Soil Acidification: Management

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Most agricultural soils in Montana have near-neutral to basic conditions with surface soil pH 6.5 to 8, yet fields with crop losses due to soil acidification have been found in 24 Montana counties. The Soil Scoop *Soil Acidification: Problems, Causes & Soil Testing* introduces soil pH, why it is a concern, agronomic practices that contribute to soil acidification, and soil testing for pH.

MANAGEMENT: PREVENTION & MITIGATION

- Use practices and rates to optimize nitrogen (N) use efficiency. Base N rate on spring soil tests and realistic yield potential and split N applications (don't apply 2nd time in dry years). Reduce nitrate (NO_3^-) loss. Plant deep rooted crops to 'catch' deep nitrate and pull base-forming cations (Ca^{2+}, K^+, Mg^{2+}) from the subsurface to the surface. Use slow-release N sources or N sources with nitrification inhibitors.
- Use calcium ammonium nitrate (27-0-0) which has less acidifying potential than urea (46-0-0).
- Use pulse crops in rotation – they don't need N fertilizer and often reduce N needs on following crops.
- Plant aluminum (Al)- or low-pH tolerant crops (Figure 1) or varieties. See our Soil Acidification website.
- Plant perennials
- Inversion till to bring up calcium carbonate ($CaCO_3$) from deeper layers, **only if followed by agronomic practices that do not further reduce soil pH.** Otherwise acidic soil literally becomes a deeper problem. One-time summer or fall tillage does not negate long term benefits of no-till (Blanco-Canqui & Wortmann 2020, Engel unpub. data).
- Increase soil organic matter (SOM) to buffer pH changes and reduce Al, manganese (Mn) and H^+ toxicity. Leave crop residue in field to retain base cations, apply manure, replace fallow.
- Lime low pH soils (pH < 5.5) for about a 15-year benefit, or seed-place about 200 to 400 lb prilled lime/acre to compensate for acid produced by a typical annual N application.
- Band P with seed (see Fertilizer eFact No. 79).

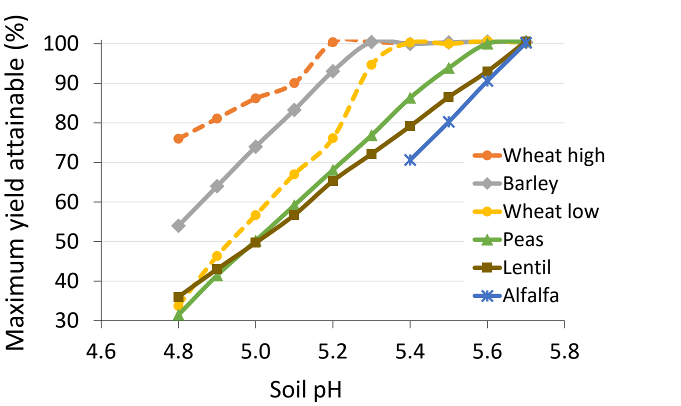

FIGURE 1. Crop species vary in tolerance to low pH, or high aluminum levels (McFarland et al. 2015).

LIMING

Liming material reacts with water in the soil to yield bicarbonate (HCO_3^-), which takes H^+ and Al^{3+} (acid-forming cations) out of solution, raising soil pH. The benefits are varied and depend on the soil pH level reached (Table 1).

Source Different materials have different 'potency' to raise soil pH. Calcium sources such as gypsum (calcium sulfate) that don't have carbonate, hydroxide, or oxide do NOT neutralize soil acidity (increase soil pH). Calcium carbonate equivalent (CCE) compares a liming material to pure $CaCO_3$. Lime Score (LS; Table 2), also called effective

Table 1. The benefits of increasing pH of acidic soils[a].

Limed soil pH	Effect
< 5.1	Few crops can produce if not limed
> 5.1 - 5.5	Reduced Al, H^+ and Mn toxcity; increased P and other nutrient availability
> 5.6 - 6.0	Increased soil microbial activity, rhizobia health for nitrogen-fixation and other mycorrhizal assisted crops (legumes and barley), plant nutrient availability
> 6.1 - 6.5	Improved soil structure; reduced crusting and power need for tillage

[a] Alberta Agriculture & Forestry

Table 2. The lime score (LS) of different liming materials (source: Anderson et al. 2013).

