Soil Acidification

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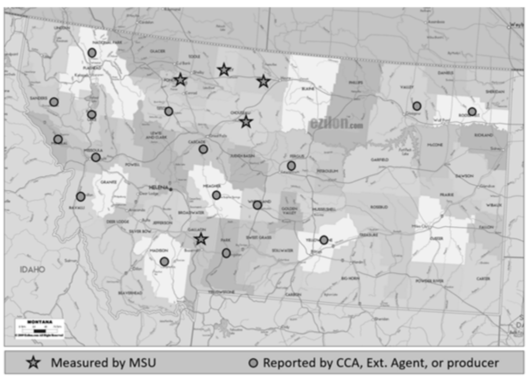
Clain Jones clainj@montana.edu 994-6076
MONTANA STATE UNIVERSITY
MSU Soil Fertility Extension

Objectives

Specifically, I will:

1. Show prevalence of acidification in Montana
2. Review acidification's cause and contributing factors
3. Depict low-pH soil affected crops
4. Discuss steps to prevent or minimize acidification

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



40% of 20 random locations in Chouteau County have pH < 5.5.

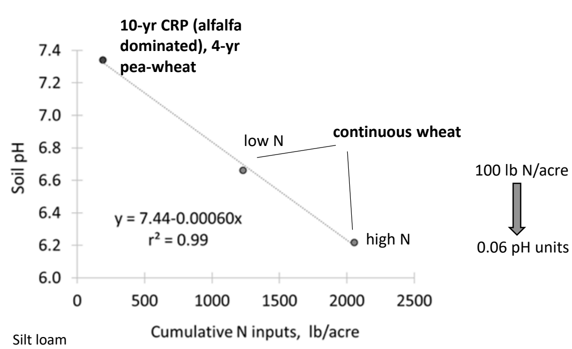
Natural reasons for low soil pH

- Soils with low buffering capacity (low soil organic matter, coarse texture, granitic rather than calcareous)
- Historical forest vegetation soils have lower pH than historical grassland
- Regions with high precipitation, leading to leaching of nitrate

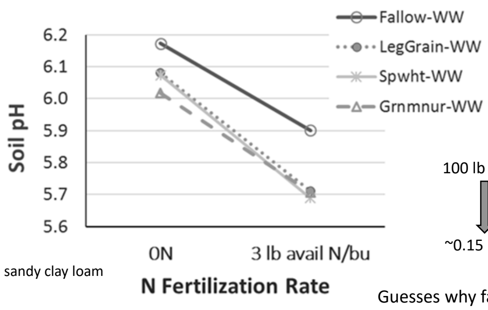
Agronomic reasons for low soil pH

- 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 uptake and less root release of basic anions (OH^- and HCO_3^-)
- Crop residue removal – removes Ca, Mg, K ('base' cations)
- No-till 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.

Effect of 14-yr of N fertilization on dryland cropping west of Bozeman, November 2016



Effect of 6-yr N fertilization and dryland crop rotation on pH west of Big Sandy, October 2017

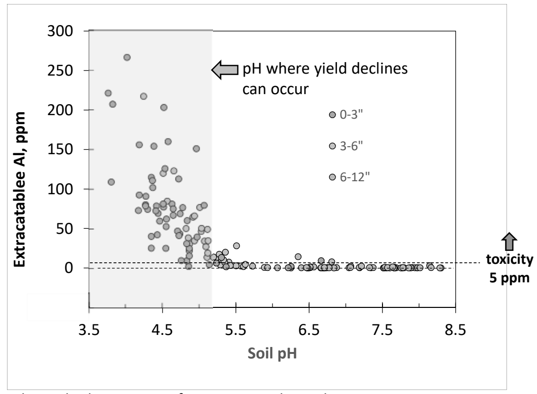


sandy clay loam

Guesses why faster rate?

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

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)

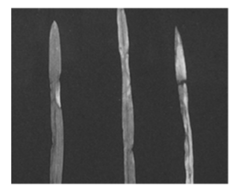

Durum wheat

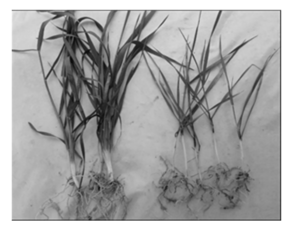
A. Robson, https://agric.wa.gov.au/n/4487

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
- similar to N deficiency

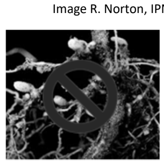

Courtesy CIMMYT.org


courtesy Engel

Acid soils have many additional negative impacts

- Mn toxicity – has not been found an issue in MT
- Herbicide persistence (Raeder et al., 2015)
- Damage to rhizobia (N-fixing by legumes)
- Increase in fungal diseases
- Toxic H^+ levels (Kidd and Proctor, 2001)


Image R. Norton, IPNI




Images from Creative Commons

Questions?

