Soil Acidification

ID, prevent, and restore

4-County Crop School, Three Forks

February 20, 2019

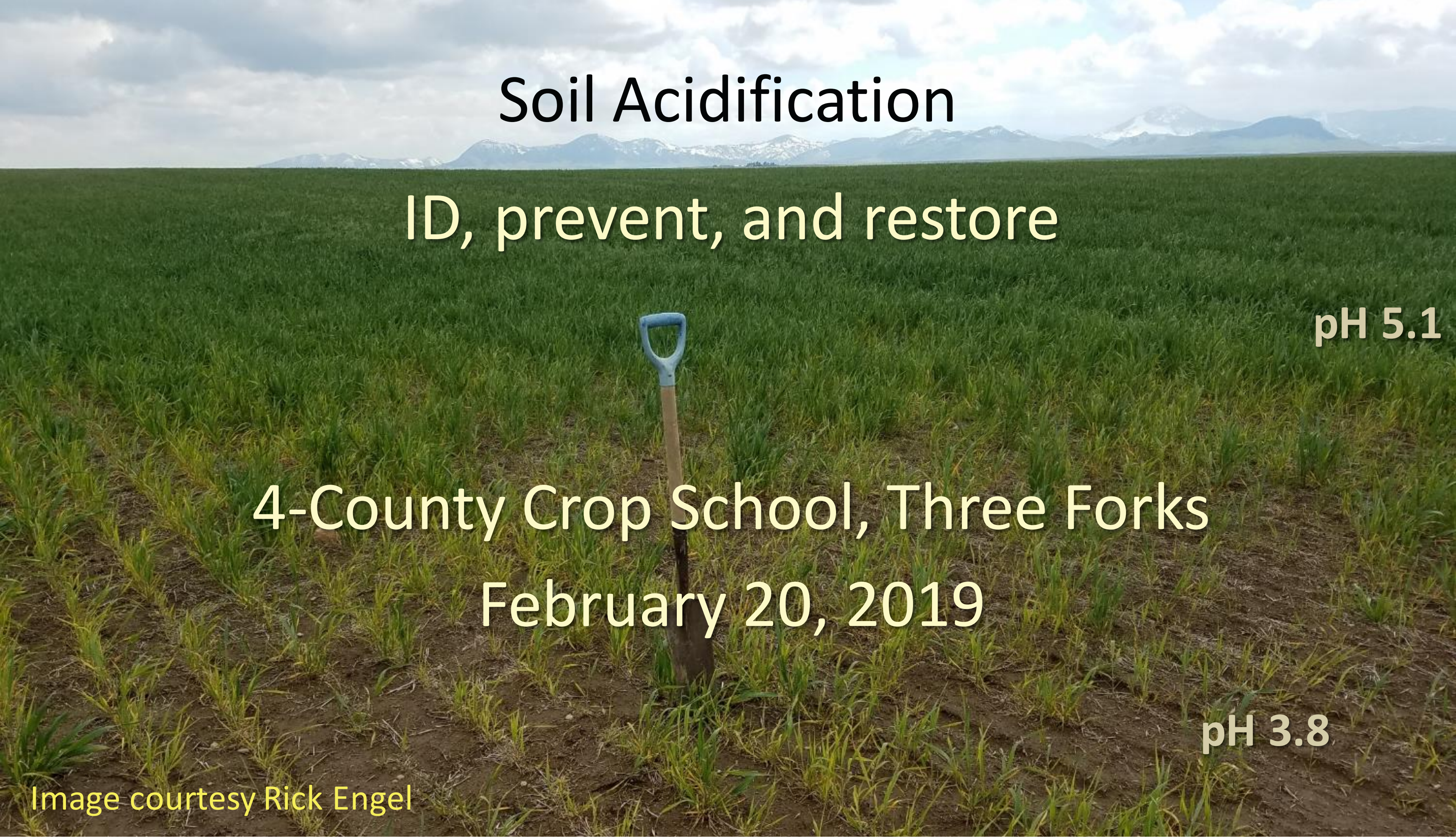


Image courtesy Rick Engel

Clain Jones clainj@montana.edu 994-6076; and Rick Engel

MONTANA STATE UNIVERSITY

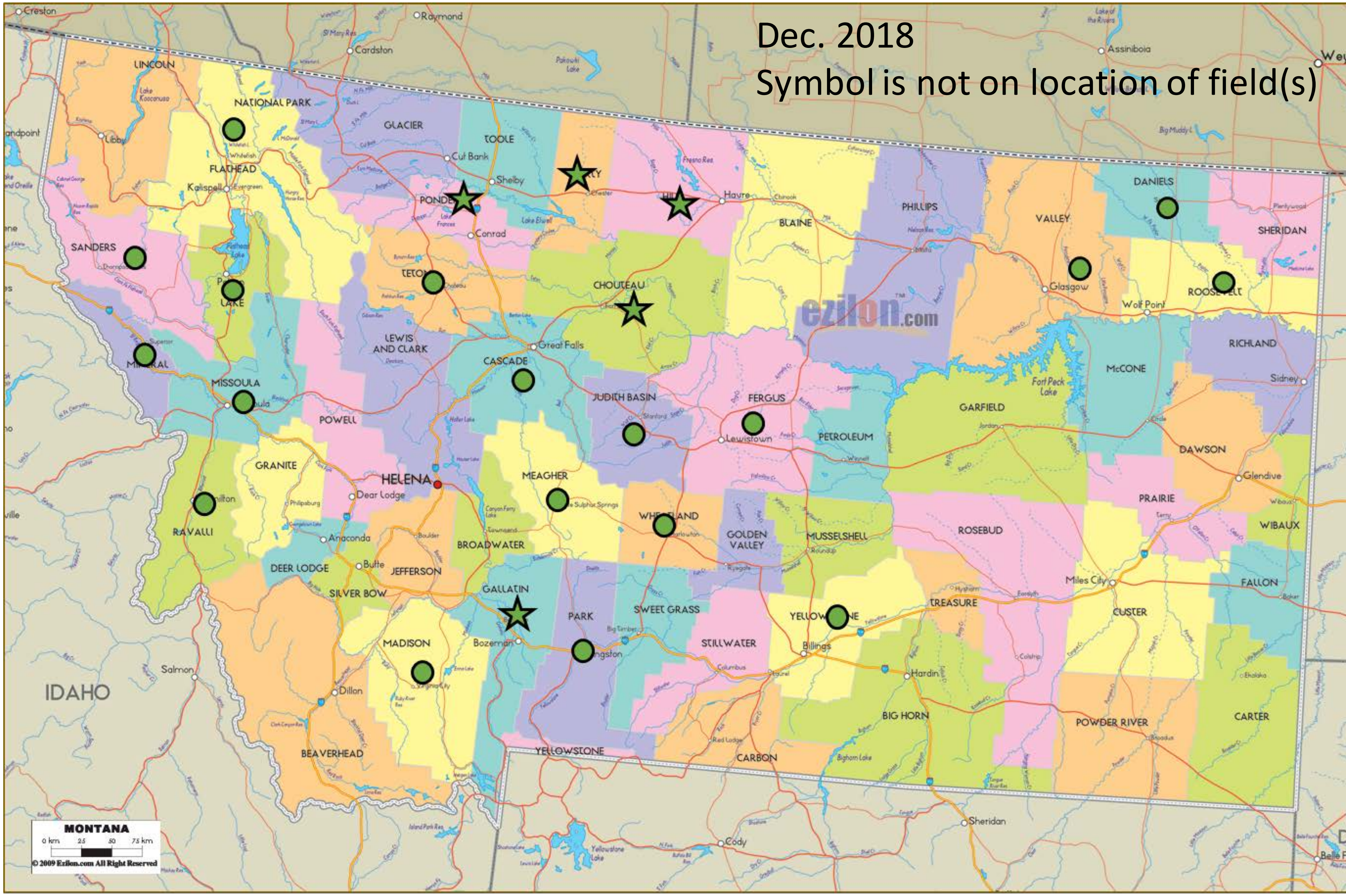
MSU Soil Fertility Extension

Objectives

1. Show prevalence of acidification in Montana (similar issue in WA, OR, ID, ND, SD, and CO)
2. Review acidification's cause and contributing factors
3. Depict low-pH soil affected crops
4. Present ways to identify low soil pH
5. Discuss steps to prevent or reverse acidification
6. Suggest crop management options in low pH soil

