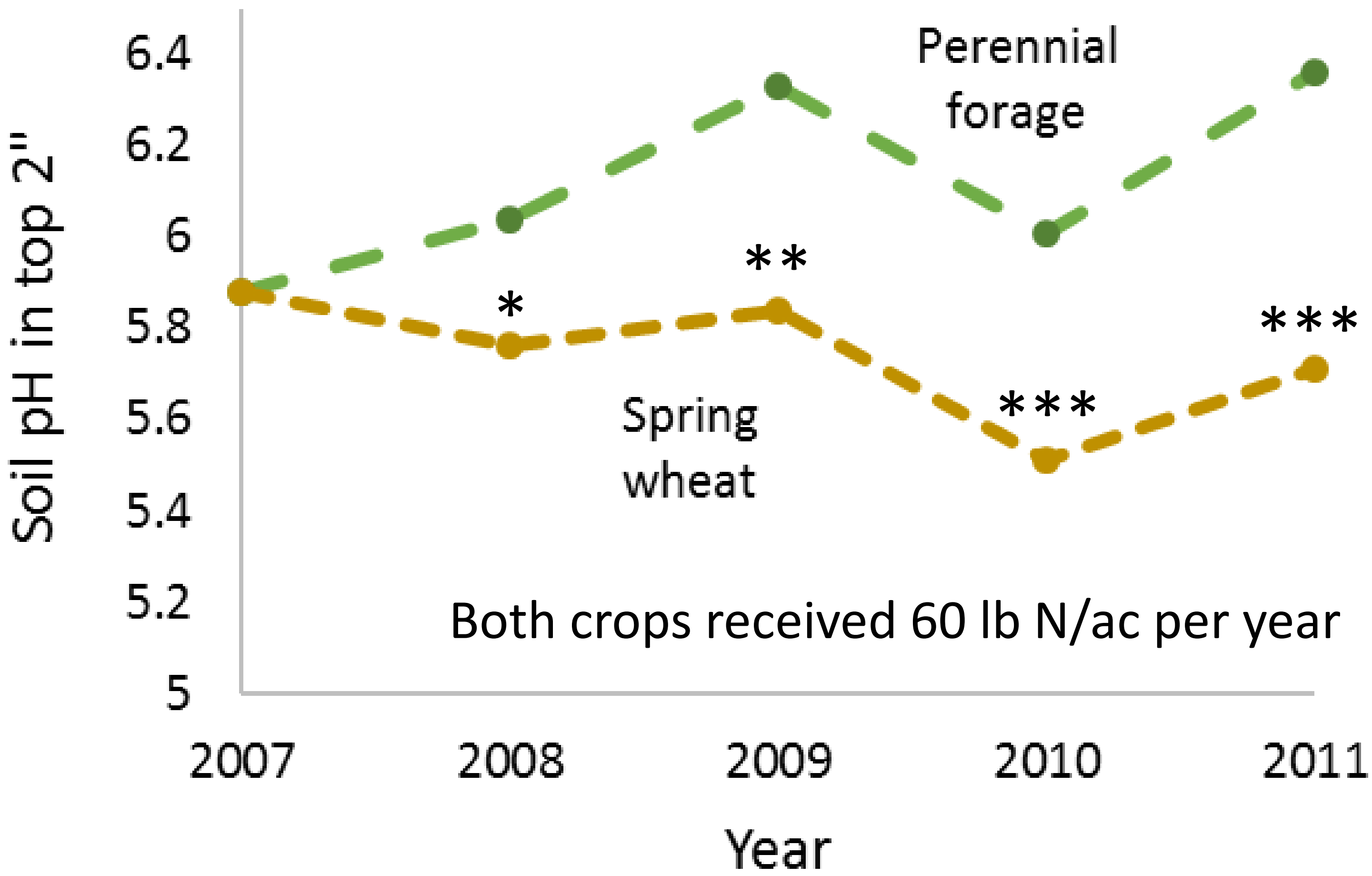
More preventive options

Image by K. Olson-Rutz

- Leave crop residue in field – retains base cations and SOM buffers pH changes and Al toxicity. 6x base cations removed by oat straw harvest than just oat grain harvest (Pierre and Banwart 1973)
- Legumes in rotation – no N fertilizer and residue increases soil surface pH more than non-legumes (Paul et al., 2003)

Which of these (or previous) might you try?

