Soil Acidity and Liming

L. A. Redmon, M. L. McFarland, V. A. Haby, and D. H. Bade

Department of Soil and Crop Sciences

What Causes Soil Acidity?

Various environmental, climatic, and cultural factors can affect formation of acid soils. The most common factors are:

✓ **Parent material:** Soils formed from acidic rocks have a lower pH than those formed from basic or alkaline parent material.

✓ **Leaching:** Rainfall/irrigation leaches basic elements such as calcium, magnesium and sodium from the soil profile, leaving the acidic elements hydrogen, aluminum and manganese.

✓ **Cultural:** Various management practices can affect the formation of acid soils, including:

♦ Soil erosion can cause the loss of basic elements thus increasing soil acidity.

♦ Removal of harvested crops depletes basic elements from the soil.

♦ Nitrogen fertilization can lead to the formation of acid soils when ammonium is converted to nitrate by soil microbes releasing hydrogen ions. Anhydrous ammonia, urea, and ammonium nitrate each produce about one-third as much acidity as ammonium sulfate.

Soil Acidity Measurement and Ratings

Soil pH is a measure of hydrogen ion activity in the soil solution. However, a buffer-pH test should be used to more accurately predict the limestone needed to raise soil pH to a desired level.

The soil pH scale extends from 0 to 14; thus soil pH in the range of 6.6 to 7.3 is rated neutral. Soils are considered slightly acid between pH 6.5 - 6.1, moderately acid between 6.0 - 5.5, strongly acid between 5.5 - 5.1, very strongly acid between 5.0 - 4.5, and extremely acid below pH 4.4. Soils with pH values above 7.4 are rated as alkaline. Although a decrease in soil pH from 6.0 to 5.0 does not appear significant, there is a 10-fold increase in soil acidity for every whole unit change in soil pH.

Importance of Liming Acid Soils

The most important benefit of liming acid soils is a reduction of the potentially toxic elements hydrogen, aluminum and manganese. Hydrogen ions only become toxic to plants in extremely acid soils (pH<4.0) and at very low calcium levels. As pH drops below 5.5, the concentration of soluble aluminum increases and becomes toxic to plant root growth when it exceeds 1.0 part per million (ppm). Below pH 5.2, the concentration of manganese can become toxic.

Optimum nutrient uptake by most crops occurs at a soil pH near 7.0. The availability of fertilizer nutrients such as nitrogen, phosphorus and potassium generally is reduced as soil pH decreases (Table 1). Phosphorus is particularly sensitive to pH and can become a limiting nutrient in strongly acid soils. Thus, reduced fertilizer use efficiency and crop performance occurs when soil acidity is not controlled. Soil pH also affects the types, concentrations and activities of soil microorganisms. As pH drops below 5.5, the population of soil microbes changes and is reduced due to aluminum and manganese toxicity and lower nutrient availability.

Table 1. Plant Nutrient Recovery as Affected by Soil Acidity

Soil pH	Nitrogen	Phosphate	Potash
		Nutrient Recovery (%)	
7.0	70	30	60
6.0	63	15	60
5.5	52	15	45
5.0	38	10	30
4.5	21	8	21

Limestone Quality

All limestones are not the same and may react more or less efficiently based on the particle size and neutralizing value of the limestone material. Smaller particles have more surface area, react more rapidly to change soil pH, and thus have a higher efficiency rating (ER). Particles larger than 0.080 inches in diameter (about the size of #9 shotgun shot) do not react with the soil to effectively change pH. As particle size decreases, the rate of reaction increases and reaches 100% for particles less than 1/1,000 inch in diameter.

The ability of a limestone to neutralize soil acidity also depends upon its calcium carbonate equivalence (CCE) or neutralizing value, which is expressed as a percentage. Pure calcium carbonate is the standard and has a CCE of 100%. All other liming materials are compared with this standard. Dolomitic limestones contain both calcium and magnesium carbonates. If a soil test indicates low magnesium, dolomitic limestone can be used to correct both the nutrient deficiency and pH.

