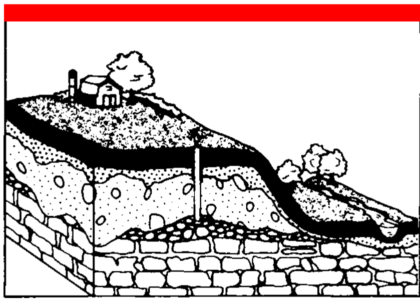

# SoilFacts

## *Soil Acidity and Liming: Basic Information for Farmers and Gardeners*

### Situation in North Carolina

Nearly all North Carolina soils are naturally acidic and need lime, which neutralizes the acidity, for optimum growth of crops, forages, turf, trees, and many ornamentals. Even though most of these soils have been limed in the past, periodic additions of lime based on soil tests are still needed. Soil-test summaries and field records compiled by the North Carolina Department of Agriculture and Consumer Services (NCDA&CS) emphasize that poor management of soil pH accounts for a high percentage of the “crop problems” in North Carolina.

### Nature and Cause of Soil Acidity

“Soil acidity” is the term used to express the quantity of hydrogen (H) and aluminum (Al) cations (positively charged ions) in soils. When levels of hydrogen or aluminum become too high—and the soil becomes too acid—the soil’s negatively charged cation exchange capacity (CEC) becomes “clogged” with the positively charged hydrogen and aluminum, and the nutrients needed for plant growth are pushed out. This is why root growth and plant development suffer when soils become too acid.

Over time, soils also become acidic because calcium and magnesium leach out, because hydrogen is added to soils by decomposition of plant residues and organic matter, or because nitrification of ammonium occurs when fertilizer (UAN solutions, urea, ammonium nitrate, ammonium sulfate, anhydrous ammonia), manure, or plant residues are added to the soil. Lime will neutralize this acidity by dissolving, whereupon it releases a base into the soil solution that reacts with the acidic components, hydrogen and aluminum.

Soil pH is an indicator of “soil acidity” (Figure 1). A pH of 7.0 is defined as neutral. Values below 7.0 are acidic, and values above 7.0 are basic or alkaline. Small changes in numbers indicate large changes in soil acidity. A soil with a pH of 5 is 10 times more acidic than a soil with a pH of 6 and 100 times more acidic than a soil with a pH of 7. Most plants can grow in slightly acidic soils, so the goal of liming is not to raise the pH to neutral (7.0), but to avoid crop problems related to excessive acidity.

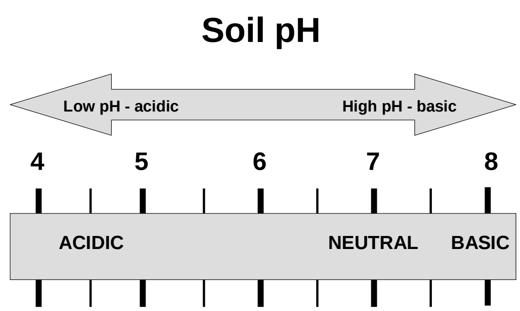


**Figure 1. General relationship between soil pH and acidity.**

### Benefits of Proper Lime Use

Proper liming provides a number of benefits:

- Plants develop healthier roots because they are exposed to less potentially toxic aluminum. Better root growth may enhance drought tolerance.

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- Lime is a source of calcium (as well as magnesium, if dolomitic limestone is applied).
- Nutrient solubility is improved by a higher pH, so plants have a better nutrient supply. (The optimum pH for most crops is 5.8 to 6.2 when grown on mineral soils in North Carolina.)
- Increased soil CEC occurs, as well as reduced leaching of basic cations, particularly potassium.
- Nodulation of legumes is enhanced, which improves nitrogen fixation.
- Triazine herbicides, such as atrazine and simazine, work better.
- Optimal pH allows the breakdown of some herbicides, preventing damage to rotational crops.
- Some nematicides work better.

## Soil Testing and Target pH to Determine Lime Rates

It is important to remember that the optimum pH is not the same for all crops or soils. For example, on most Midwestern U.S. soils most crops grow best at a pH of 6.5 to 7.0, but these values would cause micronutrient deficiencies in parts of North Carolina. Many micronutrients become less soluble as pH increases, reducing their availability to plants; for instance, manganese deficiencies frequently occur following overliming in many North Carolina soils.