Perennial forage can maintain or increase soil pH



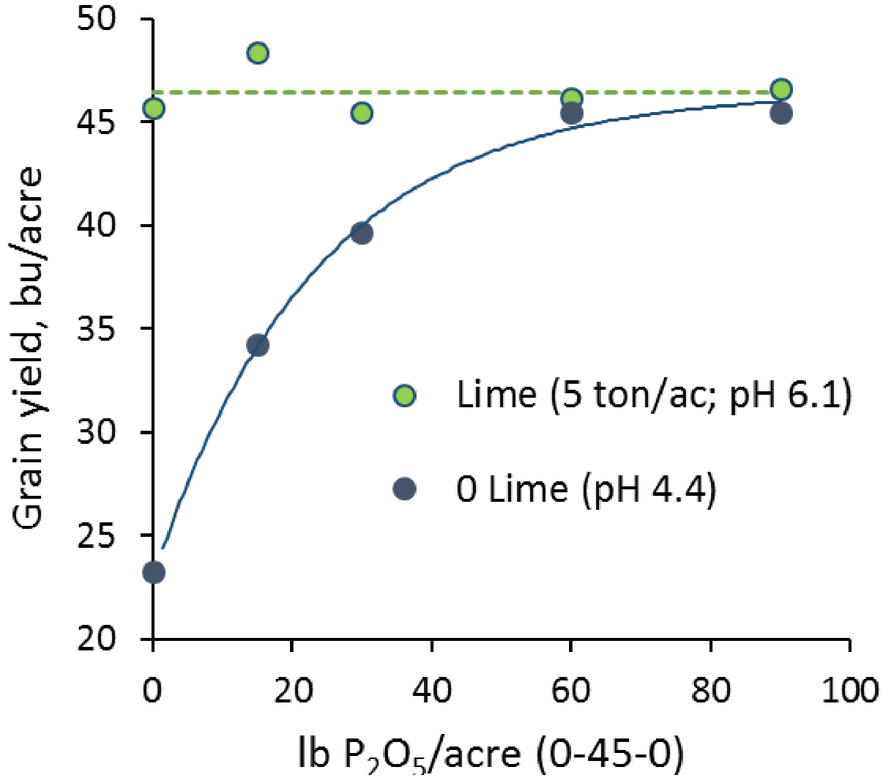
pH differs between crops with * > 90%, ** > 95%, *** > 99% confidence, Mandan, ND, Liebig et al., 2018

What else are people trying?

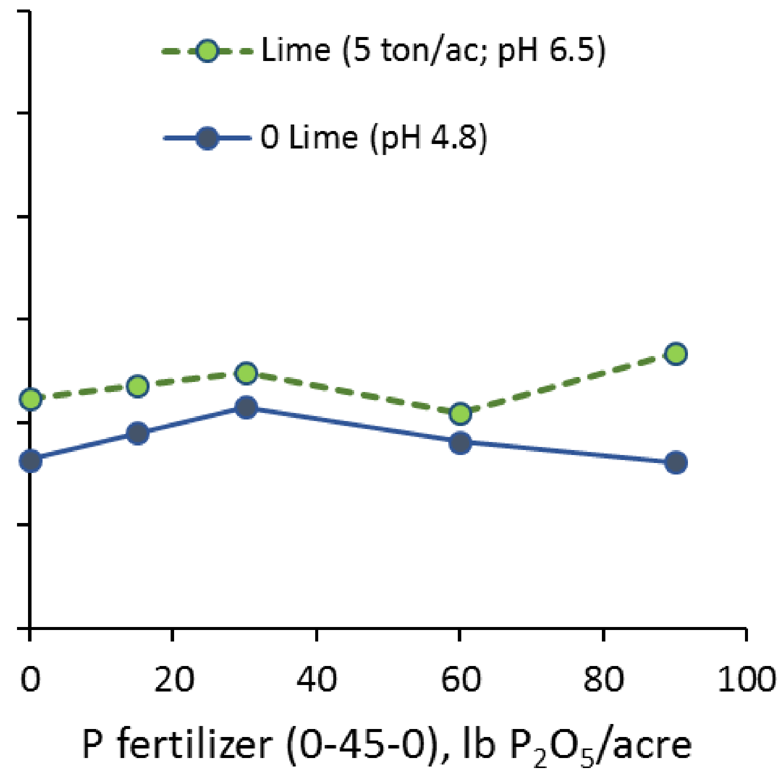
Questions?