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

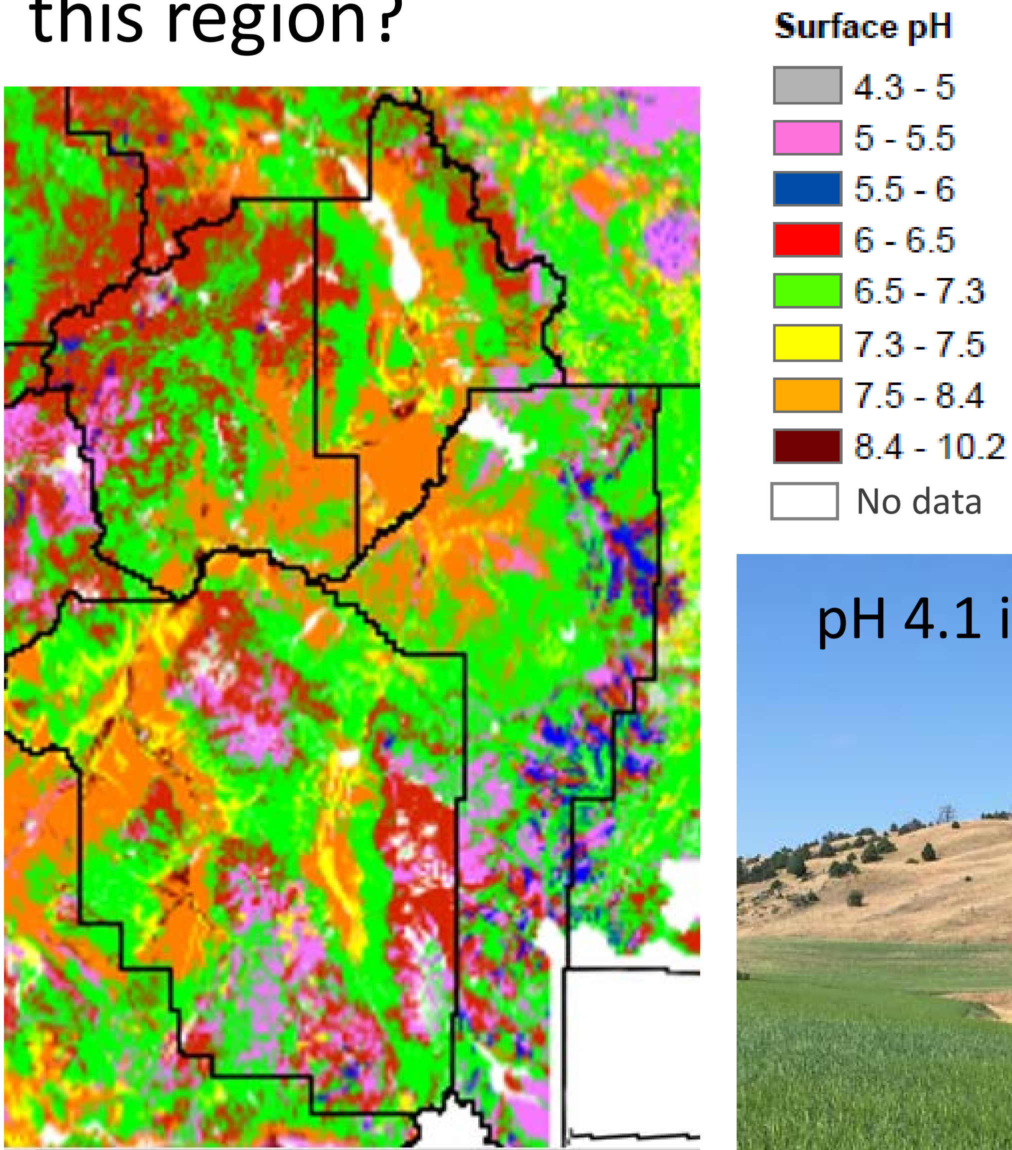
Prevalence: MT counties with at least one field with pH < 5.5



☆ 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”

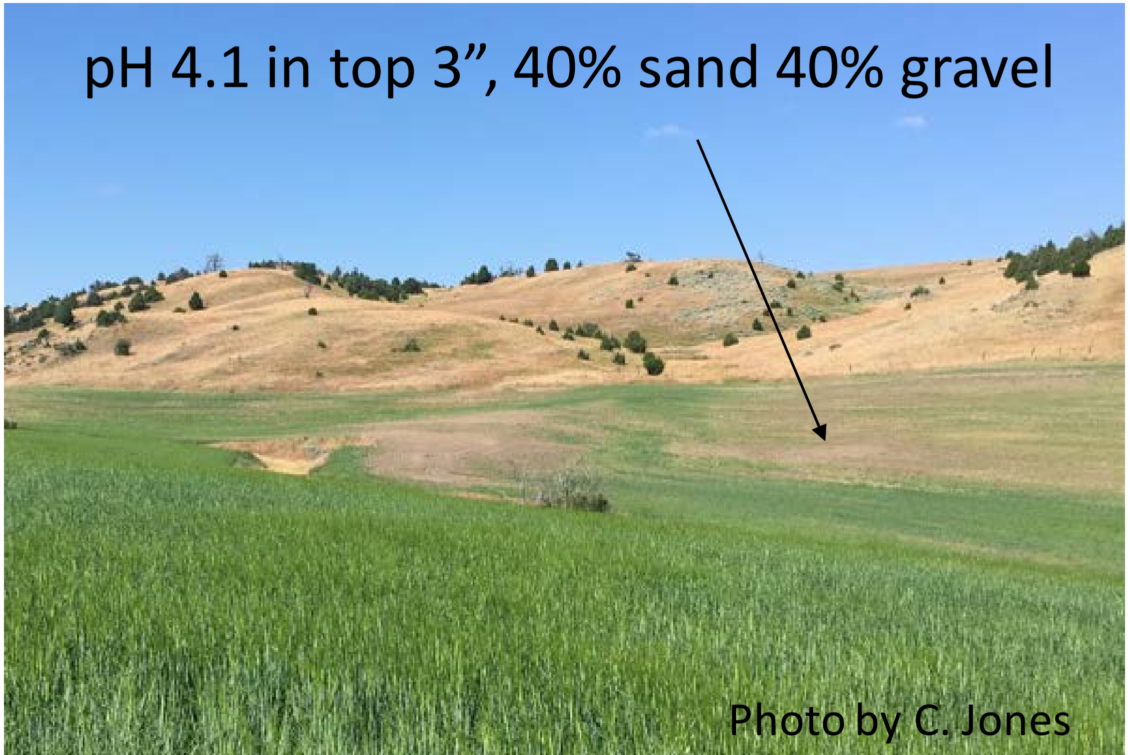
What were historical surface horizon pH values in this region?



Map courtesy of NRCS

Many arable soils in our region are high pH because of a calcium layer

Is that changing?



Natural reasons for low soil pH

- Soils with low buffering capacity (low soil organic matter, coarse texture, granitic rather than calcareous), e.g. edge of hills
- Historical forest vegetation soils have lower pH than historical grassland
- Regions with high precipitation, leading to nitrate leaching (and higher yields, therefore generally receiving more N fertilizer)

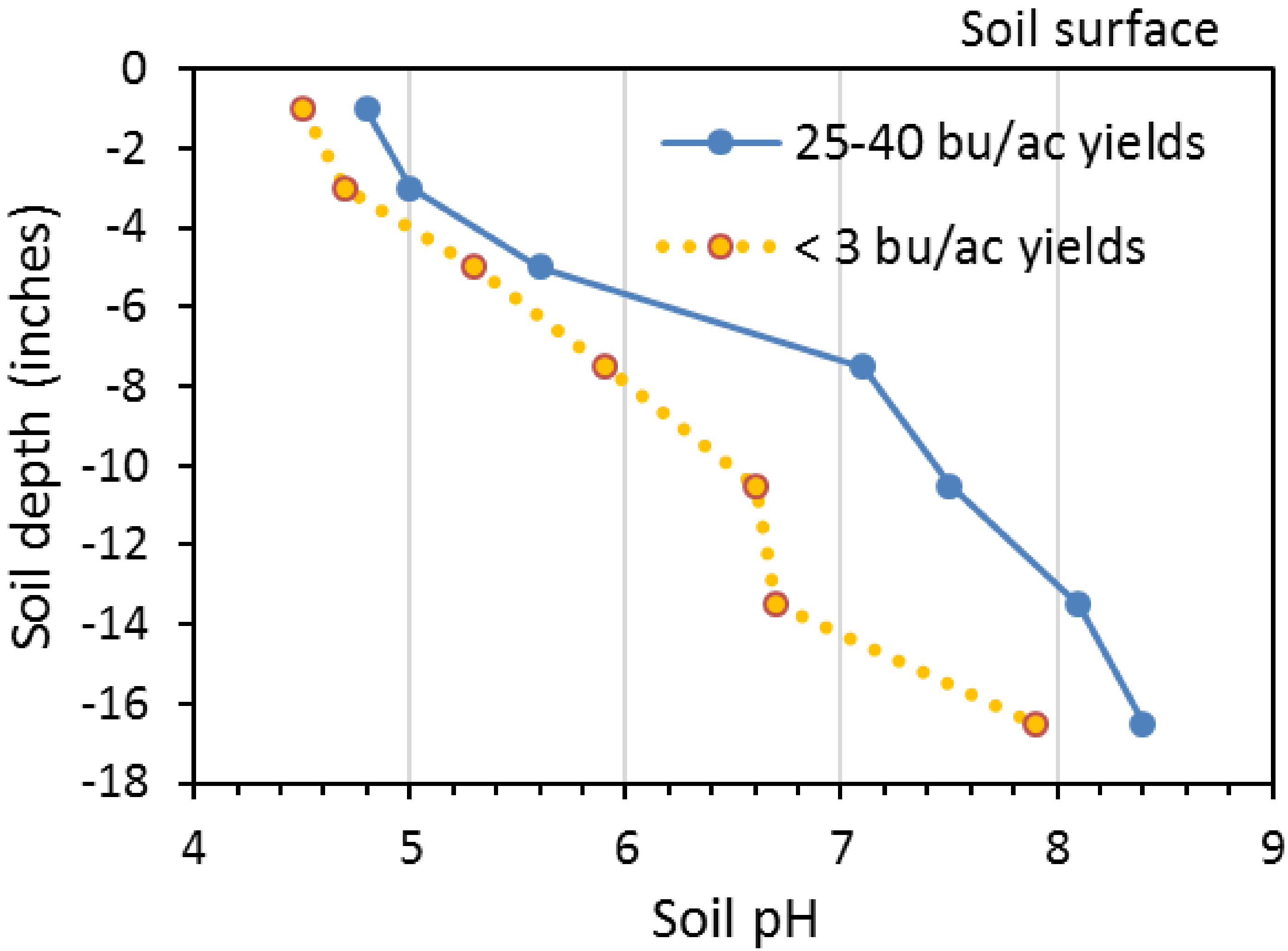
Agronomic reasons for low soil pH

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

ammonium or urea fertilizer + air + H_2O → nitrate (NO_3^-) + acid (H^+)

