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Liming Acid Soils in Tennessee

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Soil test results indicate that approximately 50 percent of the cropland in Tennessee is too acid for optimum crop production. Because of this, determining the need for lime should be the first step in developing a sound crop fertilization program. Lime neutralizes excess soil acids and increases pH. If not limed as needed, soils continue to become more acid, reducing the soil's potential to produce healthy plants and profitable yields.

What Is Soil Acidity?

Soil acidity refers to the level of acids present in soils. As acid levels increase, the pH of the soil decreases. While the pH scale ranges from 0-14, most Tennessee soils range in value from 4.5 to 7.5. Soils with pH values greater than 7.0 are alkaline or sweet, and those with values of less than 7.0 are acid or sour (Figure 1). As the soil pH decreases below 7.0, the amount of acidity rapidly increases. For example, a pH of 5.0 is 10 times more acid than 6.0 and 100 times more acid than pH 7.0.

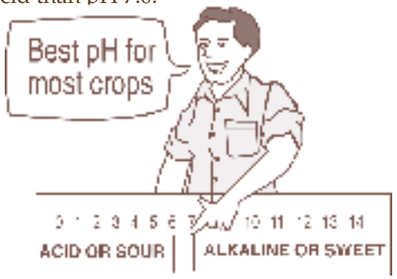

Figure 1. The pH Scale (Source: NCSA).

Causes of Soil Acidity

Several factors contribute to soil acidity. Acid levels increase as basic nutrients (calcium, magnesium, potassium) are replaced by **hydrogen** through soil erosion, leaching and crop removal. In addition, the use of acid-forming fertilizers greatly enhances acid levels. In particular, the conversion of ammonium (NH_4) nitrogen to nitrate (NO_3) nitrogen in the soil (nitrification) produces significant amounts of acid (H) as follows:

$$\text{Ammonium } (NH_4) \xrightarrow[\text{Bacteria}]{\text{Oxygen}} \text{Nitrate } (NO_3) + \text{Acid } (H)$$

As a result, about 3 to 4 pounds of agricultural limestone are needed to correct the acidity formed from each pound of actual nitrogen applied to the soil from either ammonium nitrate, urea, UAN solutions or anhydrous ammonia.

Determining the Need for Lime (Water pH)

Soil pH is determined in the University of Tennessee Soil Testing Laboratory with the **glass electrode** using 10 grams of soil in 10 milliliters of deionized water. The value obtained is a measure of the degree of acid in the soil solution and is used to indicate whether or not lime is needed (Figure 2). It is the value referred to on soil test report forms as **water** pH.

Determining the Amount of Lime (Buffer pH or Buffer Value)

While **water** pH indicates the need for lime, **buffer** pH determines how much to apply. Buffer pH is a measure of the amount of acid held (adsorbed) by soil particles (clay, organic matter) and accounts for the acid that must be neutralized when lime is added. Buffer pH is reported as **buffer value** on all University of Tennessee soil test report forms.

The relation between water and buffer pH readings may be more easily understood by considering the relation between the fuel gauge and fuel tank in an automobile. The gauge indicates the relative need for fuel but says nothing about the gallons required to fill up. This depends on the size of the tank. For example, if the tank holds 20 gallons and the gauge indicates it to be one-fourth full, then 15 gallons of fuel would be required to refill the tank. If the tank's capacity is 40 gallons, then 30 gallons of fuel would be necessary to refill the tank from one-fourth full.

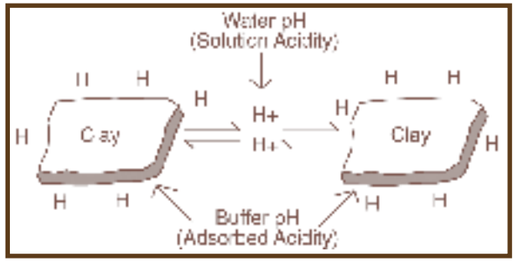

Figure 2. Relation between Water pH and Buffer pH.

When making lime recommendations, water pH is the "gauge" used to indicate the need for lime, while buffer pH is the "gauge" used to show how much lime should be applied to properly adjust the soil's pH, or "refill the tank." Clayey soils have more holding capacity or "larger tanks" than silty or sandy soils and require more lime to produce an equal amount of change in soil pH. Although water pH values may be similar for two or more soils, buffer pH values and recommended lime rates may differ greatly due to different clay levels and amounts of adsorbed acidity.