On to adaptation and restoration options

Seed-placed P_2O_5:increased durum grain yield in one farm , no response another farm



Olsen P = 48 ppm

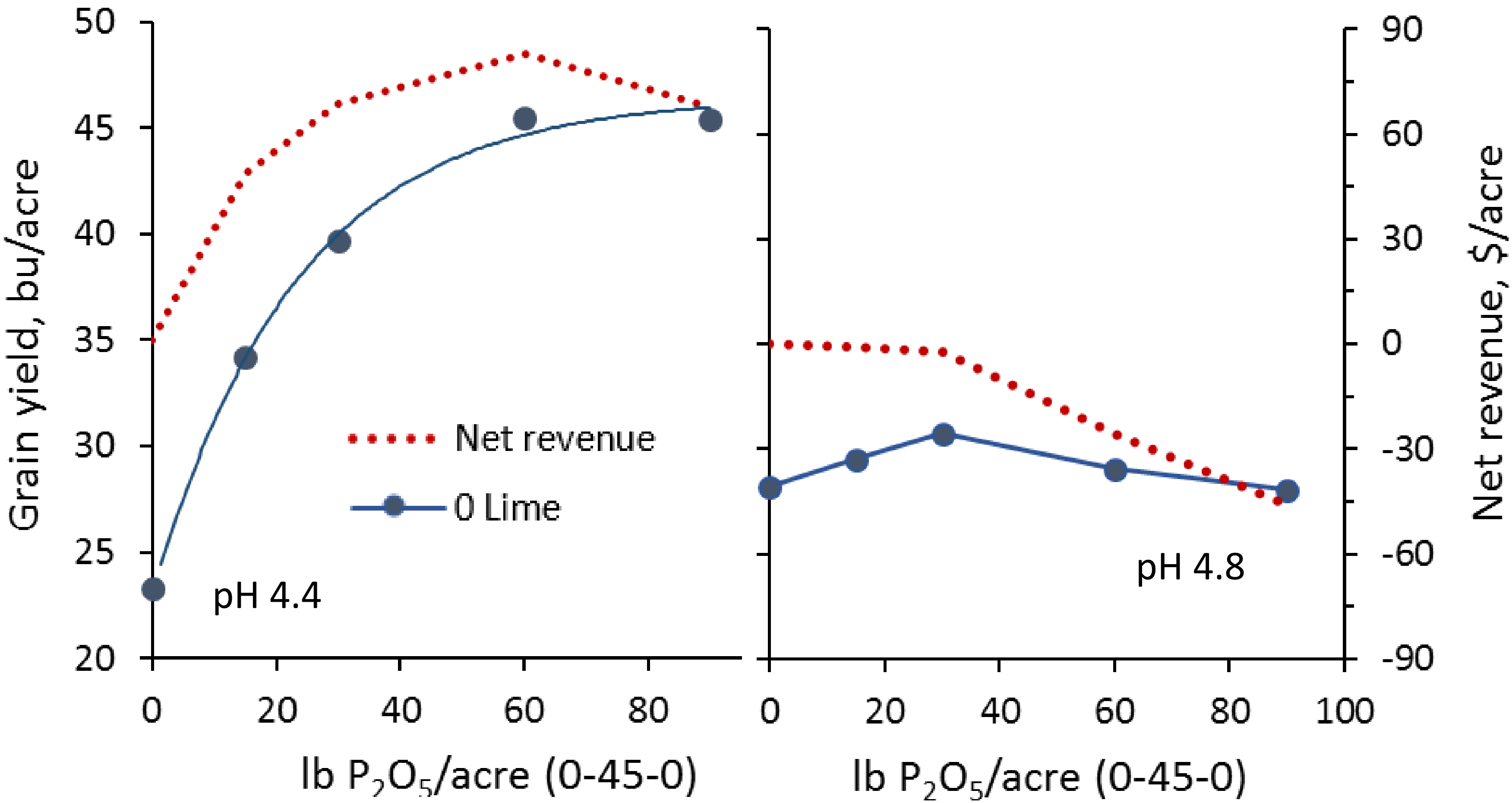


Olsen P = 53 ppm

Economics?