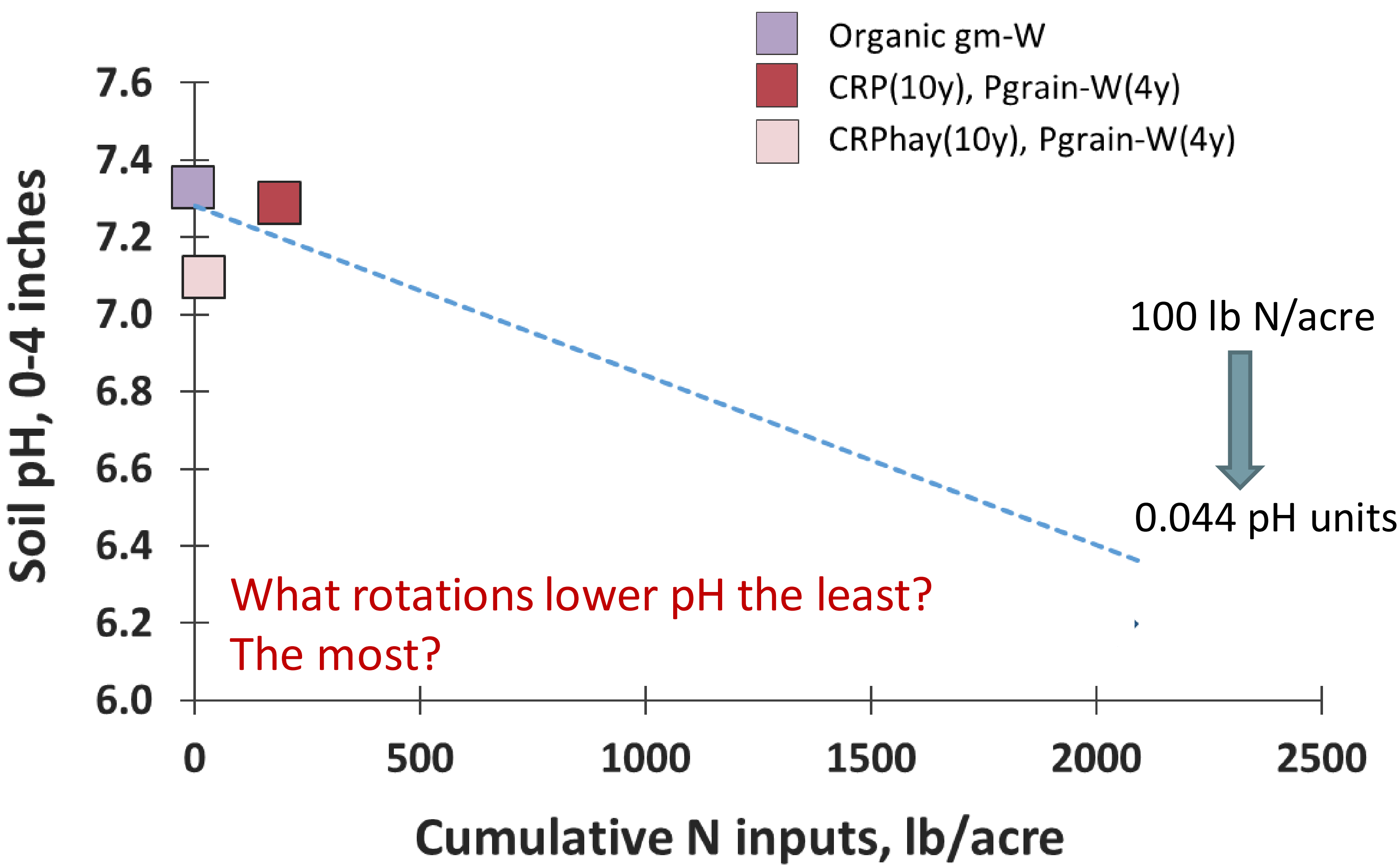
- Leaching loss of nitrate: less nitrate to take up = less root release of basic anions (OH^- and HCO_3^-)
- Crop residue removal: removes Ca, Mg, K ('base' cations).
- Lack of deep tillage concentrates acidity where N fertilizer applied
- Legumes acidify their rooting zone through N-fixation. Perennial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

Low soil pH in MT's historically calcareous soils is generally only in upper 6 inches, 0.3 pH unit difference has huge impact on barley yields



Long farm, Highwood Bench, unpub Nov 2016 data

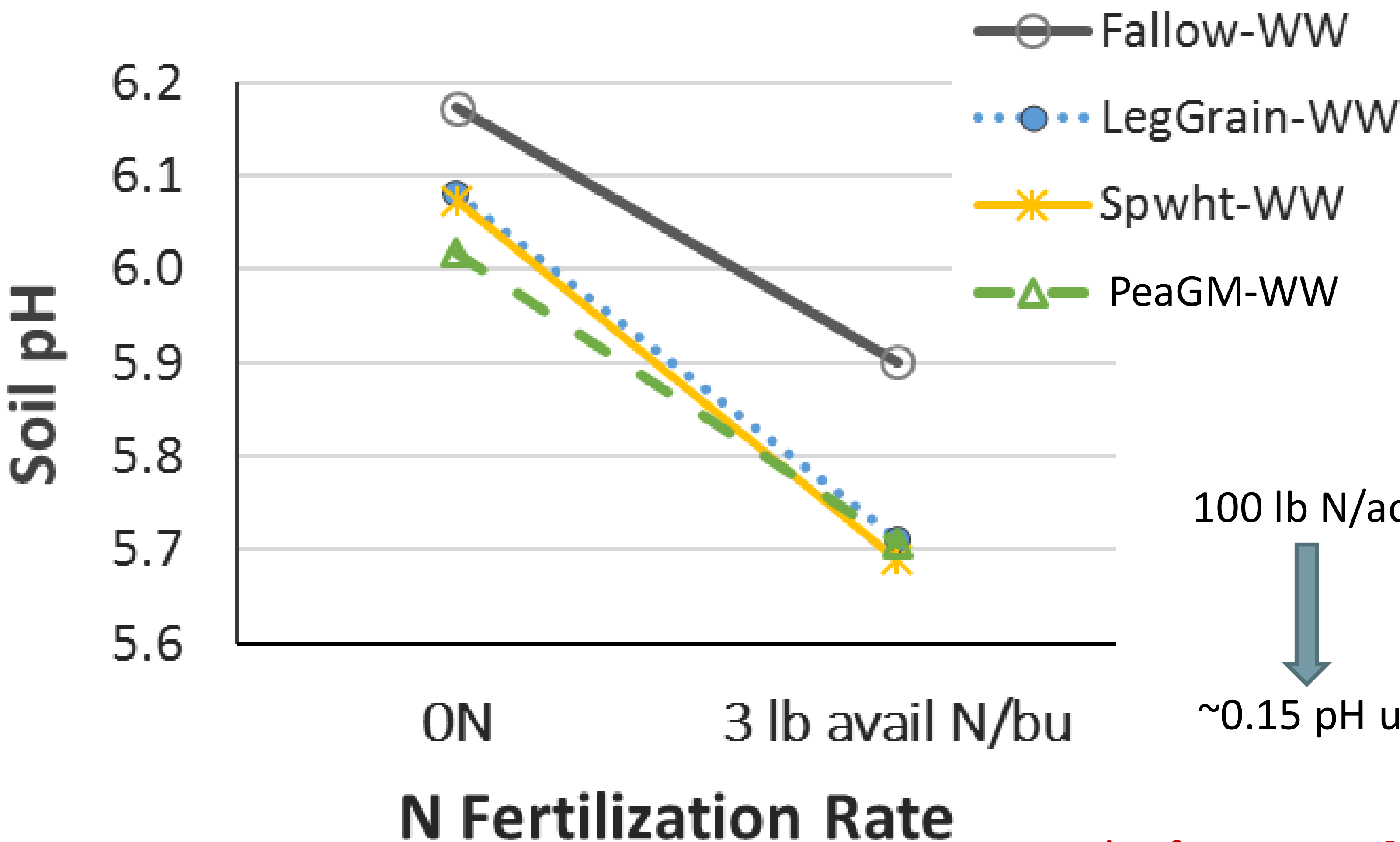
14-yr of N fertilization reduce top 4” pH on dryland cropping west of Bozeman up to 1 pH



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

Have any of you seen decreases in soil pH?