For most commonly grown field crops, mineral (MIN) soils in North Carolina have a target pH of 6.0. The state has substantial acreage of organic (ORG) soils, primarily in the east. Since organic matter ties up aluminum, plant growth is possible at lower pH levels than in mineral soils. For mineral-organic (M-O) soils, the target pH is 5.5; and for organic soils, 5.0. The amount of humic matter (HM) and the soil density (weight/volume ratio, W/V) are the criteria used for these three soil class determinations by NCDA&CS.

Another issue to consider is that different soil laboratories may use different testing methods, which they have developed for their particular soil conditions. The NCDA&CS laboratory reports both the soil pH and the "*Ac value*." The "Ac value" is a measure of the exchangeable acidity, which is the combined total of exchangeable aluminum and hydrogen cations. Both the soil pH and the Ac value are needed to calculate lime applications. Although portable soil test kits determine pH rapidly, it is not possible to make an accurate lime recommendation based solely on a pH measurement. Producers submitting soil samples to other soil test laboratories should ask questions about laboratory methods and target pH assumptions used in determining lime recommendations.

Plants differ in their ability to tolerate a low pH, with optimum values ranging from 4.5 to 6.5 (Table 1). For example, blueberries, azaleas, and native ornamentals are especially tolerant of, and grow better at, low pH (highly acidic soils). In contrast, alfalfa, cotton, and tomatoes grow better at a higher pH (lower acid soils).

**Table 1. Target pH for a variety of North Carolina plants when produced on mineral soils*.**

| *Plant group* | *Target pH* | *Species* |
|---|---|---|
| Field crops | 6.0 | Corn, millet, small grains, sorghum, soybeans, tobacco |
| | 6.2 | Cotton |
| Vegetables | 6.0 | Beans, cucurbits, cole crops, potato, spinach, sweetpotato |
| | 6.5 | Asparagus, tomato |
| Small fruits | 4.5 | Blueberry |
| | 6.0 | Blackberry, grape, strawberry |
| Forage grasses | 6.0 | Fescue, orchardgrass, and timothy (maintenance); bahiagrass; bluegrass; sudangrass |
| | 6.5 | Fescue, orchardgrass, and timothy (establishment); bermuda |
| Forage legumes | 6.0 | Crimson and white clover, lespedeza |
| | 6.5 | Alfalfa, ladino, and red clover |
| Lawns/gardens | 5.0 | Azalea, camellia, mountain laurel, rhododendron |
| | 5.5 | Centipedegrass |
| | 6.0 | Other lawn grasses, flower garden, shrubbery, shade trees |
| | 6.5 | Rose, vegetable garden |
| Nursery | 5.0 | Ginseng, native ornamentals, rhododendron |
| | 6.0 | Most other flowers |
| | 6.5 | Gypsophila |
| Trees/Orchards | 5.5 | Fir and Northern spruce Christmas trees, pine |
| | 6.0 | Apple (maintenance), pecan, hardwoods |
| | 6.2 | Peach (maintenance) |
| | 6.5 | Apple and peach (establishment), Red cedar and blue spruce Christmas trees |

** Target pH is lower for M-O and ORG soils, 5.5 and 5.0, respectively, for crops that have a target pH of 6.0-6.5 on MIN soils.*

The NCDA&CS soil test uses the following equation to calculate the amount of lime that must be added to achieve the target pH for the particular soil class and crop combination.

$$\text{Lime (ton/acre)} = Ac \times [(\text{target pH} - \text{current pH}) / (6.6 - \text{current pH})] - RC$$

(To convert the results to pounds per 1,000 square feet, divide the recommended number of pounds of lime per acre by 43.5.)

The Ac value and target pH have already been discussed. The current pH is the pH of the sample analyzed. "RC" refers to "residual credit" given to applied lime, since some lime applied within the past 12 months may not have fully reacted. The RC value depends on the soil class and how recently lime was applied.

## Example for a Mineral Soil

If current soil pH = 5.0, target pH = 6.0, Ac = 1.2, and RC = 0, since no lime has been applied within the past year, then the recommended lime rate is:

$$1.2 \times [(6.0 - 5.0) / (6.6 - 5.0)] - 0 = 0.76 \text{ ton/acre.}$$

This value is rounded off and reported as 0.8 tons per acre.

