Soil Acidification: Problems, Causes, & Testing

by Clain Jones, Montana State University Extension Soil Fertility Specialist, and Kathrin Olson-Rutz, Research Associate

Most agricultural soils in Montana have near-neutral to basic conditions with surface soil pH 6.5 to 8. However, some areas of Montana have acidic soils, especially in the seeding zone. The decrease of soil pH in the seeding zone can be relatively rapid. Idaho agricultural soils went from neutral pH to pH less than 6 in about 25 years. The Soil Scoop *Soil Acidification: Management* presents management options. More details on soil pH and references are available in *Soil pH and Soil Organic Matter*.

SOIL pH

Soil pH is a measure of the soil solution's acidity on a scale from 0 to 14. By definition, pH = -log[H^+], where [H^+] is the hydrogen ion concentration. The negative sign means as pH goes up, acidity (and H^+ concentration) goes down. Acidic soils have low pH values (<7), basic soils have high pH levels (>7), and pH 7 is neutral. Each pH unit change represents a 10-fold change in acidity. For example, a soil with pH = 6 is 10 times more acidic than a soil with pH = 7.

AGRONOMIC CONCERNS OF LOW SOIL pH

- Aluminum (Al), H^+, and manganese (Mn) toxicity lead to yellow foliage and poor growth. Aluminum toxicity creates plants with club or broom shaped roots (Figure 1).

FIGURE 1. Club roots of wheat from Al toxicity.

- Plants are hungry due to low soil nutrient levels (Figure 2). Phosphorus (P) is tightly bound to clay or iron particles, while nitrogen (N), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg) are easily leached and lost from the soil.

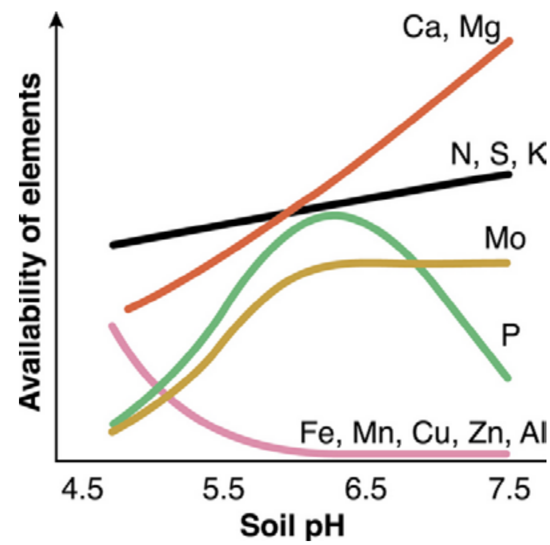

FIGURE 2. Nutrient availability as soil pH changes. Source: Government of Western Australia, Department of Agriculture and Food

- Reduced rhizobial growth; legume (e.g., pea, alfalfa) nodulation/N fixation is severely limited at pH < 6
- Increased fungal diseases (e.g., *Rhizoctonia*)
- Changes in herbicide/pesticide effectiveness and residual (e.g., Group 2, B herbicides)

CONDITIONS CONTRIBUTING TO LOW SOIL pH

- Ammonium-based N fertilizer above plant needs (Figure 3)
- No-till (concentrates acidity in 3-5" rooting zone), although even with 9" moldboard plowing N fertilizer above plant needs caused soil acidification in the 0 to 9" soil layer (Rasmussen et al., 1989).
- Soils with high sand content and/or low levels of soil organic matter (SOM)