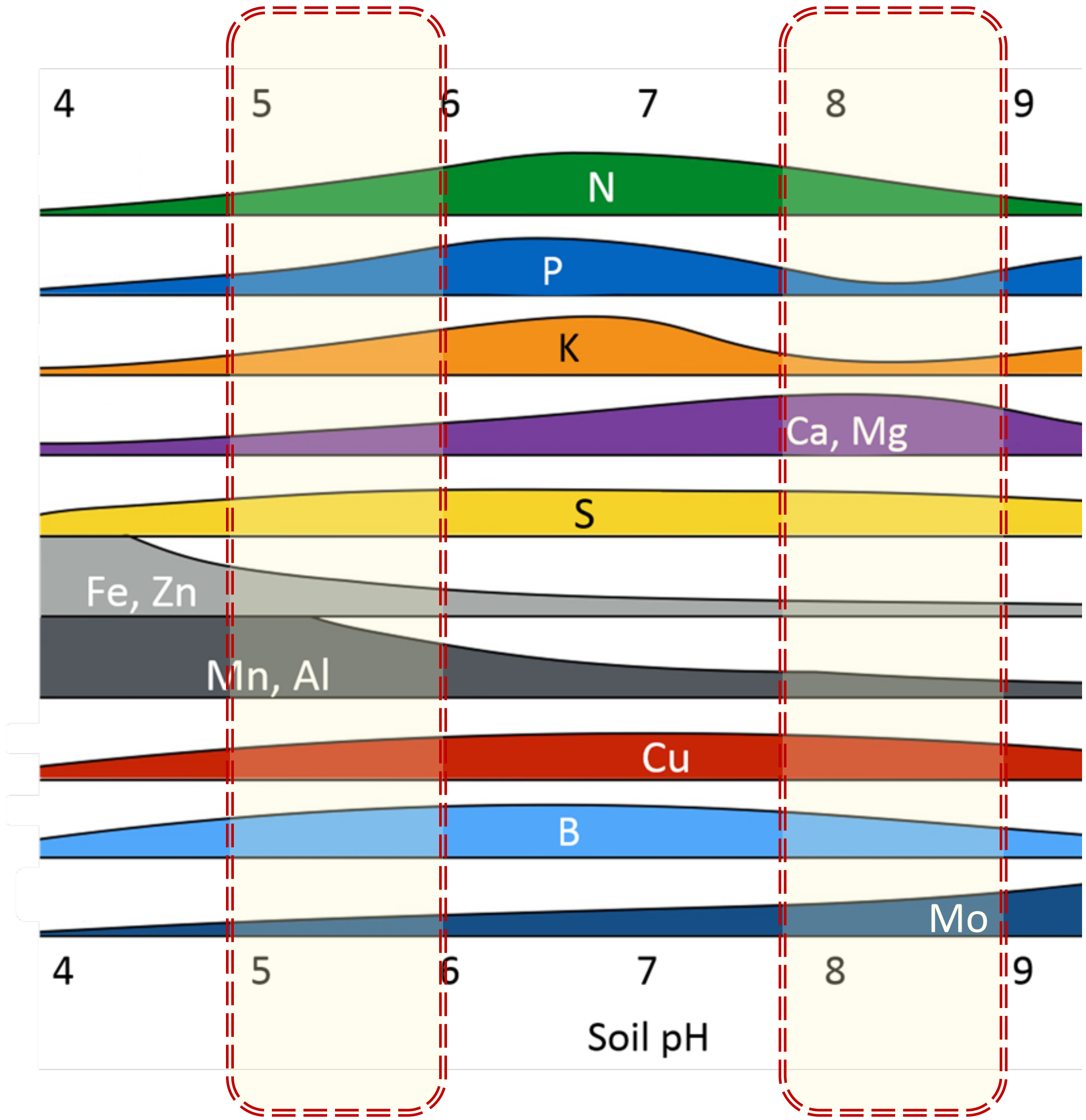
Questions?

On to impact on crop

pH affects soil nutrient and aluminum availability

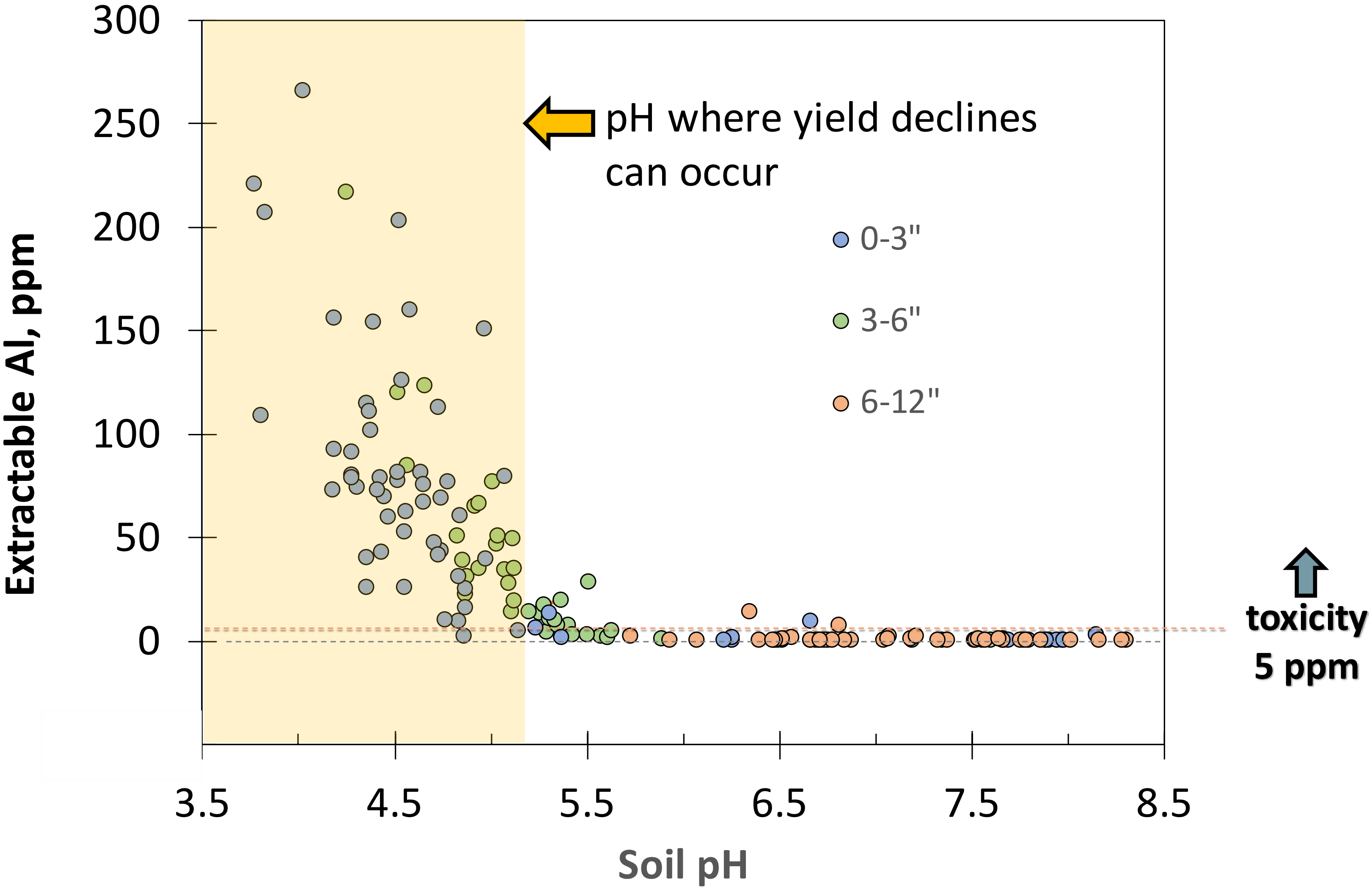
Low pH, acidic soils
may limit N, and eventually Ca, Mg, K, Mo because they don't stick tight and can leach away. P can be low because minerals form, Al toxicity

High pH, alkaline calcareous soils
may limit P, Fe, Mn, B, Cu, Zn, plant can't get them



Troeh and Wegner, 2013

Low pH increases soil Al to toxic levels



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

What to look for

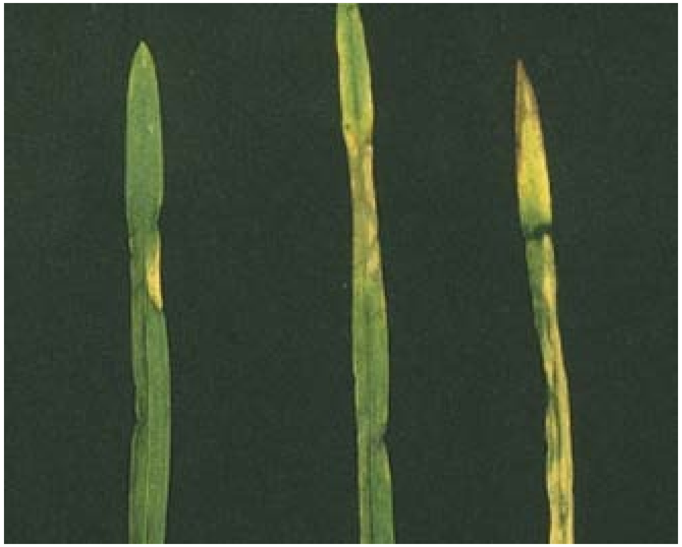
- Unexplained poor health in low or mid-slope areas
- **Al** toxicity
  - stubby club roots, no fine branching (similar to nematode damage)

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 change efficacy and persistence of chems

Have you see unexplained damage?

May be first indicator of pH change.