To convert the recommendation to pounds per 1,000 square feet, calculate:

$$0.76 \text{ ton/acre} \times 2{,}000 \text{ lb/ton} = 1{,}520 \text{ lb/acre,}$$

$$1{,}520 \text{ lb/acre} / 43.5 = 35 \text{ lb/1,000 square feet.}$$

For a more acid-tolerant crop such as Fraser fir Christmas trees, with a target pH of 5.5, the recommended lime rate would be lower:

$$1.2 \times [(5.5 - 5.0) / (6.6 - 5.0)] - 0 = 0.38 \text{ ton/acre, rounded off to } 0.4 \text{ ton/acre.}$$

## Liming Materials

Liming materials come in two types. Those containing only calcium carbonate ($CaCO_3$), calcium hydroxide [$Ca(OH)_2$], or calcium oxide ($CaO$) are called "calcitic limes." Pure calcium carbonate is used as the standard for liming materials and is assigned a rating of 100 percent. This rating is also known as the "calcium carbonate equivalent" and is referred to as the CCE. All other liming materials are rated in relationship to pure calcium carbonate.

The second type of liming material contains significant amounts of magnesium carbonate ($MgCO_3$) and is called "dolomitic lime." If a soil is low in magnesium, dolomitic lime should be used; otherwise, calcitic lime can be used. Many organic soils and some piedmont soils are naturally high in magnesium; most sandy soils in the coastal plain have little magnesium. The soil-test report will indicate which lime should be used. A magnesium fertilizer could be used instead of dolomitic lime, but the cost of this treatment is almost always considerably higher. Dolomitic limes are slightly more efficient in neutralizing soil acidity and may have CCE values greater than 100, depending on purity.

Because lime dissolves very slowly, it must be finely ground to neutralize soil acidity effectively (Figure 2). Lime fineness is measured by using sieves with different mesh sizes.

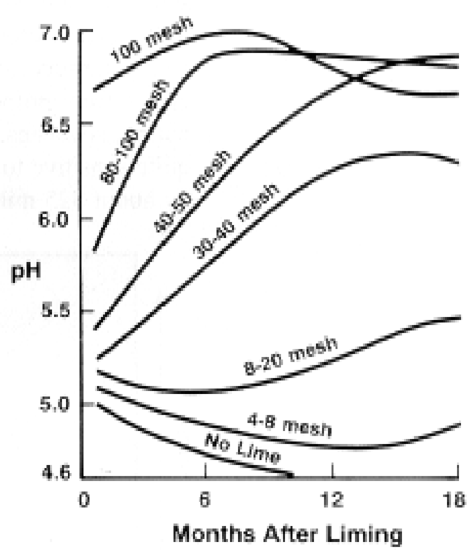


**Figure 2**. **Reactivity of lime as affected by particle size.**

Higher mesh size numbers have smaller holes, so they limit passage to finer particles. Note that 40- to 50-mesh lime raised the pH to a higher level than 8- to 20-mesh lime did during an 18-month study. Thus the ability to neutralize soil acidity depends on both the purity (CCE) and the particle size of the liming material. The effective neutralizing value (ENV) is a way to quantitatively evaluate limes based on both purity and particle size. It is calculated by multiplying the CCE (expressed as a decimal) by the relative reactivity (based on fineness). (See the section on "Adjusting Lime Rate Based on Effective Neutralizing Value" for more information.)

## Liming Product Standards for North Carolina

Size standards and other criteria have been established by the state of North Carolina for the sale of agricultural liming materials to ensure a quality product. They are:

- Agricultural liming materials must be crushed so that at least 90 percent passes through a U.S. standard 20-mesh screen (with a tolerance of plus or minus 5 percent).
- For dolomitic limestone, at least 35 percent must pass through a U.S. standard 100-mesh screen; for calcitic limestone, at least 25 percent must pass through a U.S. standard 100-mesh screen (with a tolerance of plus or minus 5 percent).
- A product must contain a minimum of 6 percent magnesium in the carbonate form to be classified as a dolomitic limestone.
- There is no minimum calcium carbonate equivalent requirement for limestone sold in North Carolina. However, the product must be labeled to show the amount necessary to equal that provided by a liming material having a 90 percent calcium carbonate equivalent. For example,

a product having a calcium carbonate equivalent of 80 percent would be labeled “2,250 pounds of this material equals 1 ton of standard agricultural liming material.”

