

## Sources of Lime for Acid Soils in Virginia

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Acid soil limits crop yields on many Virginia farms. With only a few exceptions, the climate in Virginia causes unlimed soils to be moderately to strongly acidic. This soil acidity can be directly toxic to plants but more often; it reduces the plants' efficiency at nutrient utilization, especially phosphorus (P), potassium (K), and nitrogen (N). Proper management of soil acidity is the foundation of efficient soil fertility management in Virginia.

### What is a liming material?

Acid soils are made less acidic by adding a liming material. An agricultural liming material, or "Aglime," is a material containing calcium (Ca) and/or magnesium (Mg) compounds capable of neutralizing soil acidity. These materials include: limestone (both calcitic and dolomitic), burnt lime, slaked lime, marl, and various by-products. Liming materials are carbonates, oxides, or hydroxides of Ca and/or Mg.

### Lime Quality

The two primary factors that determine limestone quality are particle (mesh) size and chemical composition. Particle size influences the speed at which the material dissolves (rate of reaction). Chemical composition determines a liming material's acid-neutralizing value or the amount of acid a set amount of material can neutralize. Pure calcium carbonate ( $\text{CaCO}_3$ ) is the standard for all liming materials and has an acid neutralizing value of 100 percent. When a liming material is evaluated, it is compared to calcium carbonate, and its neutralizing value is called the Calcium Carbonate Equivalent (CCE) value or percent CCE.

Another factor determining the quality of a liming material is its moisture content. The percent moisture content determines how much of the chemical reactive material has been replaced with water. Therefore, higher moisture content reduces the effectiveness of liming materials on a weight basis; i.e. a ton of dry lime will neutralize more acid than a ton of wet lime. However, research has shown that a 4 percent to 5 percent moisture content in a ground agricultural limestone improves spreading uniformity by reducing the blowing of fine (<100-mesh) particles as compared to totally dry (<1 percent) liming material.

The final factor determining liming material quality is its magnesium content. Therefore, the combination of the particle size, CCE, handling characteristics, and magnesium content determine the "value" of a particular liming material for a specific farm situation.

### Calcium carbonate equivalent or acid-neutralizing capacity

A liming material with a higher CCE value will have a greater effectiveness than one with a lower CCE value. Impurities, such as clay and organic matter that naturally occur in liming materials, produce variations in CCE among various liming materials.

Knowing the CCEs of liming materials can help in comparing costs and determining application rates. The CCE values of various liming materials are shown in Table 1. Liming materials with values above 100 have a greater capacity to neutralize soil acidity than calcitic lime (Tables 1 and 2) due to their chemical composition. Burnt and hydrated limes are in this category. Marl, on the other hand, has a lower CCE than calcitic lime; and therefore, more is needed per acre for the same neutralizing effect.

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Produced by Communications and Marketing, College of Agriculture and Life Sciences,  
Virginia Polytechnic Institute and State University, 2009

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Table 1. Liming materials, chemical composition, and calcium carbonate equivalent (CCE)<sup>†</sup>.

Material	Composition	Calcium Carbonate Equivalent (%) <sup>†</sup>
Calcium Carbonate	CaCO <sub>3</sub> (pure)	100 <sup>†</sup>
Calcitic limestone	CaCO <sub>3</sub>	80-100
Dolomitic limestone	CaCO <sub>3</sub> -MgCO <sub>3</sub>	95-108
Burned or Quick lime	CaO (calcium oxide)	150-175
Hydrated or Slaked lime	Ca(OH) <sub>2</sub> (calcium hydroxide)	120-135
Marl	CaCO <sub>3</sub>	70-90
Ground Oyster Shells	CaCO <sub>3</sub>	90-100
Cement kiln dusts	Ca Oxides	40-100
Power plant ashes	Ca, Mg & K Oxides	25-50
Wood ashes	Ca, Mg & K Oxides	40-50
Gypsum	CaSO <sub>4</sub>	None
Byproducts & Biosolids	variable	variable

<sup>†</sup>Calcium carbonate equivalent (CCE) is the acid-neutralizing value for a liming material relative to pure calcium carbonate that has a CCE value of 100. This is the standard method of measuring Aglime purity.

Table 2. The amount of Aglime materials at different calcium carbonate equivalences (CCE) required to equal one ton of pure calcium carbonate.