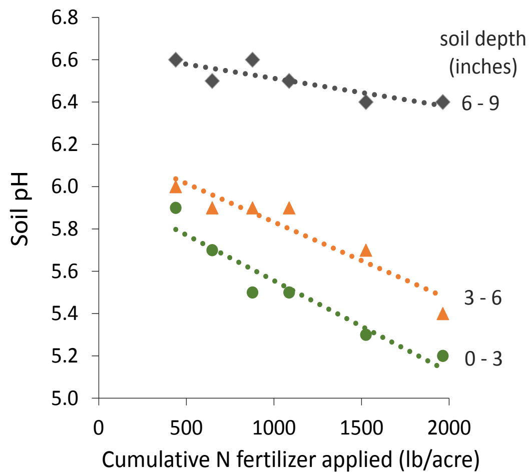

FIGURE 3. Soil pH at different soil depths after 43 years of surface broadcast ammonium-based N fertilizer on wheat-fallow with a single annual 6" stubble-mulch tillage and 2 to 4 summertime rodweedings. Soil:water 1:2 used to test pH (adapted from Rasmussen et al., 1989).

- Crop residue removal – removes Ca, Mg, K ('base' cations). For example, oat straw requires 6 times the lime to counter the acidifying effect of its removal, than oat grain harvest.
- Nitrification: ammonium or urea fertilizer + air → nitrate + acid (H^+). The nitrate (NO_3^-) not taken up by plants can be lost to leaching, leaving H^+ in the soil.
- Legumes acidify their rooting zone through N-fixation. Perennial legumes (e.g., alfalfa) more so than annuals (e.g., pea).

SOIL TESTING

Handheld pH sampling meters are now available that provide quick reliable results from soil cores to determine soil pH. The process is not difficult, but the equipment does need regular cleaning, calibration and proper storage. Field testing with meters or 'color' kits can indicate whether acidity may be an issue and help select which soils to send to a laboratory. Field tests do not provide enough information to determine lime requirements; laboratory buffer tests are necessary for lime rate calculations.

Buffer tests tend to be regionally specific to account for a region's unique soil conditions. The Woodruff, SMS, Sikora, Mehlich or modified Mehlich tests are suitable for Montana soils. It is important to be aware of which pH meters and buffer tests are used and to be consistent to ensure comparable data over time. Soil testing laboratories usually note test methods used on the soil test report. Also, pH varies seasonally, so annual comparisons should be made from samples taken the same time of year.

Soils sampled for laboratory analysis should be 1 foot deep and divided into 0-3, 3-6, 6-9, and 9-12" depth increments and kept cold or frozen until delivered. It is important to properly sample incremental depths because a low pH zone can exist in only a narrow depth increment, generally the top 3" due to N fertilizer. Sampling over a 6 or 12" depth could seriously overestimate soil pH in the critical seeding zone (0–3" depth, Reeves et al., 2016). Sampling only the top 3" would not allow one to determine if and how deep to plow to mix deep higher pH soils with low pH surface soils. Soil cores should be at least ¾" diameter and a composite of 6 to 10 subsamples should be mixed and subsampled before sending in about a 2-fist size sample. Remove plant residue or duff on the soil surface before taking the soil sample core. Samples should be kept cold or frozen until delivered.

For more information:

Eastern Oregon Liming Guide. 2013. Oregon State University Extension Bulletin, EM 9060 https://catalog.extension.oregonstate.edu/em9060

Rasmussen, P.E., and C.R. Rohde. 1989. *Soil Acidification from Ammonium-Nitrogen Fertilization in Moldboard Plow and Stubble-Mulch Wheat-Fallow Tillage*. Soil Science Society of America Journal. 53:119-122. doi:10.2136/sssaj1989.03615995005300010001x

Reeves, J.L., and M.A. Liebig. 2016. *Depth Matters: Soil pH and Dilution Effects in the Northern Great Plains.* Soil Science Society of America Journal. 80:1424–1427. doi:10.2136/sssaj2016.02.0036n

Soil Acidification: Management http://landresources.montana.edu/soilfertility/soilscoop.html

Soil pH and Organic Matter, Nutrient Management Module No. 8. http://landresources.montana.edu/nm/index.html

Washington State University – assorted lime fact sheets http://smallgrains.wsu.edu/soil-and-water-resources/soil-acidification-in-the-inland-northwest/

MSU Soil Fertility website http://landresources.montana.edu/soilfertility/

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