- Pelleted lime must slake down to the fineness criteria specified above when it comes in contact with moisture.

## Lime Form

The most commonly used liming material in North Carolina is finely ground dolomitic rock, but calcitic lime is also widely used. Additional liming materials include burnt lime or hydrated lime, pelleted lime, liquid lime, wood ash, and industrial slags. North Carolina has few good natural lime sources. Calcitic marl liming materials (soft marine shell deposits) are available in the coastal plain, but there are no dolomitic lime deposits in the east. Dolomitic lime is commonly obtained from the mountains of Virginia or Tennessee.

Most agricultural lime is sold in bulk as a damp powder because dry lime is very dusty and difficult to handle and spread. However, lime is occasionally excessively wet. Because lime is sold by the ton, you should be aware you may be purchasing a substantial amount of water. You should adjust lime rates accordingly.

Lime pellets are not large grains of solid limestone; they are formed from lime that has been finely ground. Pellets are less dusty and easier to spread, but they are more expensive than powdered lime. Pelleted lime comes into contact with fewer soil particles than finely ground lime. As a result, soil pH changes are slower with the pellets. Soil reaction will be enhanced if the soil can be tilled several days after the pellets have been mixed into the soil and become soft. Pelleted lime is convenient for landscape use, but is not an economical source for most field crops.

Lime is sometimes sold as a suspension, often called “liquid lime.” It consists of fine lime particles mixed with water and a suspending clay. All the lime particles must be 100-mesh or finer. Up to 1,000 pounds of lime can be suspended in a ton of liquid product. The main advantages are ease of handling and precise application. Although it is a fluid, this material does not react any faster than dry lime of the same particle size. All of the lime in a suspension is fast acting, and a ton of product (1,000 pounds of fine lime particles plus clay and water) will raise the pH as fast as a ton of dry lime. However, due to particle size and enhanced initial reactivity, the effectiveness is short lived, compared to regular agricultural limestone, and liming will probably have to be repeated every year. Suspensions may also raise soil pH slightly above the target pH, and they are a considerably more expensive way to correct soil acidity.

Occasionally, industrial byproduct liming materials become available. If the neutralizing value is known and the material is ground finely enough to react in the soil, these can be economical substitutes. Often such materials contain other plant nutrients. Wood ash and steel mill slag are two examples of such products. These products must meet the legal standards above to be sold as liming materials in North Carolina. Even if they do not meet all of the standards, they can be sold as fertilizer and may still be capable of reducing soil acidity and supplying a variety of nutrients. If a product does not meet all the specifications of the lime law, the supplier is barred from making claims about liming effectiveness, and the purchaser must have the material tested. Each lot of such materials should be analyzed, as considerable variation in CCE and fineness may occur. As with conventional lime, the ENV needs to be known in order to determine the appropriate application rate.

## Adjusting Lime Rate Based on Effective Neutralizing Value

All lime rates recommended by the NCDA&CS laboratory are based on a standard agricultural lime with a CCE of 90 percent (0.9) and a fineness factor of 100 percent (1.0), so ENV=0.90. The actual materials available for application vary widely. Calculating the effective neutralizing value (ENV) of a liming material accounts for the two contributing effects (purity and fineness) that determine expected soil pH increase after application. (For all calculations, use decimals rather than percentage values.)

Have a laboratory screen the liming material with mesh sizes 8 and 60:

$$ENV = CCE \times [(A \times 0.5) + (B \times 1)]$$

A = proportion of particles between 8- and 60-mesh size (assume 50 percent effective),

B = proportion of particles finer than 60-mesh size (assume 100 percent effective),

**Example**: A liming material with a CCE of 80 percent (0.80) was found to have 95 percent of particles finer than 8-mesh, and 50 percent finer than 60-mesh.

Using the equation above:

A=45% (0.45) since 95% (finer than 8-mesh) minus 50% (finer than 60-mesh) equals 45% (between the 8- and 60-mesh sizes).