Source	LS
Limestone ($CaCO_3$)	90 - 100
Dolomite ($CaCO_3$ + $MgCO_3$)	95 - 110
Hydrated lime ($Ca(OH)_2$)	120 - 135
Burnt lime or calcium oxide (CaO)	150 - 175
Sugar beet lime (free in Billings)	60[a]

[a] Olsen's Agricultural Laboratory, Inc., McCook, NE

neutralizing value (ENV), combines CCE with moisture and fineness to calculate liming rates. Fineness is determined by the particle size. Particles that pass a 100-mesh sieve react within a few weeks, 60 to 100-mesh in 1 to 2 years, and 20-mesh in 2 to 3 years (Mullins et al. 2009). Liming with spent sugar beet lime is explained in Fertilizer eFact No. 80.

Timing Monitor soil pH to determine if mitigation is necessary. All but very fine lime reacts slowly over several years and must be incorporated. Apply lime at least the fall prior to a spring planting. For perennial crops, apply enough before seeding for the longevity of the stand. Humid days with little wind are ideal for surface application.

Rate The following is needed to calculate a liming rate:

- Lime score (Table 2 or on lime material label)
- Current and desired pH (> 5 to reduce Al, H^+, Mn toxicity; > 5.5 to have some buffer; > 6 to be good for 10+ years)

The lime rate can be estimated as:

Lime rate (ton $CaCO_3$/acre) = 1.5 x (pH increase)

Lime rate is given in units of $CaCO_3$ (100% CCE) and must be adjusted by the lime score (LS) of the product being used (Tables 2 and 3). Then calculate the most economical available source.

The above equation was based on two clay loam soils. Silty and sandy soils require less lime, while soils higher in clay require more. We are in still in somewhat trial and error stage of lime rates for different soil types.

Table 3. Liming calculation for 6,000 lb $CaCO_3$/acre		
Calculation step	**Product A**	**Sugar beet lime**
1. Look up LS	89	60
2. Adjust for LS lb = (6,000/LS) x 100	6,741=3.4 ton	10,000=5 ton
3. Cost per ton	$75	$35
4. Cost per acre	$253	$175

On-farm strip trials are highly suggested to evaluate liming. A 'semi-truck'-load carries about 23 ton sugarbeet lime, which is 14 ton $CaCO_3$ (Table 2; 23 ton x 0.60). To raise a soil pH from 4.5 to pH 6 requires 1.5 ton $CaCO_3$ x 1.5 pH increase = 2.25 ton $CaCO_3$/acre. Therefore, a single truck-load could treat a little over 6 acres. Preventive measures start looking appealing.

Lime Placement Options

- On surface with 4 to 6"tillage or 2 sweeps. Without tillage, 1.5 ton aglime on silty clay loam only increased soil pH to 1.5" depth after 6 years (Mellbye 1992); sugarbeet lime on loam increased soil pH to only 2" depth after 2 years (Fertilizer eFact No. 80). Adding higher rates of lime does not offset the need for tillage.
- With irrigation water
- Surface spray ultra-fine lime – increased soil pH at 1" depth within 6 months (McFarland 2016)
- In seed row – currently pelleted lime is more expensive than conventional ag-lime
- Inject fluid (liquid) lime into seeding zone - quick acting but more expensive

The economics of variable rate applications are not yet known in Montana, but given the high cost of lime application, variable rate makes sense. Aerial images (e.g., Google Earth) along with ground truthing, are an inexpensive way to map areas that have low productivity and may need liming.

For more information and references:

MSU Extension Soil Fertility: Cropland Soil Acidification webpage *http://landresources.montana.edu/soilfertility/acidif/index.html*

Soil Acidification: Problems, Causes & Soil Testing http://landresources.montana.edu/soilfertility/soilscoop.html

MSU Fertilizer eFacts no. 78, 79, 80

Anderson, N.P., et al. 2013. *Applying Lime to Raise Soil pH for Crop Production (Western Oregon)*. Oregon State University Extension Bulletin EM 9057

Engel, R. Professor Emeritus, Montana State University

McFarland, C., et al. 2015. *Soil pH and Implications for Management: An Introduction*. Washington State University Extension Bulletin FS170E

McFarland, C. 2016. *Liming No-till Soils and Determining Lime Requirement in the Palouse Region*. Washington State University M.S. Thesis.

Mellbye, M. 1992. *Surface Limed Soil—Six Years Later*. OSU Extension Update (Linn County), Vol. XI, No. 9, p. 6. http://hdl.handle.net/1957/38002

Mullins, G.L., et al. 2009. *Sources of Lime for Acid Soils in Virginia*. Virginia Extension Publication 452-510.

Blanco-Canqui, H., and C. Wortmann. 2020. *Does occasional tillage undo the ecosystem services gained with no-till? A review.* Soil & Tillage. doi:10.1016/j.still.2019.104534

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