Engel unpub data
using Ag lime

Seed-placed P_2O_5 may or may not pay off



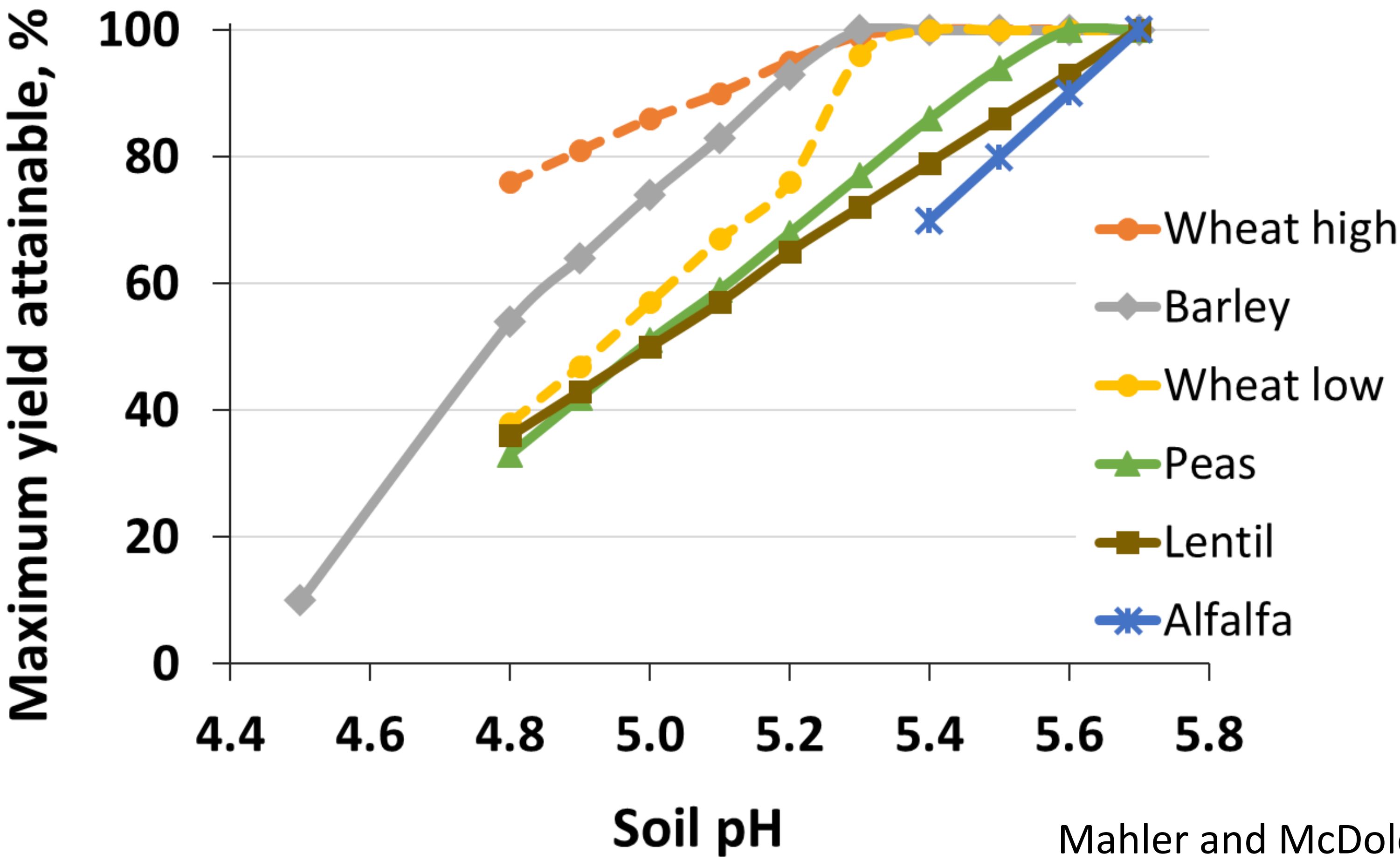
What to do?

TSP \$0.50/lb P_2O_5

Field strip trials

Adaptation: Select tolerant crop species. Legumes are least tolerant.