B=50% (0.5)

$$ENV = 0.80 \times [(0.45 \times 0.5) + (0.5 \times 1)] = 0.80 \times 0.725 = 0.58$$

The actual rate of a liming material to be applied can then be calculated from the soil-test recommendation, assuming that standard agricultural lime has an effective neutralizing value of 90 percent (0.9). Compared to standard ag lime: 0.9 / 0.58 = 1.55; thus 1.55 tons of this material should be used for every 1 ton of lime recommended on the soil test. If this material had been evaluated using just

CCE, the lime equivalence would have been calculated as: 0.9 / 0.8 = 1.12 tons product per ton standard agricultural lime.

## Application and Incorporation

Within one to three years, lime moves little in the soil and neutralizes acidity only in the zone where it is applied. To be most effective, lime must be uniformly spread and thoroughly incorporated. The poorest, but most common, method of application to field crops is by spinner spreader. Double spinner spreaders apply more uniformly than single spinner spreaders; however, both types normally apply more lime immediately behind the spreader than to its sides. In practice, rates are adjusted after checking the spreader pattern and making appropriate correction. If the application is not correct, strips of underlimed and overlimed soil could result, possibly reducing crop yields.

Lime can be applied more evenly using full-width (box) or boom spreaders. Full-width spreaders allow lime to fall to the ground by gravity. The rate is determined by the size of the openings in the box and by ground speed. Boom spreaders use drag chains, augers, or air pressure to move lime out the booms and drop it on the ground. If adjusted properly, both types of spreaders are vastly superior to the spinner type. The main limitations to their use are the high initial cost and more complex operation. Most commercial farmers likely will continue using spinner spreaders, but every attempt should be made to spread lime evenly.

Lime can be applied to yards and gardens by hand or with small manual or garden tractor spreaders. The best way to achieve uniform application at the appropriate rate is to measure the amount needed to cover the entire area, apply half while traveling with swaths oriented in one direction, and apply the other half with swaths oriented perpendicularly.

The most commonly used lime incorporation tool for field crops is the disk. Its main limitation is that it incorporates lime only about half as deeply as the disk blades penetrate. Even with repeated passes, it will not incorporate lime well. Offset disks that throw the soil perform better. The best incorporation implement is a heavy-duty rotary tiller that mixes the soil throughout the root zone.

Bottom plowing immediately after spreading lime will likely bury the lime too deeply. If plowing, the best approach is to apply half the lime, then disk and bottom-plow, then apply the other half, and disk again. However, this process is costly and is not generally used. Certain other tillage practices, such as bedding or middle busting, will help with lime incorporation in the long run. Chisel plowing is very ineffective for lime incorporation. Although lime is applied on the surface to established pastures and lawns, it should be incorporated at establishment to reduce soil acidity.

Lime can be incorporated into lawns and gardens with rototillers, spades, or rakes to a depth of 4 to 8 inches. For established lawns, lime can either be left on the surface or applied prior to aeration.

## Liming and Long-Term No-Till

Long-term no-till cultivation is becoming increasingly popular in North Carolina and obviously limits the ability to incorporate lime into the soil profile. A survey of no-till fields in North Carolina detected slightly higher soil pH at the surface with no-till management, a reflection of surface lime application. Nevertheless, producer experience suggests no inherent problem maintaining optimum soil pH with surface liming in long-term continuous no-till. It is critical, however, to correct soil acidity and other fertility problems, particularly low phosphorus levels, by thorough incorporation of lime and fertilizer prior to the adoption of no-till management. Research in Pennsylvania has documented that low soil pH problems can persist for several years following application of lime to the surface of no-till fields.

## Conclusion

Maintenance of proper soil pH can increase your crop income and improve your lawn and garden performance. However, varying rates of lime are recommended, depending on the best pH for the particular soil class and crop combination. To test your soil's pH and lime requirement, send a soil sample to Agronomic Division, North Carolina Department of Agriculture and Consumer Services, 1040 Mail Service Center, Raleigh, NC 27699-1040 (**http://www.ncagr.com/agronomi/index.htm**).

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*Prepared by*

**Carl Crozier**, Soil Science Extension Specialist, North Carolina State University

**David H. Hardy**, Agronomic Division, North Carolina Department of Agriculture and Consumer Services

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