CCE of Liming Material %	Pounds of lime needed to equal one ton of Pure calcium carbonate (CaCO <sub>3</sub> )	Tons of lime needed to equal one ton of Pure calcium carbonate (CaCO <sub>3</sub> )
50	4000 <sup>†</sup>	2.00
60	3333	1.67
70	2857	1.42
80	2500	1.25
90	2222	1.11
<b>100</b>	<b>2000</b>	<b>1.00</b>
110	1818	0.91
120	1667	0.83
135	1481	0.74
150	1333	0.67
175	1143	0.57

<sup>†</sup> Calculated based on a lime recommendation of 1 ton of pure calcitic lime. Pounds of lime needed = (CCE of pure CaCO<sub>3</sub> ÷ CCE of liming material) · 2000 lbs.

## Particle size

Particle size is measured by standard size sieve mesh (Fig. 1) and is the main factor influencing the rate of reaction of lime applied to soil; the finer its grind, the more surface area the Aglime has available to react with soil acidity. Mesh size is a measure of the number of openings per linear inch of a sieve. The relative sizes of lime particles of different meshes are shown in Figs. 2-5. A 20-mesh sieve has 20 openings per linear inch or 20 x 20 = 400 openings per square inch, whereas

a 100-mesh sieve has 100 openings per linear inch or 100 x 100 = 10,000 openings per square inch. Crushed limestone material passing a 100-mesh sieve is smaller, has more surface area, and therefore, reacts with soil acidity more rapidly than 20-mesh material.

A certain percentage of the particles in a liming material must be sufficiently fine (pass a 100-mesh sieve) to react rapidly with soil acidity and supply the nutrient elements calcium and magnesium. Another percentage (those that pass a 60- to 100-mesh sieve) should react

within one to two years with the remainder (those that pass a 20-mesh sieve) reacting in a period of two to three years. A high-quality agricultural limestone has a range of particle sizes that allows it to have both immediate (two-week) and long-term (three-year) capacity to react with soil acidity. This need is the basis for the Virginia Agricultural Liming Materials Act (Code of Virginia Section 3.1-126.1), which sets the requirements for Aglime at 30 percent passing a 100-mesh sieve, 50 percent passing a 60-mesh sieve, and 90 percent passing a 20-mesh sieve (Figs. 2-5).

Research has shown that limestone pulverized to 100-mesh, or finer, reacts rapidly to neutralize soil acidity. On the other hand, 10- to 20-mesh limestone dissolves very slowly and therefore, is only slightly effective in raising soil pH (reducing soil acidity). The effect of

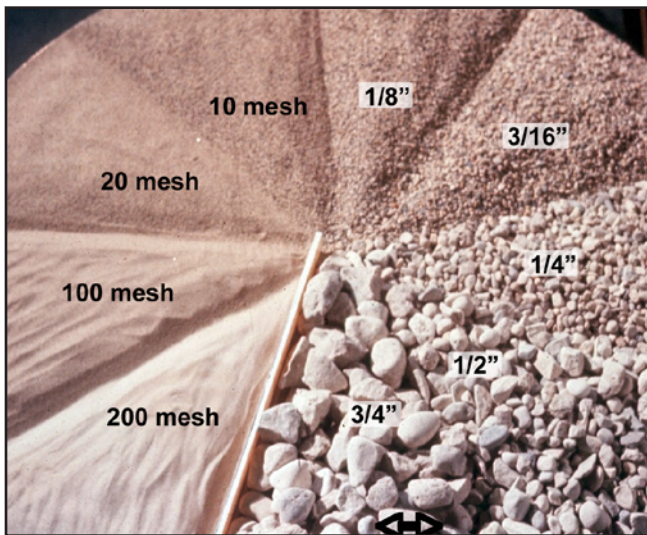


Fig. 1. Particle-size wheel for crushed limestone (National Stone Association, Washington, D.C.).



Fig. 2. Agricultural limestone particles ground to pass a 10-mesh sieve and retained on a 20-mesh sieve (i.e., -#10 +#20).



Fig. 3. Agricultural limestone particles ground to pass a 20-mesh sieve and retained on a 60-mesh sieve (i.e., -#20 +#60).



Fig. 4. Agricultural limestone particles ground to pass a 60-mesh sieve and retained on a 100-mesh sieve (i.e., -#60 +#100).