L. A. Redmon, Associate Professor and Extension Agronomist, Texas Agricultural Extension Service, Overton; M. L. McFarland, Associate Professor and Soil Fertility Specialist, Texas Agricultural Extension Service, College Station; V. A. Haby, Professor, Texas Agricultural Experiment Station, Overton; D. H. Bade, Professor and Extension Forage Specialist, Texas Agricultural Extension Service, Bryan.

Calculating Application Rates Based on Effective Calcium Carbonate Equivalence

Effective Calcium Carbonate Equivalence (ECCE) combines the fineness efficiency rating (ER) and the calcium carbonate equivalence (CCE) to estimate the percentage of effective limestone in a given product. The percentage ECCE of a product should be available from the vendor. It is important because limestone rates recommended by soil testing laboratories are based on use of 100% effective limestone (dry weight basis).

Agricultural grade limestones generally have an ECCE value of 50-70%. Therefore, if a soil test recommendation for lime is 1.0 ton/acre, the actual application rate of a limestone with an ECCE value of 60% would be 1.67 tons/acre (Table 2). Limestones with an ECCE in the range of 95-100% are becoming increasingly available in the market. In many cases, limestone with an ECCE value of 95-100% that is priced slightly higher per ton is a better buy than standard agriculture grade limestone since a lower application rate is needed (Table 2).

Timing of Limestone Application

Limestone can be applied at any time, however, several factors should be considered when planning an application. Soil moisture is critical to the reaction of limestone, thus rainfall patterns in the area should be used as a guide. Soils should be sufficiently firm to support heavy equipment and minimize compaction. If subsoil pH is low, a long period will be required for the limestone to effect a change in the soil pH with depth. In addition, coarse limestone reacts more slowly and, as with all limestones, is most effective when incorporated into the soil. When a more rapid and longer lasting pH adjustment is needed, the use of finely ground, high ECCE limestone is advisable.

Methods of Application

Dry bulk limestone is typically applied using fertilizer spreader trucks. A moisture content of 7 to 9% in fine limestone is needed to minimize dust and achieve a uniform spreading pattern.

Liquid lime is a combination of very fine limestone (100 mesh or smaller) in water with 1 to 2% clay to form a suspension that is about 50 to 60% solids. With proper calibration, this enables uniform product application with no dust. Fluid lime reacts the same as finely ground dry limestone of similar neutralizing value and particle size. At 60% solids including 2% clay, one ton of fluid lime made with calcium carbonate will provide 1,160 lbs. of acid-neutralizing limestone that is as effective as the limestone used to make the suspension. Thus, approximately 1.72 tons of fluid lime (product) would be required to provide the same quantity of acid-neutralizing lime as one ton of dry lime of equivalent quality. Fluid lime is usually more expensive per ton than limestone applied dry due to increased costs for finely ground materials, freight and product application. Although fluid lime reacts fast in the soil because of its extreme fineness, its long-term effectiveness for neutralizing soil acidity is similar to dry liming materials that have an ECCE = 100%.

Do You Need More Information?

For more comprehensive discussion of soil acidity and liming, see the following publications:

Managing Soil Acidity. McFarland, M.L. et al., 2001. Soil and Crop Sciences Publication No. SCS-2001-05 available at http://soiltesting.tamu.edu.

Liming Acid Soils. Haby, V.A. et al., 2001. TAES Bulletin No. B-1720 available at http://www.overton.tamu.edu.

Acknowledgments

Table 2. Use of ECCE to Calculate Limestone Rate and Compare Product Cost

Limestone ECCE (%)	Soil Test Lime Requirement (Tons/Acre)	Application Rate [Lime required/(ECCE/100)]= (Tons/Acre)	Cost Per Ton ($)	Cost Per Acre ($)
100	1 ton	1 ton/1.00 = 1.00	35.00	35.00
80	1 ton	1 ton/0.80 = 1.25	32.00	40.00
60*	1 ton	1 ton/0.60 = 1.67	29.00	48.43

*If one ton of limestone per acre is recommended and the liming material to be used has an ECCE of 60%, then the application rate of this material would be 1 ton divided by 0.60 = **1.67 tons/acre.**