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^+

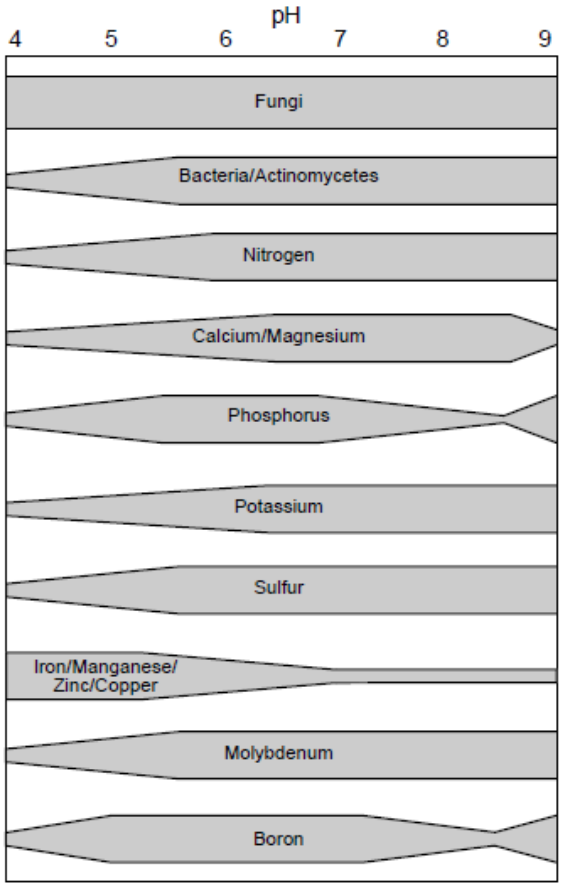
Introduction

- Factors influencing soil pH:
  - parent material
  - length of weathering and soil formation
  - climate
  - organic matter mineralization
  - NH_4^+ fertilizer rate and nitrification to NO_3^-
  - cropping system and crop harvest
  - land use and management

- Most agricultural soils in dry climates have alkaline conditions.

- Acidic conditions occur in soils:
  - derived from parent material high in elements such as silica
  - high proportion of sand with low buffering capacities
  - 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 Al^{3+}, Mn^{2+}, and 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.

Crop	Optimum Soil pH range	Suggested optimum pH
Alfalfa	6.2-7.5	7.0
Barley	5.5-7.0	6.5
Corn	5.5-7.0	6.5
Soybean	5.5-7.0	6.5
Wheat	5.5-7.0	6.5
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

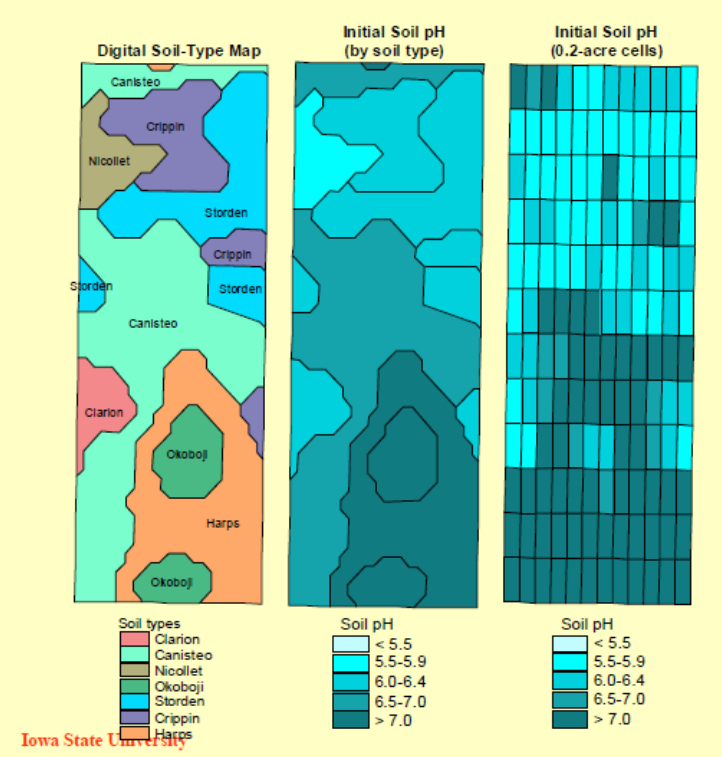
- Frequency of needed soil sampling will depend on:
  - soil properties
  - cropping system or rotation
  - the source and amount of N applied
  - the quality and type of liming material used

- 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.

Soil Sampling: Methods, Timing, and Frequency



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_2CO_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:
  - the amount of reserve soil acidity to be neutralized
  - 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

Liming Material	CCE	Equivalent to one ton pure limestone
	- % -	----- lb -----
Calcium carbonate	100	2000
Calcitic limestone	85-100	2350-2000
Dolomitic limestone	95-109	2100-1830
Burned lime	150-175	1330-1140
Hydrated lime	120-135	1670-1480
Basic Slag	50-70	4000-2900
Baked oyster shells	80-90	2500-2200
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.