What is Acidity?

An acid is a substance that gives off hydrogen ions (H^+).
A base is a substance that gives off hydroxyl ions. (OH^-).

pH is an expression of the concentration of hydrogen ions in solution

$$pH = -\log(H^+ \text{ activity})$$

pH scale ranges from 1 - 14, pH = 7 is neutral, > 7 is basic, < 7 is acidic

What is the Origin of Soil Acidity?

Soils are acid when a considerable portion of the cation exchange capacity is filled with H^+ and Al^{3+}, instead of the basic cations, Ca^{2+}, Mg^{2+}, K^+, and Na^+. H^+ and Al^{3+} replace the basic cations from the exchange complex and they can be leached deep into the soil profile or groundwater.

In soils, H^+ arises from several factors:

1. Carbon dioxide from decomposing organic matter and root respiration.

$$CO_2 + HOH \longrightarrow H_2CO_3 \longrightarrow HCO_3^- + H^+$$

2. Ammonium- and organic-N are oxidized to form nitrate and H^+.

$$NH_4^+ + 2O_2 \longrightarrow NO_3^- + H_2O + 2H^+$$

3. Sulfur oxidation.

$$2S + 3O_2 + 2HOH \longrightarrow 2SO_4^{2-} + 4H^+$$

4. Root release of H^+ to maintain cation anion balance within the plant.

5. Acid rain--sulfuric acid and nitric acid. Generally, minimal effects except near point source discharges.

6. Crop removal of basic cations.

Active and Potential Acidity

Active: Hydrogen ion in solution

Potential: Aluminum (primarily) and H^+ on the exchange complex. When the soil is limed $A1^{3+}$ is displaced from the exchange sites by Ca^{2+}. The $A1^{3+}$ hydrolyzes (see equations below) and generates more H^+. Lime must be added to the soil to neutralize the H^+ generated from $A1^{3+}$ hydrolysis, as well as that present in the soil solution prior to liming.

$A1^{3+}$	$+ H_2O$	$Al(OH)^{2+}$	$+ H^+$
$AI(OH)^{2+}$	$+ H_2O$	$Al(OH)_2{}^+$	$+ H^+$
$Al(OH)^{2+}$	$+ H_2O$	$Al(OH)_3$	$+ H^+$

Lime Requirement

Soil pH indicates if lime is needed, not how much is needed.

Lime requirement is dependent on initial soil pH, desired soil pH, and a measure of the potential acidity. Potential acidity is often referred to as the soil's buffer capacity or resistance to change in pH. Usually, the higher the clay and organic matter content the greater the soil's buffer capacity. More lime is needed to change the pH of a soil with a high buffer capacity than a soil with a low buffer capacity. More lime is needed to change the pH of a clayey soil than a sandy soil.

The buffer capacity of a soil is determined in the laboratory by mixing soil with a buffer solution. The buffer solution alone has a high pH. The decrease in pH of the buffer/soil mix is an indication of the buffer capacity of the soil. If the buffer capacity of the soil is low, the pH of the buffer/soil mix will be close to that of the original pH of the buffer. If the buffer capacity of the soil is high, then the pH of the buffer/soil mix will be much lower than the initial pH of the buffer. For example:

Initial pH of buffer = 8.00

Soil texture	initial soil pH	target pH	pH of soil/buffer mix	lime rec.
Sand	5.5	6.5	7.80	700 lb/a
Sandy loam	5.5	6.5	7.60	1400 lb/a
Clay loam	5.5	6.5	7.20	2800 lb/a

Factors in Acid Soils Detrimental to Plant Growth

Acid Soil Complex -- plant growth problems at low pH are often multi-faceted.

1. ALUMINUM toxicity.

    Affects plant roots- Sparsely branched large-diameter roots at low pH. Tissue levels of Al relate poorly to toxicity.

2. Manganese toxicity.

    Affects plant tops. Occurs below pH 5.5. Cotton, soybean, and tobacco are sensitive.

3. iron toxicity -- minor problem

4. Calcium deficiency. Peanut, tobacco, and tomato are sensitive.

5. Magnesium deficiency.

    Conditions that are conducive to Mg deficiency are:

    1. low CEC
    2. use of low magnesium liming material
    3. high rate of $NH4^+$ fertilizer
    4. high rate of K fertilizer
    5. excessive leaching of soil profile
    6. crops with high requirement for Mg - tobacco, cotton, and soybean.

6. Molybdenum deficiency (soybeans and cauliflower).

In most cases liming to pH 5.5 to 6.0 alleviates Mo deficiency. In some cases liming > 6.0 needed to eliminate Mo deficiency.

7. Nitrogen, phosphorous, and sulfur deficiency because of slow organic matter decomposition -- minor problem.

8. Reduced phosphorous availability due to precipitation with aluminum.

9. Poor nodulation of legumes.

Liming Materials

	Chemical Formula	Rel. Neutr. Value	Origin
Calcitic limestone	$CaC0_3$	90-100	Natural deposits
Dolomitic limestone	$CaC0_3$:$MgCO_3$	95-108	Natural deposits
Hydrated lime	$Ca(OH)_2$	120-135	Steam burned
Burned lime	Ca0	150-175	Kiln burned
Calcium silicate	$CaSi0_3$	30-60	Slag
Wood ashes	variable	40-85	Steam boilers

See page 250 for more complete description of origin of these materials.

FACTORS AFFECTING LIME REACTION

Relative Neutralizing Value

Relative ability of a liming material to neutralize acidity compared with pure $CaC0_3$

Chemical measure which:

reflects chemical composition -- oxide, hydroxide, carbonates (handout)
level of impurities

Does not necessarily relate to rate and extent of reaction in soil.

Fineness

The smaller the particle the faster the reaction. (overhead)

Effective calcium carbonate or neutralizing index. An attempt to integrate calcium carbonate equivalence and fineness so that various liming materials can be compared. (p. 254, note 8-2).

Lime law (handout/overhead)

Chemical Composition

Dolomite particles are less reactive than calcitic.

"When lime is required and soil test for magnesium is medium plus or above, any source of lime may be used. When lime is required and soil test magnesium is medium or less, use dolomitic limestone. The use of dolomitic limestone every time the soil is limed will not result in magnesium toxicity or cause a ration imbalance situation in the soils in South Carolina." (Circular 476, p. 13)

Incorporation and Mixing

Expose as much lime surface area to as much soil surface area as possible.

Time and Frequency of Liming

At anytime in the cropping sequence that soil pH is below the acceptable range.

Frequency of liming is dependent on several factors.

1. Neutralization by acid-forming nutrient sources; particularly those containing organic-N, ammonium-N, and ammonia-N.

2. Organic matter decomposition and carbon dioxide release.

3. Leaching of basic cations.

4. Removal of basic cations by crop harvesting.

5. Erosion of topsoil, releaving acid subsoil behind.

6. Acid rain.

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