Soil Acidification
Causes and Solutions

NWARC Crop Production Update
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Image courtesy Rick Engel

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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

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:
  
  \[
  \text{ammonium or urea fertilizer + air + H}_2\text{O} \rightarrow \text{nitrate (NO}_3^-\text{)} + \text{acid (H}^+\text{)}
  \]

- Leaching loss of nitrate: less nitrate to take up = less root release of basic anions (OH\(^-\) and HCO\(_3^-\)) to maintain neutral charge in root. Concern under irrigation, sandy soils

- Crop residue removal: removes Ca, Mg, K ('base' cations)

- No-till concentrates acidity where N fertilizer applied, though occurs in tilled soils too.

- 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 Montana’s historically calcareous soils is generally only in upper 6 inches

Rick Engel, unpub data.
14-yr of N fertilization reduce top 4” pH on dryland cropping west of Bozeman up to 1 pH

Silt loam, 2% SOM

Engel, Ewing, Miller, unpub data
6-yr N fertilization reduce soil pH (0-3"") west of Big Sandy

- Sandy clay loam, 1.1% SOM
- Alternate year was always winter wheat; Jones and Miller unpub data

Graph:
- Soil pH vs. N Fertilization Rate
- Lines for Fallow-WW, LegGrain-WW, Spwht-WW, PeaGM-WW
- Points for 0 N and 3 lb avail N/bu
- 100 lb N/acre
- ~0.15 pH units
Have any of you seen decreases in soil pH?

Questions?

On to identifying low soil pH
Dropping pH increases aluminum availability

R. Engel unpub data, 5 locations in north-central MT

Soil pH

Extractable Al (ppm)

pH where yield declines can occur

toxicity 5 ppm

R. Engel unpub data, 5 locations in north-central MT
What to look for

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

photo sources: Engel

Durum wheat

Field pea

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
Poor N fixation may be indicator of low pH

Drew et al. 2014

Note: Vertical axis goes up by factor of 10s!
Acid soils have additional negative impacts

- Change in herbicide efficacy and persistence – unexplained damage may indicate pH change.
- Increase in some fungal diseases (e.g., Cephalosporium stripe)
- Mn toxicity – has not yet been found an issue in MT
- Toxic H⁺ levels (Kidd and Proctor, 2001, Scotland)
Have any of you seen ‘unexplained’ poor crop health or low N fixation?

Questions?

On to management
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
Ask crop adviser to soil test differently than normal

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/reduce leaching

• Soil test close to application time. Make sure enough PKS
• Use conservative pre-plant rate, top-dress as needed
• Apply N close to peak crop uptake
• Reduce N rates especially when protein discounts low
• Use variable, site specific rates: Less N in low production areas
• Change N source: minimize MAP (11-52-0) and AS (21-0-0-24), include legumes, manure if available. Consider gypsum as sulfur source
More management options

- Leave crop residue in field – retains base cations and SOM buffers pH changes and Al toxicity
- Legumes in rotation – no N fertilizer and residue increases soil surface pH more than non-legumes (Paul et al., 2003)
- Inversion till to mix acid zone throughout plow layer – one-time summer tillage doesn’t negate long term benefits of no-till (Norton et al., 2014)

If consider the cost of liming to remediate acidification, and/or lost yield, changing ‘standard’ practices may be economically reasonable.
Perennial forage can maintain or increase soil pH

pH differs between crops with * > 90%, ** > 95%, *** > 99% confidence Mandan, ND Liebig et al., 2018
Seed-placed $P_2O_5$ a quick acting ‘band-aid’ to increase wheat yield even when (or only when?) P soil test is sufficient

Soil pH 4.4, Olsen P = 49 ppm

Engel unpub data
Seed-placed P$_2$O$_5$ or lime increased durum grain yield significantly at pH 4.4 site, not at pH 4.8 site

Engel unpub data

Note at lower pH site, lime or seed-P increased yield by 22 bu/ac!
Managing low pH: Adapt

- Plant Al-tolerant crops or varieties, MT variety trial results are available at [http://landresources.montana.edu/soilfertility/acidif/index.html](http://landresources.montana.edu/soilfertility/acidif/index.html)

- Fertilize after vulnerable seedling stage

- Seed deeper?

McFarland et al., 2015

“Wheat high” are Al and acid tolerant varieties
Managing low pH: Remediate with lime

- A lot of lime is required to impact soil pH
- Only lime areas with low pH

Sugar beet lime, tons/acre

Δ Soil pH (Fall 2018 – Fall 2017)

0-4” depth

Engel unpub data

pH 4.7

pH 6.5

y = 0.495x - 0.0329x^2

r^2 = 0.99
Summary

• Cropland soils are becoming more acidic, largely due to N fertilization
• This reduces yields for several reasons
• Good new is: if identify a problem now, can 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 and seed-placed P fertilization can help adapt to acid soils
• Liming, perhaps tilling, or planting perennials can mitigate acidification
Thank you!

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](http://landresources.montana.edu/soilfertility/acidif/index.html)

Questions?