What Does Lime Do?

Applying lime to acid soils provides the following benefits:

1. Reduces amounts of soluble aluminum and manganese to non-toxic levels. As soil pH increases, the availability of manganese decreases, which prevents plants from taking up toxic amounts (Figure 3). **Manganese toxicity** becomes a major problem in many plants when the soil pH drops to near 5.0.
2. Supplies calcium, and if dolomitic limestone is used it supplies both **calcium and magnesium**, which are essential plant nutrients. Also, the availability of **secondary and micronutrients** is about optimum in the pH range of 6.1 to 6.5.
3. Increases the efficiency of N, P and K. For example, the efficiency of applied phosphate may be more than doubled when soil pH is increased from 5.0 to 6.1 because of less fixation or tie-up in the soil (Figure 4).
4. Enhances microorganism activity. Acid soils slow the growth and multiplication of certain microorganisms, which in turn reduces soil processes such as the release of nutrients from organic matter decomposition (**mineralization**) and **nitrogen fixation** in legumes.
5. Improves the effectiveness of certain **herbicides** (atrazine, etc.).
6. Increases **yields and profits**. University of Tennessee research indicates that three tons of limestone applied to soybean fields with soil pH values of 5.1 to 5.5 increased yields an average of 11 bushels per acre. In burley tobacco tests, yields were increased 1,024 pounds when four tons of limestone were applied to a soil with pH 4.4.

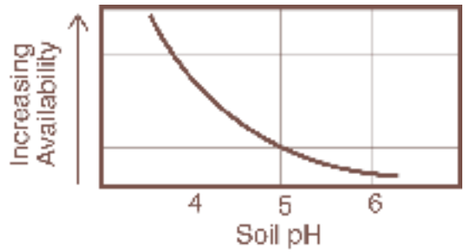

Figure 3. Influence of Soil pH on Manganese Availability.

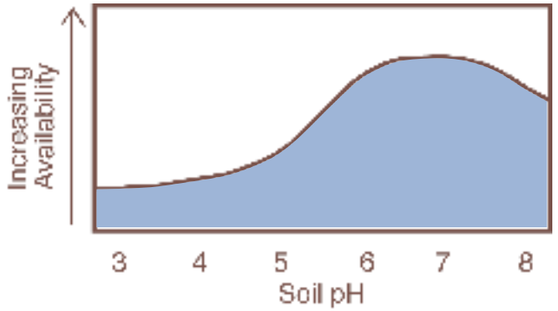

Figure 4. Influence of Soil pH on Phosphorus Availability.

When and How to Apply Lime

Although lime can be applied whenever soil, weather, crop and labor conditions permit, **fall** is an excellent time for spreading. Fields are usually dry, lime dealers are less rushed and growers are not occupied with spring planting.

Lime should be spread **uniformly**. Uneven distribution may present problems for several growing seasons since lime is not applied every year. The time interval between lime applications will vary depending upon soil type, weather conditions, cropping systems and fertilization (see Extension PB 1061).

Lime Sources

The primary function of a liming material is to correct acid soil conditions. Thus, materials that are easily spread and provide the greatest liming value at the least cost are the most desirable. The most common and economical liming material available in Tennessee is ground or **agricultural limestone**. Limestones containing both calcium and magnesium are DOLOMITIC. Those containing only calcium are

calcitic. When soils are acid and magnesium levels are deficient, a dolomitic limestone should be applied to increase both pH and magnesium levels. Dolomitic limestones sold in Tennessee usually contain about 9 percent magnesium.

If other materials are used, equivalent amounts should be applied (Table 1). For example, one ton of calcitic limestone is equivalent in potential neutralizing value to about 1,500 pounds of calcium hydroxide or 3,000 pounds of basic slag.

Pelletized Lime

Pelletized lime is produced by binding or compressing smaller lime particles into larger granules or pellets. The larger particle are easier to spread and create less dust when handling. For this reason, pelletized lime is often the choice for lawn and garden use. However, if the pellets do not readily slake or break down when in contact with rain or irrigation, their effectiveness in raising soil pH may be reduced. The cost of pelletized lime is usually greater than conventional lime sources because of the added expense in processing.

State Liming Law

The Tennessee Liming Materials Act requires that no liming material be offered for sale that does not have a minimum calcium carbonate equivalent of 75. It must also be ground so that at least 85 percent passes through a 10-mesh sieve and at least 50 percent passes through a 40-mesh sieve. In addition, liming materials sold must have a relative neutralizing value (RNV) of 65 or greater to meet state requirements.