Prevention: Scout and soil test

1. Scout your fields to look for 'unexplained' poor plant health
2. Look at pH on prior soil tests from composited samples
   - pH < 6 likely have spots with pH near or below 5 (go to step 3)
   - 6 < pH < 7.5 don't assume you have no areas with low pH
   - pH > 7.5, likely don't have problem (yet).
3. Field test with pH color strips kits or pH 'stick' on a soil/water slurry of top 3". Test both healthy and unhealthy areas for comparison.
4. Send 0-3" depth sample to lab for pH (<5?) and KCl-extractable Al (> 5 ppm?). Test 3-6" if might till.
5. pH varies seasonally and annually, test from same area and time of year to compare for a trend

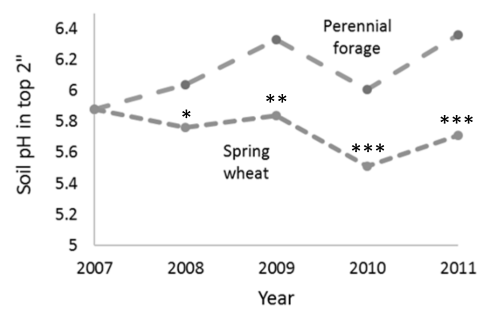
Management to prevent acidification:
Increase nitrogen fertilizer use efficiency

- 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
- Plant lower N-needing crops, including pulses
- Plant perennial forages (list of acid-tolerant varieties on our soil acidification website)
- Reduce N rates especially when protein discounts low
- Use variable, site specific rates: Less N in low production areas limited by other than N (e.g., low pH, shallow soils)

Management to prevent acidification:
Change N source?

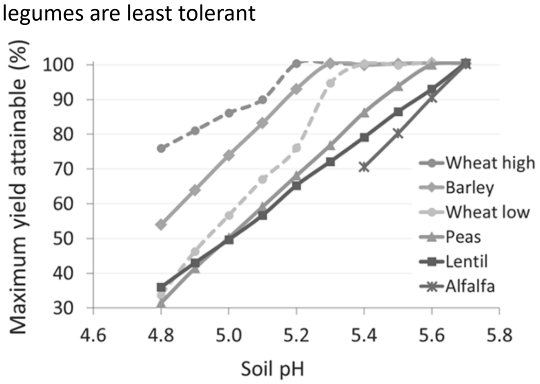
- Minimize use of ammonium fertilizers (11-52-0, 21-0-0-24)
- Use calcium ammonium nitrate ($$) instead of urea or UAN (CAN shouldn't volatilize so can likely also lower rate)
- Include legume rotations, manure if available

Perennial forage can maintain or increase soil pH



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

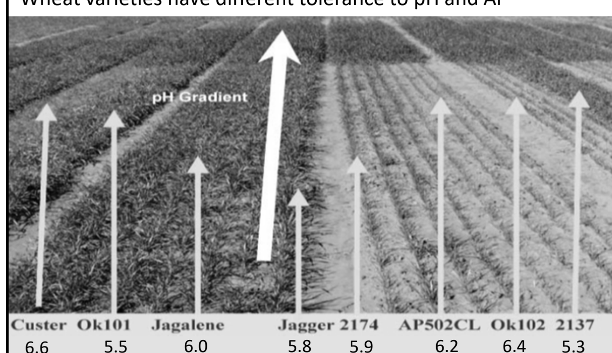
Adaptation: Crop species vary in tolerance to low soil pH
legumes are least tolerant



McFarland et al., 2015

"Wheat high" are Al and acid tolerant varieties

Wheat varieties have different tolerance to pH and Al



Threshold pH

(Kariuki et al, 2007)

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

Liming rate

Image: Oregon State University

- Know:
  - Calcium carbonate equivalent (CCE; how source compares to pure $CaCO_3$)
  - Lime score (LS; adds factors for moisture and fineness to CCE)
  - Current soil pH and desired pH
    - > 5 to reduce Al toxicity
    - > 5.5 to have some buffer
    - > 6 to be good for 10+ years
  - Desired crop
- Rate: from soil test lab or calculate (WSU equation)

  Lime rate (ton/acre) = 1.86*(final desired pH – 4.6)

  Note: R. Engel is conducting research to develop MT specific recommendations

Sugarbeet lime

Stoltzfus lime spreader, Stoltz Mfg.

- 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)

Summary

- Cropland soils are becoming more acidic, largely due to N fertilization
- This reduces yields for several reasons
- Sound nutrient, crop, and residue management can slow or prevent soil acidification
- Crop and variety selection can help adapt to acid soils
- Liming, perhaps tilling, or planting perennials can mitigate acidification

Questions?

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

For more information see the 2 *Soil Scoops* on soil acidification and more presentations at MSU Soil Fertility website:
http://landresources.montana.edu/soilfertility/soilscoop.html

MSU's cropland soil acidification website
http://landresources.montana.edu/soilfertility/acidif/index.html