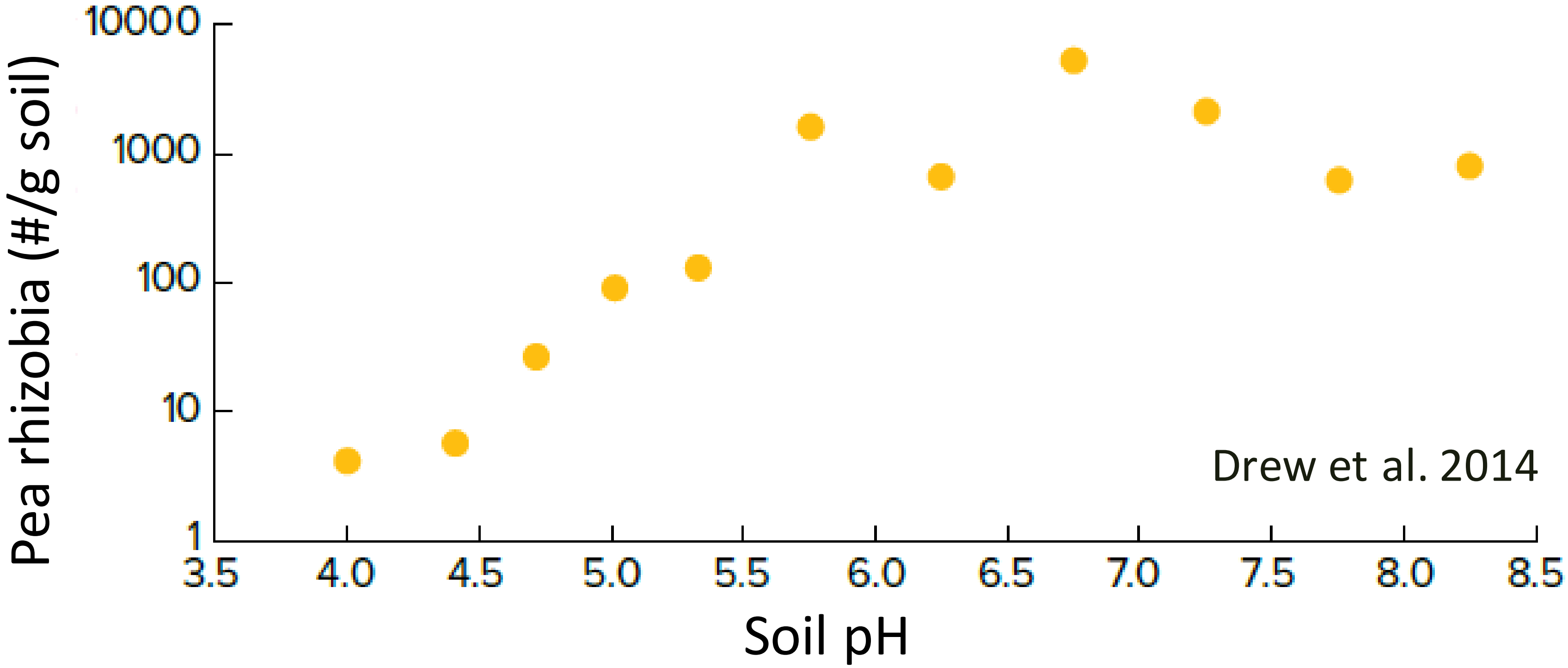
Field pea: Gov. West. Australia

Barley: Thom Weir, FarmersEdge

Canola: Gov. West. Australia

- Small changes in pH across a field = difference between high crop safety with low efficacy, and high crop damage with weed control.
- Chemical treatments and rotation intervals may need modification. Read and follow label directions.

Poor N fixation may be indicator of low pH



Have any of you seen ‘unexplained’ low N fixation?

Acid soils have additional negative impacts

- Increase in some fungal diseases (e.g., Cephalosporium stripe) and root rot
- Mn toxicity – has not yet been found an issue in MT

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

Questions?

On to diagnosis and prevention

Diagnose: scout, soil test

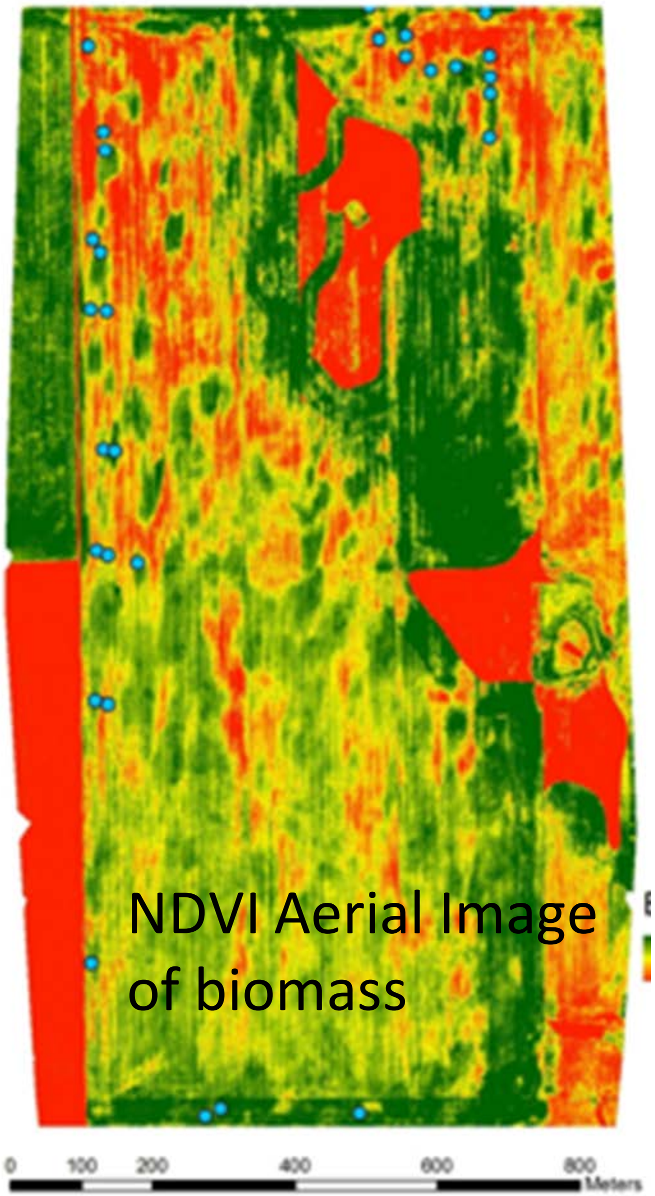
Look at pH on prior soil tests from composited samples

- 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).

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



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
- Large overlap with management 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

