Module 8: Soil pH and Lime Management

To view the chapter for this topic click here.
Introduction

• Soil pH: measure of the soil acidity and alkalinity.

• If soil pH:
  - less than 7 → acidic
  - around 7 → neutral
  - greater than 7 → alkaline

• Soil pH is influenced by the relative proportion of acidic and basic cations on the soil exchange complex.

• Common acidic cations → $H^+$, $Al^{3+}$, $Fe^{2+}$, and $Fe^{3+}$

• Common basic cations → $Ca^{2+}$, $Mg^{2+}$, $K^+$, $NH_4^+$, $Na^+$
Introduction

• Factors influencing soil pH:
  o parent material
  o length of weathering and soil formation
  o climate
  o organic matter mineralization
  o NH$_4^+$ fertilizer rate and nitrification to NO$_3^-$
  o cropping system and crop harvest
  o land use and management

• Most agricultural soils in dry climates have alkaline conditions.

• Acidic conditions occur in soils:
  o derived from parent material high in elements such as silica
  o high proportion of sand with low buffering capacities
  o in regions with high precipitation
Relative Nutrient Availability and Microbial Activity

Nutrient availability and microbial activity as affected by soil pH; the wider the band, the greater the relative availability or activity. Adapted from N. Brady. The Nature and Properties of Soils, 10th ed.
Negative Effect of Acidic Soils

- Less solubility of essential and non-essential elements.

- Increased solubility and toxicity from $\text{Al}^{3+}$, $\text{Mn}^{2+}$, and $\text{H}^+$.

- Often greater weed stress because of the poor crop growth and low competition.

- Reduced soil microbial activity.
Testing for Soil pH

- Soil pH measurement:
  - soil to water ratio of 1:1 (most common in the U.S.) or 1:2
  - saturated soil paste
  - dilute salt solutions (such as KCl or CaCl$_2$)

- It is important to be aware of the soil pH test being used and to be consistent across sampling to ensure comparable data over time.

- For example, pH measured with dilute salt solutions will have a lower pH value than measured with water.
### Suggested Optimum Soil pH for Crops

- The optimal soil pH varies widely for different plant species.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Optimum Soil pH range</th>
<th>Suggested optimum pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>6.2-7.5</td>
<td>7.0</td>
</tr>
<tr>
<td>Barley</td>
<td>5.5-7.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Corn</td>
<td>5.5-7.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Soybean</td>
<td>5.5-7.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Wheat</td>
<td>5.5-7.0</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Source: Havlin et al., 2005. Soil fertility and fertilizers.
Soil Sampling: Methods, Timing, and Frequency

• Appropriate soil sampling is critical in determining liming needs.

• At least 12 cores at random locations across the area of interest are recommended.

• Sampling and limestone application should be completed several months in advance of crop planting.

• Soil pH may fluctuate during the year, so sample timing should be consistent and be appropriate for the cropping system.
Soil Sampling: Methods, Timing, and Frequency

- Frequency of needed soil sampling will depend on:
  - soil properties
  - cropping system or rotation
  - the source and amount of N applied
  - the quality and type of liming material used

- Sampling at least every three to five years is recommended.

- Results from samples collected from producer’s fields and field-scale research have shown very high pH variation within fields and even within soil map units.

- Dense soil sampling approaches and variable rate technologies are being adopted at a rapid rate by producers.
Example of soil pH spatial variability using a zone or grid soil sampling approach for a central Iowa field with several soil types. Adapted from A.P. Mallarino, Iowa State University.
Managing Soil pH for Alkaline Soils

- Alkaline soils: exchange complex is saturated with basic cations.

- In soils with pH 7.2 to 8.5, pH is controlled by dissolution of free lime.

- In soils with pH 8.5 to 10.5, pH is controlled by exchangeable Na\(^+\) and Na\(_2\)CO\(_3\).

- Decreasing pH of alkaline soils is difficult and typically impractical on a field scale.

- Soil pH reduction can be achieved in localized (small areas) by application of:
  - elemental sulfur (S), ferrous sulfate (FeSO\(_4\)), and aluminum sulfate [Al\(_2\)(SO\(_4\))\(_3\)]
  - salt issues can develop if the amount of acidifying material applied is large, and Al toxicity is possible.
Managing Soil pH for Acidic Soils

• Application of N fertilizers and many manure sources increase soil acidity.

• Liming is the most common method for neutralizing soil acidity.

• Liming materials are most often materials such as CaCO$_3$ and MgCO$_3$.

• Limestone reacts with CO$_2$ in the soil to yield bicarbonate (HCO$_3^-$), which reacts with H$^+$ and Al$_3^+$.  
  • These reactions take acidic cations off the exchange complex and out of solution.

• The amount of limestone material to apply depends on:
  o the amount of reserve soil acidity to be neutralized
  o the quality of the liming material (purity and particle size)
Rate of Limestone Application

- The amount of limestone needed to adjust soil pH depends on:
  - desired pH level for a particular crop
  - initial soil pH
  - soil cation exchange capacity (the soil clay and OM content)

- Analytical methods have been developed to determine lime requirement:
  - soil incubation
  - direct titration
  - buffer solutions (SMP, Sikora, Mehlich, etc.)
  - fast direct titrations with a single addition of a base
Timing of Limestone Application

- Crops with greater sensitivity to low pH should have pH corrected well in advance of seeding.

- If subsoil pH is low, a long period will be required for the limestone to effect a change in the soil pH with depth.

- Coarse limestone particles react more slowly.

- Incorporation into the soil will provide faster reaction and pH adjustment.

- Surface application will have most impact on pH near the soil surface.

- When a rapid pH correction is needed, the use of a finely ground limestone or agricultural ground limestone with good quality should be considered.
Variable Rate Liming

• Variable rate liming has recently grown in popularity.

• Variable rate liming helps target appropriate rates to field areas having lower-than-optimum pH and reduces or avoids application in areas with high pH.

• This application method increases liming efficiency and therefore profitability.
## Liming Materials

<table>
<thead>
<tr>
<th>Liming Material</th>
<th>CCE</th>
<th>Equivalent to one ton pure limestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium carbonate</td>
<td>100</td>
<td>2000</td>
</tr>
<tr>
<td>Calcitic limestone</td>
<td>85-100</td>
<td>2350-2000</td>
</tr>
<tr>
<td>Dolomitic limestone</td>
<td>95-109</td>
<td>2100-1830</td>
</tr>
<tr>
<td>Burned lime</td>
<td>150-175</td>
<td>1330-1140</td>
</tr>
<tr>
<td>Hydrated lime</td>
<td>120-135</td>
<td>1670-1480</td>
</tr>
<tr>
<td>Basic Slag</td>
<td>50-70</td>
<td>4000-2900</td>
</tr>
<tr>
<td>Baked oyster shells</td>
<td>80-90</td>
<td>2500-2200</td>
</tr>
</tbody>
</table>

Source: Havlin et al., 2005. Soil fertility and fertilizers.
Summary

- Soil pH is considered the single most important chemical property of soil.

- Limited solutions exist for reducing pH in high pH soils.

- Soil acidity reduces plant nutrient availability, increases toxicity of some elements, and reduces activity of many microbes.

- Lime application is the most common way to neutralize acidity.

- Buffer solutions, single titrations, and indexes that include soil characteristics are the most widely used approaches to determine lime rate requirements.

- The large within-field spatial variability found in many U.S. regions justifies variable rate technology for limestone application.