Fig. 5. Agricultural limestone particles ground to pass a 100-mesh sieve (i.e., -#100).

the same application rate of different mesh-sized lime particles on the pH of a Canfield silt loam soil over a period of 18 months is illustrated in Fig 6. Smaller particles with a size of 20- to 30-mesh or above were effective in neutralizing soil acidity whereas larger particles of 8- to 20-mesh or below were relatively ineffective. The results presented in Fig. 6 are from a greenhouse study where lime was thoroughly mixed with soil and watered to maintain optimum moisture conditions. The rate of reaction of agricultural lime under these conditions is generally more rapid than one would expect under field conditions. However, under field conditions, particle size is an important factor affecting the rate of lime decomposition. Large particles (4- to 8-mesh) dissolve very little (10 percent) over a one- to four-year period (Table 3), demonstrating the ineffectiveness of course lime materials for reducing soil acidity. The smaller particles (80- to 100-mesh) can be expected to react completely over a period of one to four years. Thus, particles coarser than 20-mesh have little value as Aglime material because of their slow reaction rate.

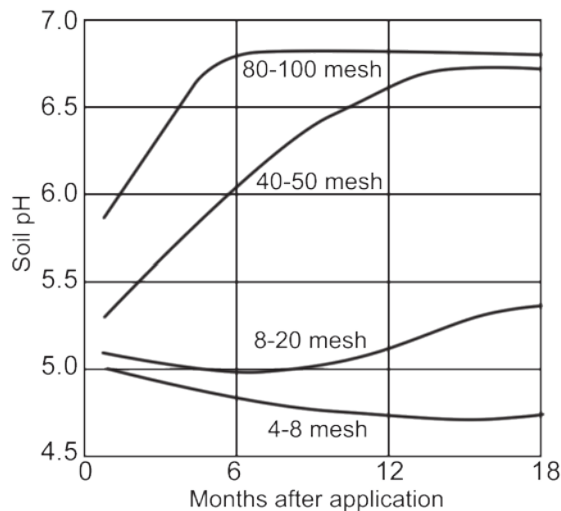


Fig. 6. Effect of dolomitic limestone of different mesh sizes on the pH of soil at various times after application (Meyer and Volk, *Soil Science Society of America Journal* 73:37-52).

Table 3. The effect of fineness of grind on the reactivity of Aglime in soil.†

Sieve Mesh Size	Years after application	
	1	4
	Percent Reacted	
coarser than 8	5	15
8 to 20	20	45
20 to 50	50	100
50 to 100	100	100

†AGR-106. 2002. Cooperative Extension Service, University of Kentucky. Meyer and Volk (1952).

The reaction rate of limestone depends on the soil pH and the degree of mixing of lime with the soil, as well as on the particle size. The more acid (lower pH) the soil is, the more rapid is the lime reaction rate. In addition, the better the limestone is mixed with soil, the more rapid the lime reaction rate. Reaction rate also depends on the solubility of the liming material. Burnt and hydrated lime are more soluble in water than ground Aglime, and thus react more rapidly to neutralize soil acidity. The quick-acting characteristics of these lime materials can be an advantage in certain situations, even though the materials are more difficult to handle and spread than ground Aglime.

### Comparing acid-neutralizing value of liming materials

Liming materials of equal CCE and mesh size should cost about the same, assuming equal hauling distance from the manufacturer to the field. Burnt and hydrated limes are more expensive per ton but a smaller amount is needed because of their higher CCEs. Cost comparisons must always be based on equivalent amounts of CCE needed per acre. Lime recommendations based on soil test reports, unless otherwise specified, are typically for Aglime that has a CCE value of 95 to 100. If burnt lime with a CCE of 175 is used, only 1,140 pounds (0.57 ton) are needed to achieve the same effect as one ton of ground limestone with a CCE of 100 (Table 2). The equivalent amount per acre of any liming material can be calculated with the following formula.

$$\frac{\text{CCE of Lime A}}{\text{CCE of Lime B}} \times \text{rate/acre of Lime A} = \text{Equivalent rate/acre of Lime B}$$

Where:

CCE = Calcium carbonate equivalent or the acid-neutralizing value (usually 100 for lime recommendation on soil test report)