Material	Calcium Carbonate Equivalent	Pounds to Equal One Ton of Pure Calcium Carbonate
Limestones		
Pure	100	2000
Calciate	85-100	2360-2000
Dolomitic	95-109	2100-1890
Calcium Hydroxide		
Hydrated or Slaked Lime	135	1480
Calcium Oxide		
Burnt or Quick Lime	179	1120
Basic Slag	60-70	3330-2860

Table 1. Equivalent Amounts of the Liming Materials Based on Calcium Carbonate Equivalent.

Calcium carbonate equivalent, fineness of grind and the relative neutralizing value are required to be indicated in a conspicuous manner on the label or tag of bagged materials and on the delivery slip or invoice for materials sold in bulk.

NOTE: Sieve or mesh size refers to the number of openings per linear inch of screen. For example, a 40-mesh sieve contains 40 openings per linear inch or 1,600 openings per square inch.

Relative Neutralizing Value (RNV)

The relative neutralizing value of a liming material is determined by calculating the total particle size efficiency and multiplying by the calcium carbonate equivalent as follows:

Percent Material In Each Size Range		Efficiency Factor		Particle Efficiency
5 (coarser than 10 mesh)	x	.33	=	1.6
20 (10-40 mesh)	x	.73	=	14.6
40 (40-60 mesh)	x	.93	=	37.2
35 (finer than 60 mesh)	x	1.00	=	35.0
Total Particle Size Efficiency			=	88.4

If the above material had a calcium carbonate equivalent (CCE) of 90 percent, the RNV would be: 88.4 (particle size efficiency) X .90 (CCE) = 79

The Importance of Limestone Quality

The quality of agricultural limestone is determined by **calcium carbonate equivalent and fineness of grind**. The calcium carbonate equivalent determines how much acidity a given amount of ground limestone will neutralize in the soil. Fineness of grind determines the rate limestone reacts with soil acids. Limestones coarser than 60-mesh will require from a few weeks to several months to produce significant changes in pH, while limestones 60-100 mesh will produce significant changes within two to three weeks when weather conditions are favorable and recommended amounts are applied (Figure 5). Limestones finer than 100 mesh produce results similar to 60-100 mesh materials when applied under similar conditions. **Thus, small amounts of "extremely fine" liming materials should not be substituted for recommended amounts of good quality ground limestone.** Also, extremely fine materials may be difficult to spread and handle.

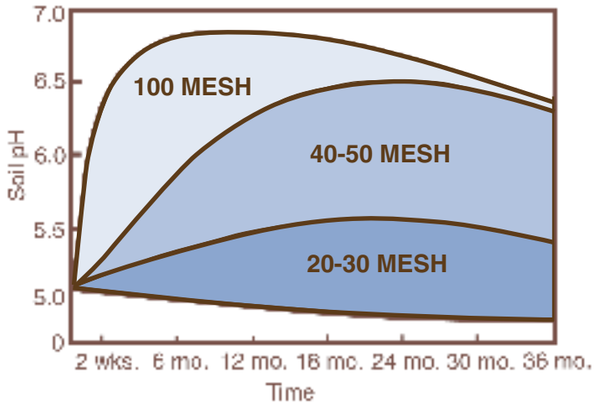

Figure 5. Relation between particle size and rate of change in soil pH when equal amounts of limestone are applied under similar conditions.

Agricultural limestones meeting state requirements usually contain adequate amounts of 60-100 mesh material.

Liming No-Till Soils

Lime is very important to no-till crops, especially corn where large amounts of nitrogen fertilizers are applied to the surface without incorporation. The nitrogen tends to produce extremely acid conditions in the top 2 inches of soil. If not neutralized, the acid will greatly reduce nutrient availability and herbicide activity, resulting in low fertilizer efficiency and poor weed control.

Where lime is needed, the same amount is recommended for no-till as for conventional practices. Research does not indicate any advantage to applying smaller amounts more frequently.

If soils are extremely acid initially (approximately 5.0 or less to several inches), root development and plant growth may be restricted unless the limestone is incorporated into the soil. Surface applications will require more time to neutralize acidity to greater depths than when incorporated into the soil.

Soil samples for determining pH should be collected to a depth of 6 inches for both conventional and no-till row crops and pastures.

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