Soil Acidification: Management

MONTANA STATE UNIVERSITY EXTENSION

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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 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 – no left-over N. Base N rate on spring soil tests and realistic yield potential, split N applications (and don't apply 2nd time in dry springs), and place N in the root zone.
- Reduce nitrate (NO_3^-) loss. Use slow-release N sources or N sources with nitrification inhibitors, and plant deep rooted crops to 'catch' deep nitrate. Deep rooted crops can also pull base-forming cations (Ca^{2+}, K^+, Mg^{2+}) from the subsurface to the surface.
- 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
- Plant aluminum (Al)- or low-pH tolerant crops (Figure 1) or varieties such as Judee, Wesley, Overland, or AAC Gateway (from 1 Oklahoma study)

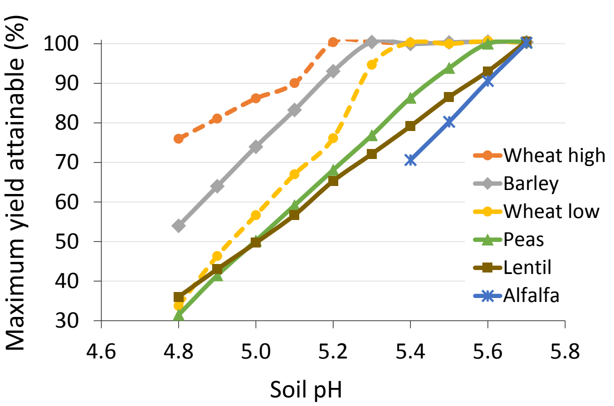

FIGURE 1. Crop species vary in tolerance to low pH, or high aluminum levels (McFarland et al., 2015).

- Inversion till to mix acid zone throughout plow layer and bring up calcium carbonate ($CaCO_3$) from deeper layers. A soil with 5% $CaCO_3$, typical in Montana, contains 100 tons of $CaCO_3$ in the top foot. One-time summer tillage doesn't negate long term benefits of no-till (Norton et al., 2014).
- 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 or apply manure. Replace fallow with crops or cover crops.
- Seed-place lime to compensate for annual N application or amend whole field with several years' of potential lime need. Broadcast conventional ag-lime needs to be tilled to affect the seeding zone. Other options are presented below.
- Band P with seed (binds some Al).

LIMING

Liming material reacts with carbon dioxide and 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 carbonate equivalent (CCE) compares a liming material to pure $CaCO_3$. Lime Score (LS; Table 2), also called effective neutralizing value (ENV), combines CCE with factors for moisture and fineness to calculate

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

Soil pH	Effect
6.1 - 6.5	Improve soil structure; reduce crusting; reduce power need for tillage
5.6 - 6.0	Increase soil microbial activity; increase rhizobia health for nitrogen-fixation and other mycorrhizal assisted crops (legumes and barley); increase plant nutrient availability
5.1 - 5.5	Reduce Al, H^+, and Mn toxicity; increase availability of P and other nutrients
< 5.1	Few crops can produce if not limed

[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

liming rates. Fineness is determined by the particle size. Those 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). The particle size distribution of liming material determines how quickly and how long the material increases soil pH.

Timing Take preventive measures and monitor soil pH to determine if mitigation is necessary. All but very fine lime takes several years to penetrate the seeding zone. Apply lime at least the fall prior to a spring planting. For perennial crops, ideally apply enough before seeding for the longevity of the stand. Humid days with little wind are ideal to minimize the amount of lime blown away during surface application.

Rate The following information is needed to calculate a liming rate:

- Lime score (Table 2 or on lime material label)
- Current soil pH and desired pH (> 5 to reduce Al, H^+, Mn toxicity; > 5.5 to have some buffer; > 6 to be good for 10+ years)
- Soil texture (sand<sandy loam<silt loam<clay loam)
- Desired crop

The lime rate can come from either the soil test lab based on the soil test and desired crop, or estimated (adapted from McFarland, 2016).

Lime rate (ton/acre) = 1.86*(desired pH increase)

Lime rate is given in units of $CaCO_3$ (100% CCE) and has to be adjusted by the lime score (LS) of the product being used (see calculation box). Then calculate the most economical available source. Lime rates above 2 ton/acre are not economical if only top-dressed without incorporation (Anderson et al., 2013).

Lime Placement Options

- On surface with 4–6" tillage or 2 sweeps of minimum tillage
- With irrigation water
- Surface broadcast – doesn't move deep, 1.5 ton lime applied to silty clay loam increased soil pH to 1.5" depth after 6 years, but no deeper (Mellbye, 1992)
- Ultra fine lime surface sprayed – increased soil pH at 1" depth within 6 months (McFarland, 2016)
- Place pelleted lime in seed row – products and results are under investigation, 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, but it makes sense to not apply lime where it is not needed.

Example 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

For more information:

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

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

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

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McFarland, C., D.R. Huggins, and R.T. Koenig. 2015. *Soil pH and Implications for Management: An Introduction*. Washington State University Extension Bulletin FS170E

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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

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Norton, U., P. Bista, R. Ghimire, and J.B. Norton. 2014. *One-time summer tillage does not negate long-term benefits of no-till*. Crops & Soils. May-June:24-25.