"Wheat high" are Al and acid tolerant varieties



Mahler and McDole 1987
Long pers comm

MT variety trial results are available at
http://landresources.montana.edu/soilfertility/acidif/index.html

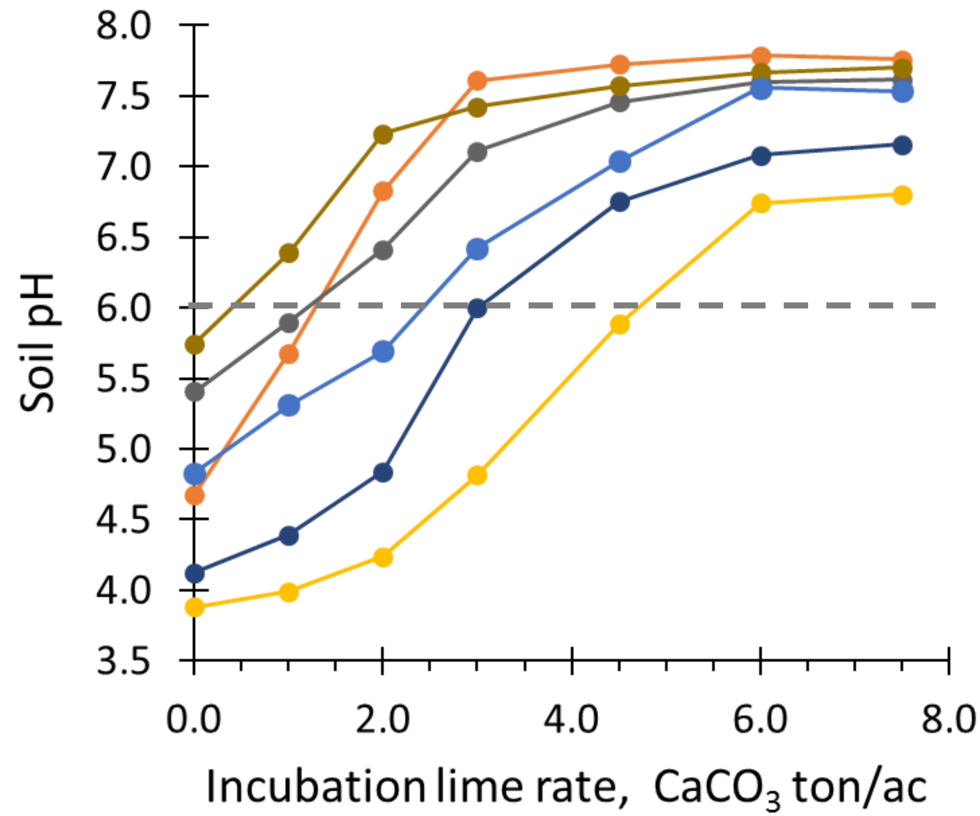
Restoration: liming

pH Goal

- > 5 to reduce Al toxicity
- > 5.5 to have some buffer, rhizobia health for N fixation
- > 6 to be good for 10+ years

The lower the soil pH, the more lime it takes to get to pH 6

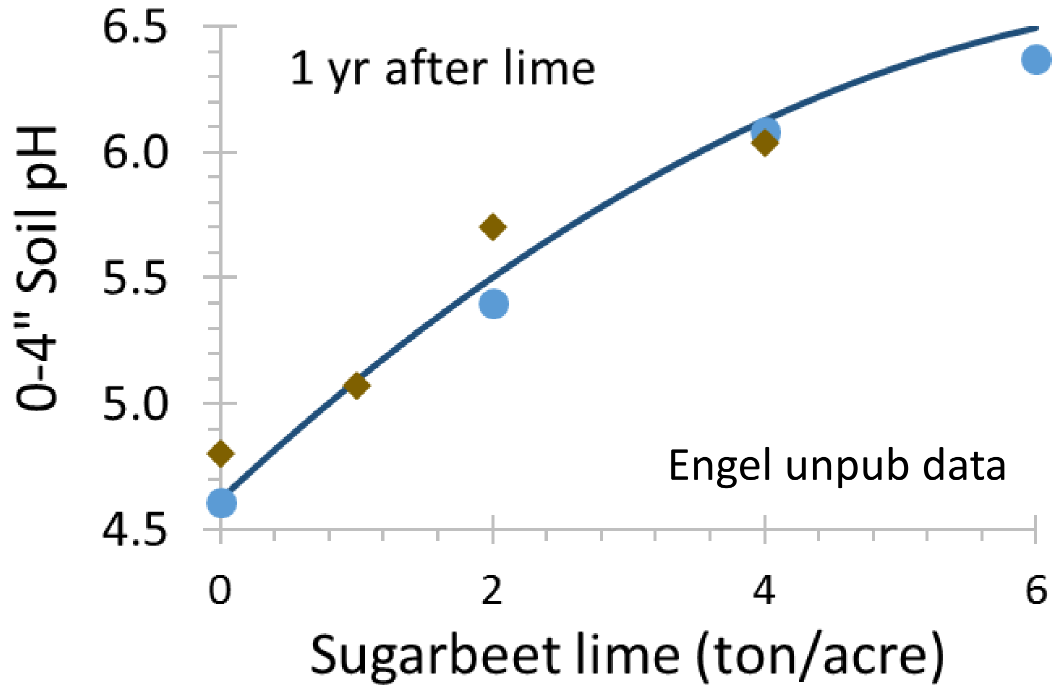
- 10 acidic MT cropland soils tested, 6 shown here
- Incubated in lab with fine grade lime for 90 days
- pH 4 soil = 3-4 ton $CaCO_3$ → pH 6
- pH 4.7-5.4 soil = 1.75 ton $CaCO_3$ → pH 6