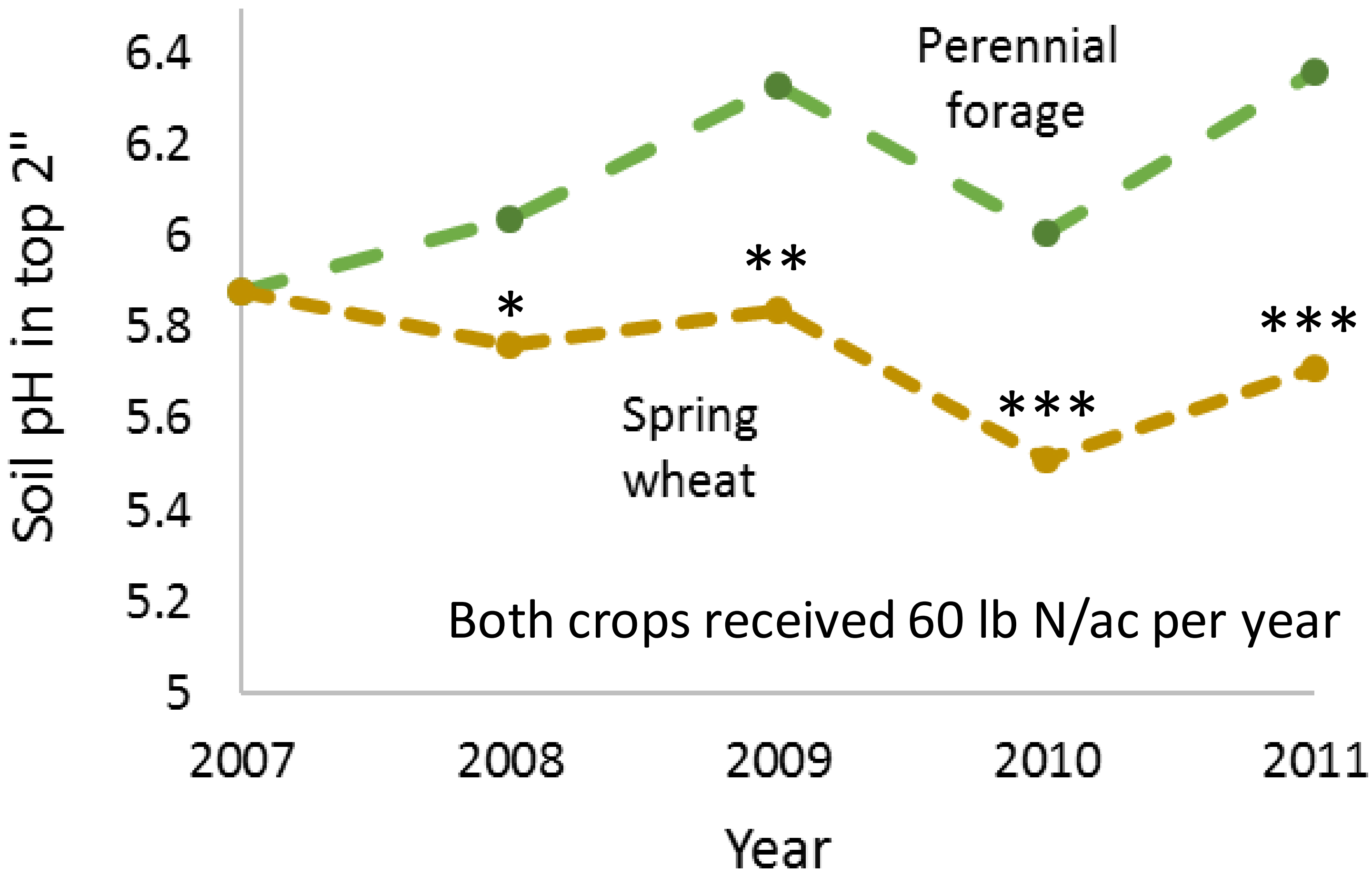
More preventive options

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

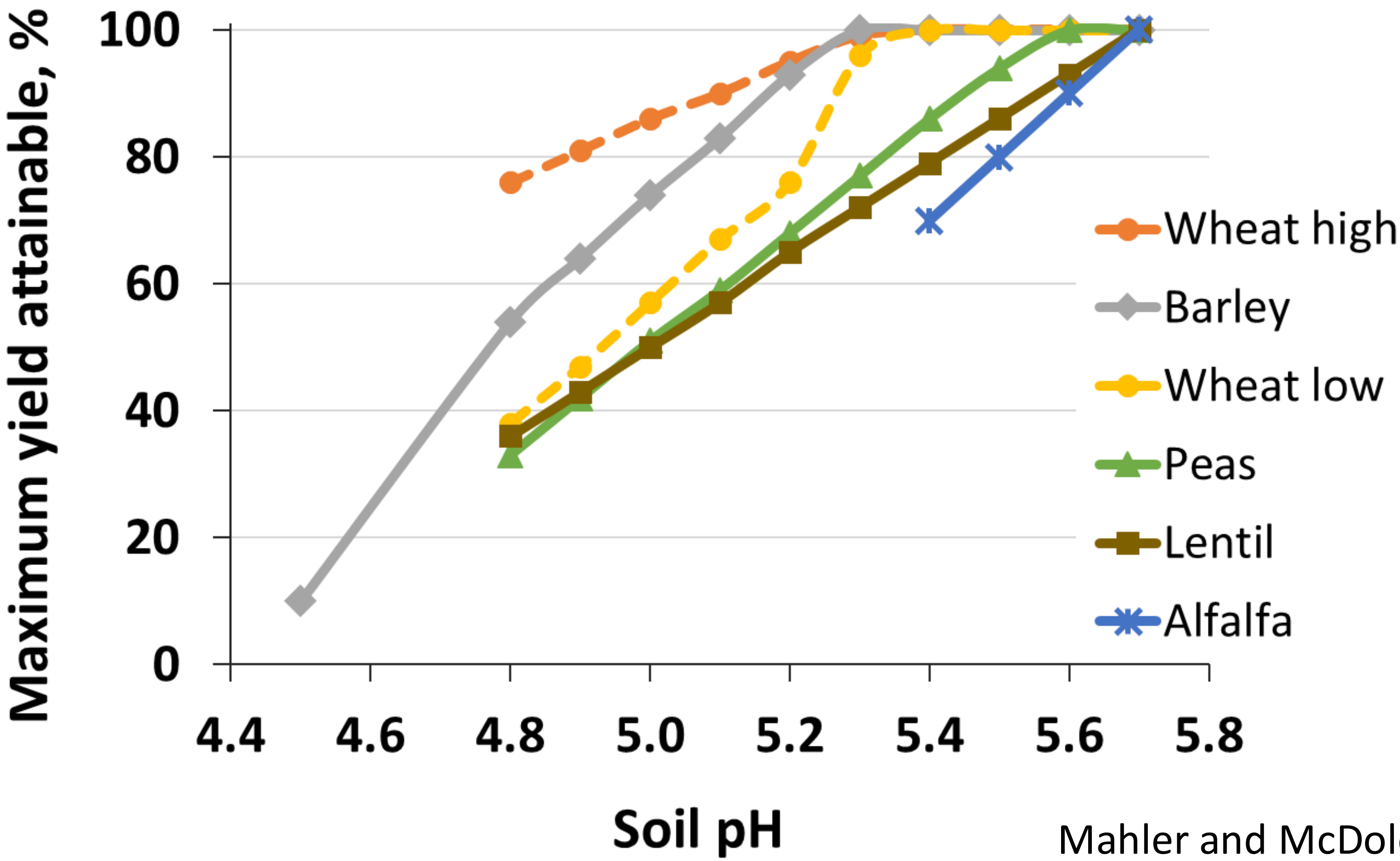
What else are people trying?

Questions?

On to adaptation and restoration options

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

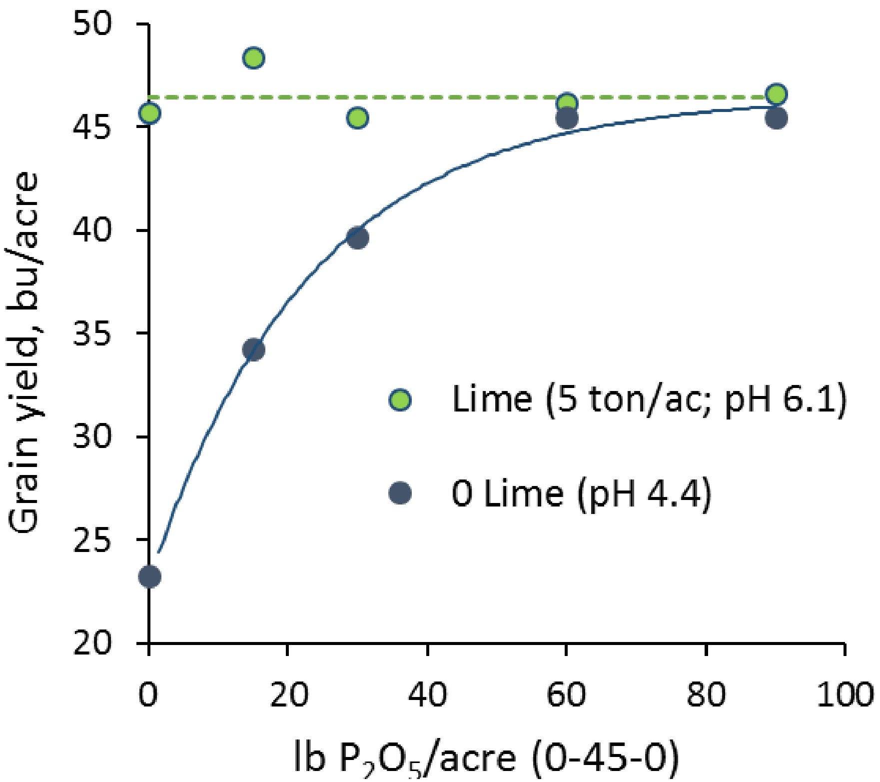
“Wheat high” are Al and acid tolerant varieties

