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 (NO₃⁻) loss. Plant deep rooted crops to ‘catch’ deep nitrate and pull base-forming cations (Ca²⁺, K⁺, Mg²⁺) 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 (CaCO₃) 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).

**LIMING**

Liming material reacts with water in the soil to yield bicarbonate (HCO₃⁻), which takes H⁺ and Al³⁺ (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 CaCO₃. Lime Score (LS; Table 2), also called effective

<table>
<thead>
<tr>
<th>Limed soil pH</th>
<th>Effect</th>
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<tbody>
<tr>
<td>&lt; 5.1</td>
<td>Few crops can produce if not limed</td>
</tr>
<tr>
<td>&gt; 5.1 - 5.5</td>
<td>Reduced Al, H⁺ and Mn toxicity; increased P and other nutrient availability</td>
</tr>
<tr>
<td>&gt; 5.6 - 6.0</td>
<td>Increased soil microbial activity, rhizobia health for nitrogen-fixation and other mycorrhizal assisted crops (legumes and barley), plant nutrient availability</td>
</tr>
<tr>
<td>&gt; 6.1 - 6.5</td>
<td>Improved soil structure; reduced crusting and power need for tillage</td>
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</tbody>
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**Figure 1.** Crop species vary in tolerance to low pH, or high aluminum levels (McFarland et al. 2015).
The lime rate can be estimated as:

\[
\text{Lime rate (ton CaCO}_3/\text{acre}) = 1.5 \times (\text{pH increase})
\]

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 lime rate.

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.

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


MSU Fertilizer eFacts no. 78, 79, 80


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