Engel unpub data

Restoration needs a lot of lime

- Rate:
  - Find from online tables (or your lab) with buffer pH and target pH
  - Or use MSU preliminary results
- Only lime field areas with low soil pH



Initial pH	Ton SBeet lime	
	To pH 6.0	To pH 6.5
4.0	4.7	7.2
4.5	3.8	6.3
5.0	2.8	5.2
5.5	1.6	4.0

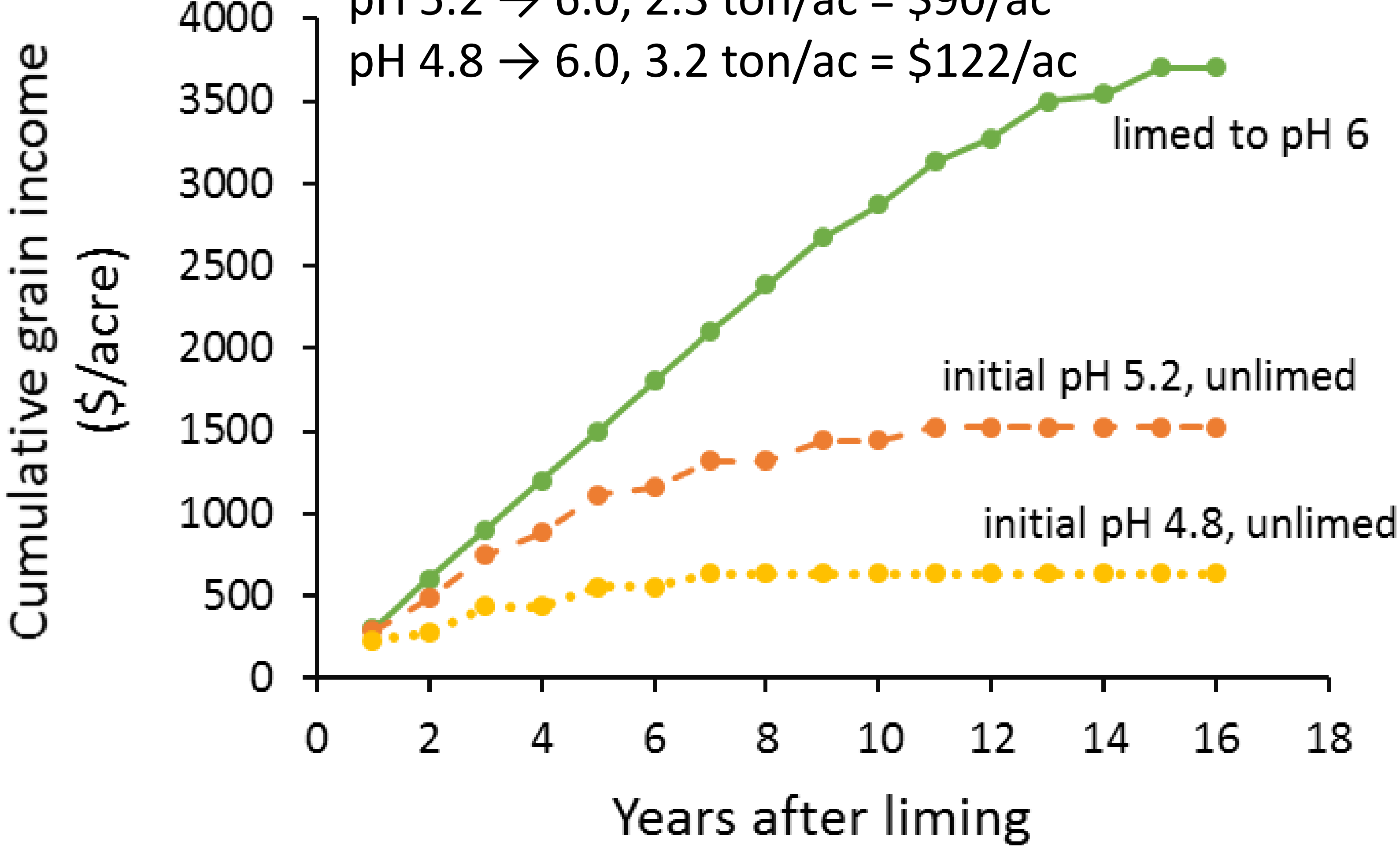
Liming is a capital investment

ROI??

Lime needed

pH 5.2 → 6.0, 2.3 ton/ac = $90/ac

pH 4.8 → 6.0, 3.2 ton/ac = $122/ac

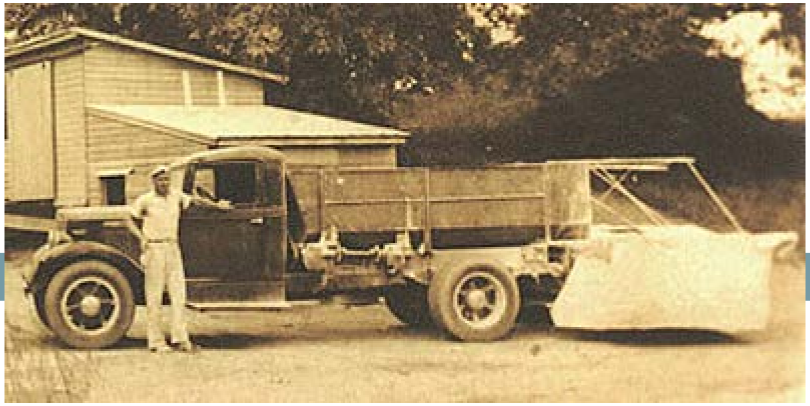


Mahler and McDole 1987 yield decline curves

50 bu/ac yield potential, $6/bu grain, $35/ton lime + $10/ac to spread

low-pH tolerant wheat/low-pH sensitive durum rotation; 100 lb N/ac/yr

Lime sources


Stoltzfus lime spreader, Stoltz Mfg.

- Sugarbeet lime
  - Good – it doesn't cost anything
  - Bad – shipping costs (up to $35/ton); challenging material to work with (moisture and clumping), need a wet lime spreader, contains chunks and some trash, and incorporation w/ tillage needed for best results
  - Rates of 3-6 tons/acre may be necessary to bring pH to acceptable level (pH > 6)
- Aglime – more expensive and further away
- Pelletized lime? Expensive and need about 400 lb/acre per year just to offset typical N rate.

Tillage?


Photo by W.H. Lathrop, 1945.
Rice Soil And Water Cons. Dist

- Inversion till to mix acid zone with higher pH zone below – one-time summer tillage doesn't negate long term benefits of no-till (Norton et al., 2014)
- Problem: eventually make low pH zone deeper, when need to lime, requires more lime and deeper tillage. Will negate some no till benefits.

Summary

- Soil tests, the online economic N calculator and assorted publications are available to help determine N rates
- Cropland soils are becoming more acidic, largely due to N fertilization
- This reduces yields for several reasons
- Identify whether fields have a problem **now** to slow or prevent acidification with sound management
- Selecting crop rotations with lower N needs is likely best way to prevent further acidification
- Crop and variety selection or seed placed P fertilizer can help adapt to acid soils
- Liming or planting perennials can reverse acidification

Questions?

Image from Oregon State University, Lane County, OR 1926.

For more info. on soil acidification see MSU's cropland soil acidification website
http://landresources.montana.edu/soilfertility/acidif/index.html

This presentation and more info. on soil fertility topics is available at
http://landresources.montana.edu/soilfertility