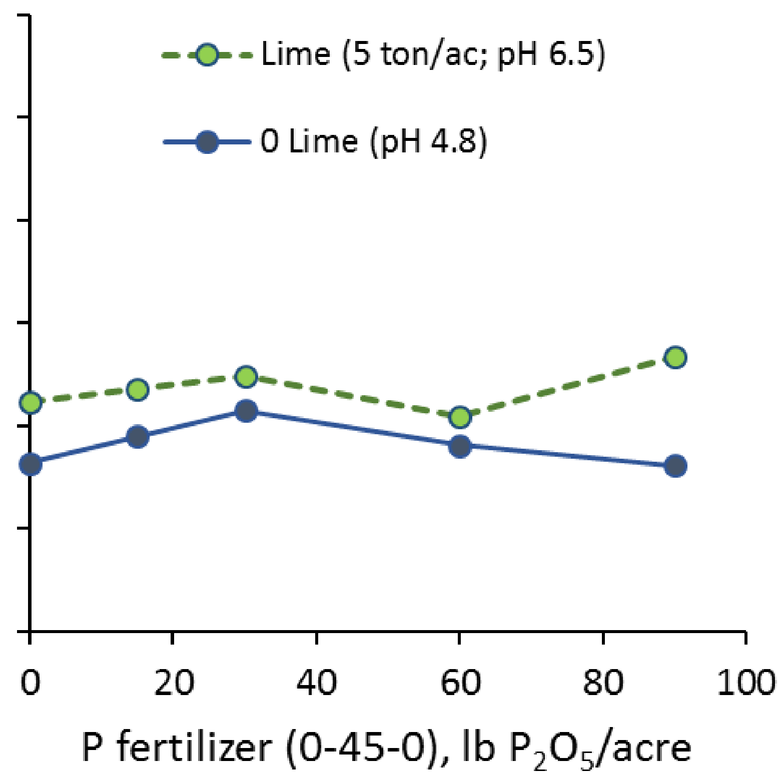


Mahler and McDole 1987
Long pers comm

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

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





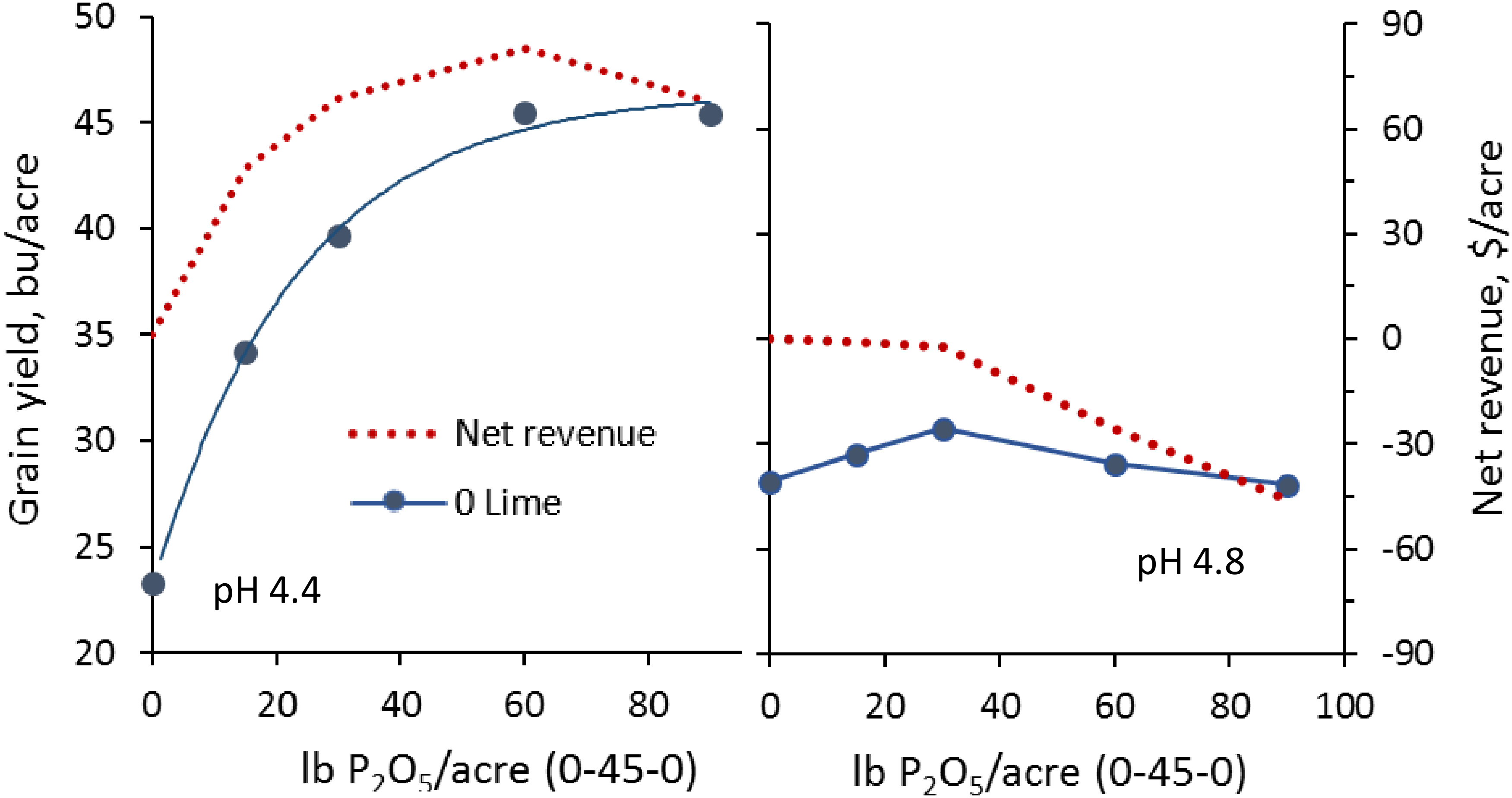
Olsen P = 48 ppm

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?

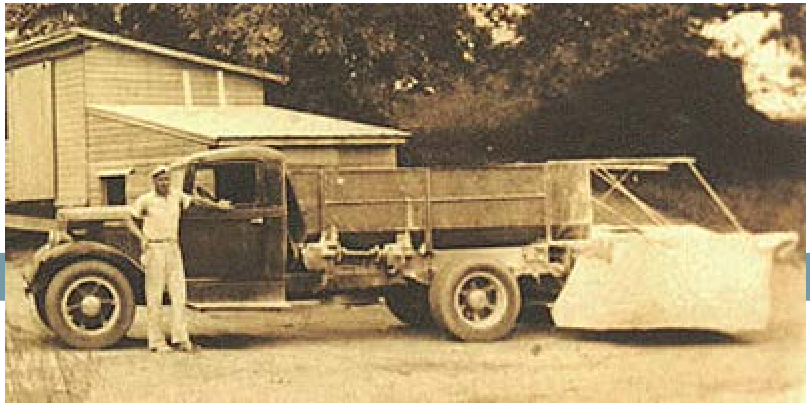
TSP \$0.50/lb P_2O_5

Field strip trials

Restoration: Liming

- Know:
  - Calcium carbonate equivalent (CCE; how the source compares to pure $CaCO_3$)
  - Lime score (LS; adds factors for moisture and fineness to CCE)
  - Current soil pH (from a lab) and desired pH
    - > 5 to reduce Al toxicity
    - > 5.5 to have some buffer, rhizobia health for N fixation
    - > 6 to be good for 10+ years
  - Buffer pH – a lab measurement of soil's ability to buffer (resist) pH change with lime addition. Regionally specific test.
  - Desired crop

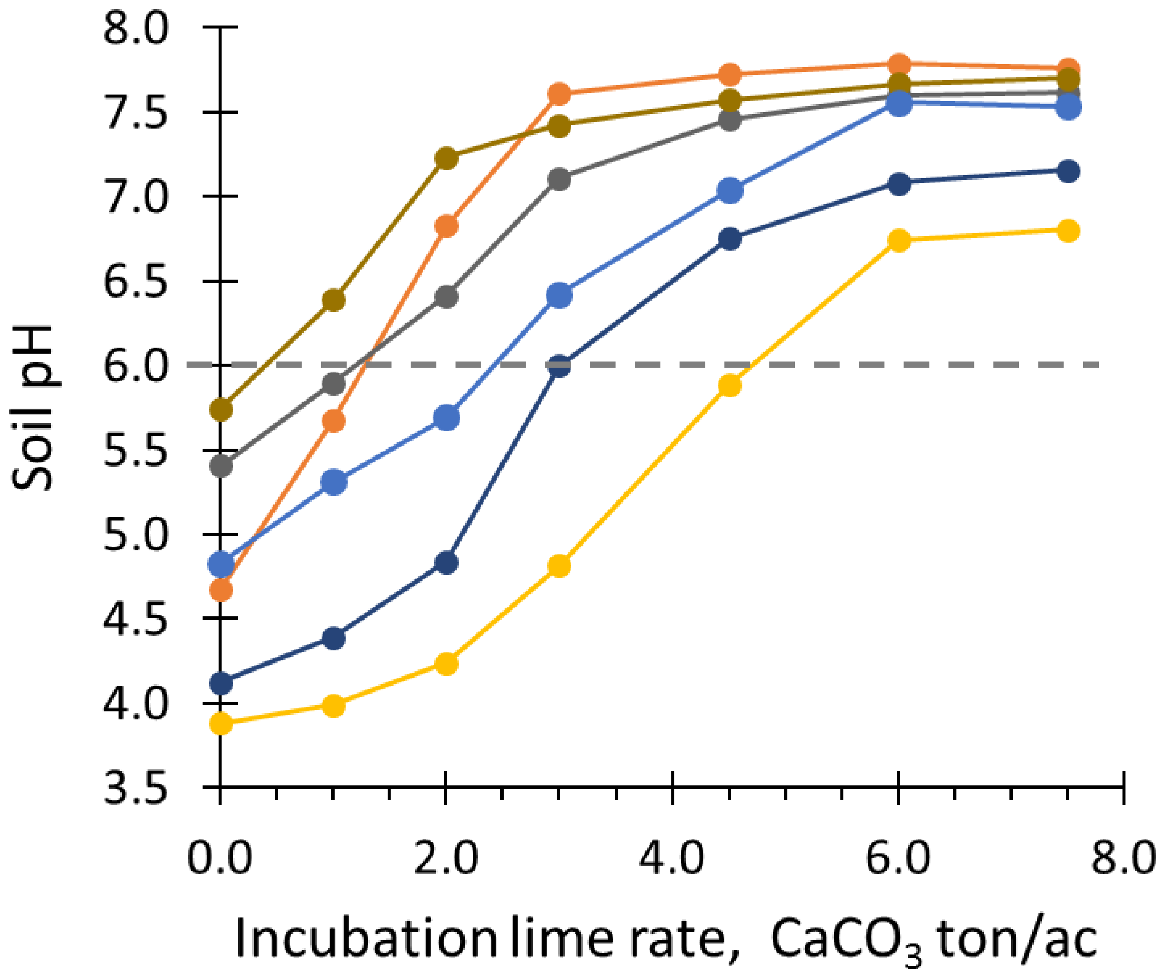
Lime sources



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.

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



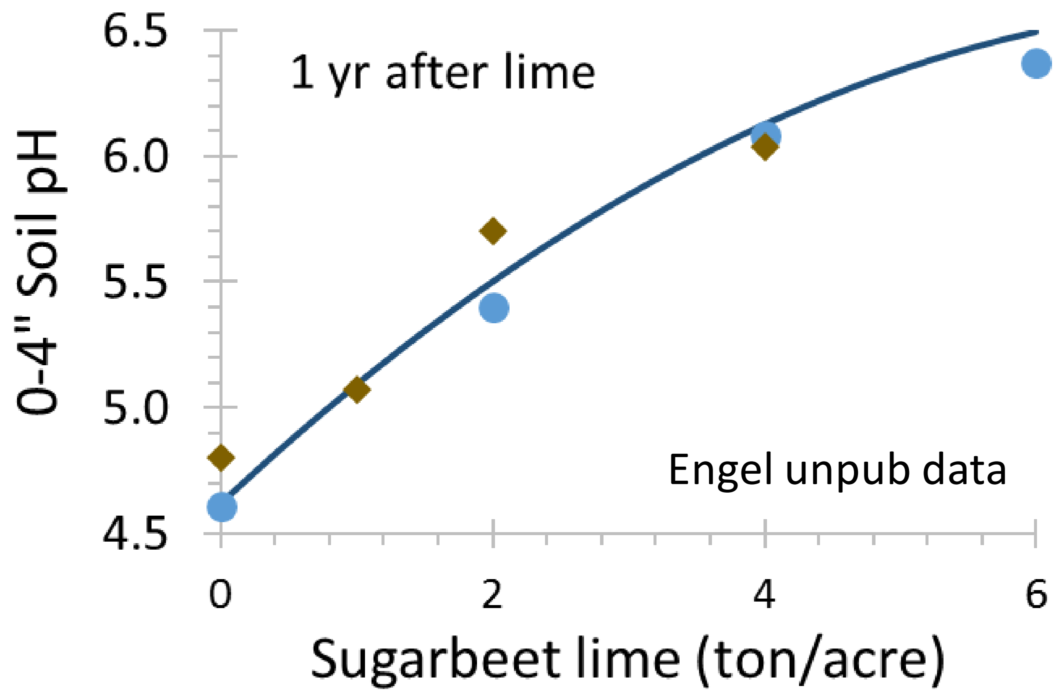
- 10 acidic MT cropland soils tested, 6 shown here
- Incubated in lab with lime for 90 days
- pH 4 soil = 3-4 ton $CaCO_3$ → pH 6
- pH 4.7-5.4 soil = 1.75 ton $CaCO_3$ → pH 6

Engel unpub data

This is using very fine grade lime

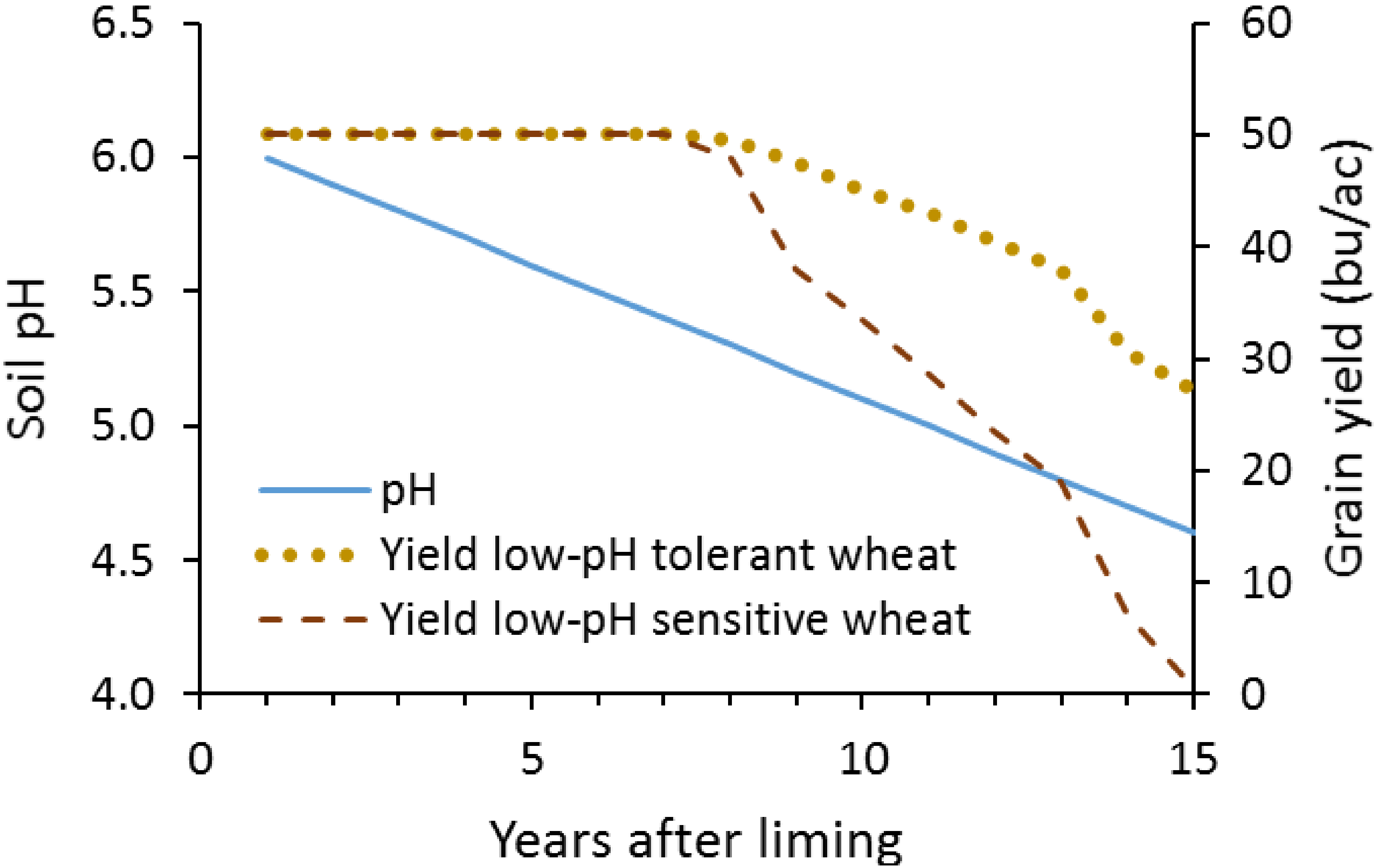
Restoration needs a lot of lime

- 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

Yield declines as lime 'wears off' and soil again becomes acidic (assumes linear pH decline)



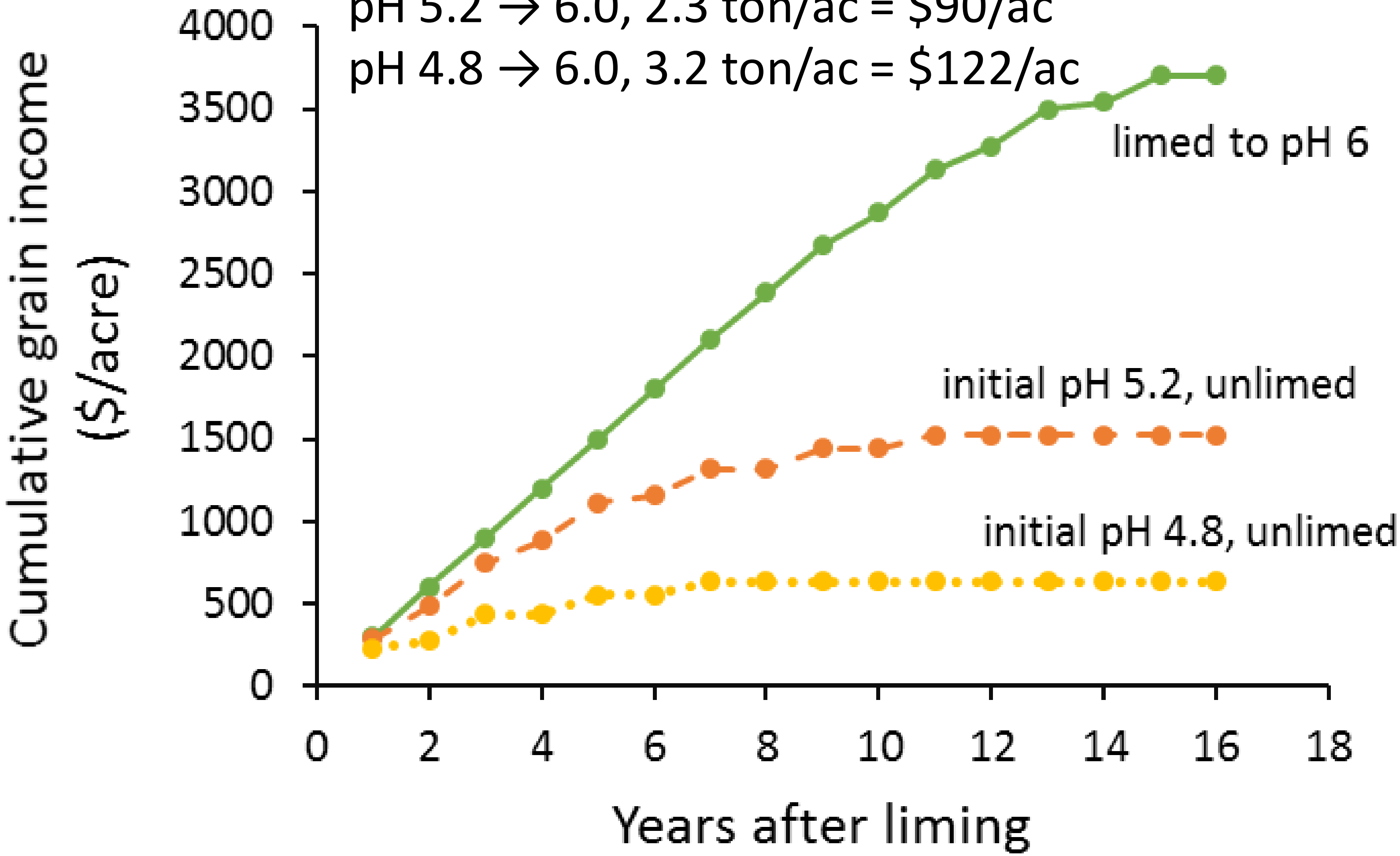
Modeled. Assumes 100 lb N/ac per year causes 0.1 pH drop/year

Mahler and McDole 1987, ID

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

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.

Good news

- MT has less acidic soil issues than other regions; catch and prevent now.
- MT's issue generally in upper 3", Palouse Prairie and SK have low pH at 3-6". Why important?
- Many MT cropland soils have large pH range with calcareous parent material
- P and metal micronutrient availability better at low to neutral pH

Soil survey northern Idaho

Soil pH	% of fields in each category	
	1982-'84	2014-'15
>6.4	6	<1
6.0-6.4	11	4
5.8-5.9	16	3
5.6-5.8	22	7
5.4-5.5	18	9
5.2-5.3	11	25
5.0-5.1	10	26
<5.0	6	26

Schroeder, Univ of Idaho, unpub data

Summary

- 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

Thank you!

Questions?

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

For more information and links to additional resources on soil acidification see MSU’s cropland soil acidification website http://landresources.montana.edu/soilfertility/acidif/index.html

If you have questions about soil and buffer pH tests go to https://www.youtube.com/watch?v=w9PWZSaFfb4