A = Lime shown on soil test report

B = Liming material chosen by buyer

### Liming Materials

The most common material used for liming agricultural soils in Virginia is finely ground dolomitic or calcitic limestone. Aglime is a material composed of varying concentrations of calcium and magnesium carbonates and must have a minimum of 85 percent CCE to be

labeled and sold as “Aglime” in Virginia (Virginia Agricultural Liming Materials Act 1994 and supporting regulations, Virginia Department of Agriculture and Consumer Services). Particle size is specified by state law and regulated through the Virginia Department of Agriculture and Consumer Services. Current particle size requirements are shown in Table 4. Particle size for Aglime is regulated since crushed limestone must be ground fine enough to react and neutralize soil acidity in a reasonable length of time. In addition to Aglime, there are several materials that can be used to adjust soil pH. All will neutralize soil acidity, but they have different characteristics and properties that influence their use and value. The more common liming materials are discussed below.

Table 4. Mesh screen analysis (Minimum Screening Standards) of agricultural limestone marketed in Virginia (The Virginia Agricultural Liming Materials Act, Code of Virginia Section 3.1-126.1)

<b>Agricultural Liming Material</b>	<b>Mesh Screen Size</b>	<b>Percent Guaranteed to Pass (5% Tolerance)</b>
Ground Limestone	20	90
	60	50
	100	30
Pulverized Limestone	20	95
	100	70

### Calcitic and dolomitic limestone

These liming materials are made by grinding or crushing mined limestone rock. The product is distributed in bulk or in bags. **Calcitic limestone** is a term widely used by agronomists when referring to Aglime with a high calcium content. It is composed primarily of calcium carbonate, but it may also contain small amounts of magnesium carbonate. In Virginia, calcitic limestone is any material that has 85 percent or more of the total acid-neutralizing value, expressed as CCE, derived from calcium carbonates. **Dolomitic limestone** is composed of calcium and magnesium carbonates. In Virginia, dolomitic limestone is any Aglime that has 15 percent or more of the total carbonate content as magnesium carbonate. The CCE of dolomitic Aglime is often higher than that of calcitic Aglime because of the difference in chemical (Mg versus Ca) composition.

Calcitic lime reacts slightly faster than dolomitic lime of the same particle size but the difference in reactivity rates is negligible under field conditions. **The factor to consider in deciding which Aglime to use is the need for magnesium and the relative cost of the liming materials.** Dolomitic lime contains an appreciable amount of both magnesium and calcium that are essential nutrient elements in plant growth; whereas, calcitic lime contains mostly calcium. They have essentially the same capacity for neutralizing soil acidity as indicated by their CCE values (Table 1).

Research has shown that plant growth is optimum when more calcium than magnesium is available to the plant. However, the ratio of plant-available calcium to magnesium can be nearly equal before plant growth is adversely affected. Acid soils that are deficient in magnesium (low to very low in the soil test) should be treated with dolomitic limestone. Either dolomitic or calcitic lime may be used in all other situations.

### Burnt lime, quick lime, or oxide lime

Burnt lime is made by roasting crushed limestone in a kiln to drive off carbon dioxide (CO<sub>2</sub>). This changes the chemical form of the limestone from a carbonate to an oxide, leaving a material that is highly concentrated in calcium oxide or calcium and magnesium oxide. The CCE of burnt lime depends on the purity of the crushed limestone from which it is made and usually ranges between 150 and 175. No other liming material has such a high neutralization value. Approximately 0.57 ton (1,140 pounds) of burnt lime with a CCE value of 175 is equivalent to 1 ton of calcitic Aglime with a CCE of 100 (Table 2). Burnt lime is sold in bags because of its powdery nature, unpleasant handling properties, and reactivity with moisture in the air. This is a highly reactive and caustic material that produces heat when mixed with water. Thus, burnt lime must be handled carefully to avoid breathing the dust or contact with the skin and eyes. Due to its caustic nature, burnt lime will “burn” green plant tissue. Burnt lime neutralizes soil acidity very rapidly, but it may be difficult to mix with the soil. Thorough mixing immediately after application is necessary because when burnt lime absorbs moisture from the soil, it forms clumps.

### Hydrated or slaked lime

Hydrated lime, frequently called slaked or builders’ lime, is calcium hydroxide (Ca(OH)<sub>2</sub>). This material is manufactured by reacting burnt lime with water

to form calcium hydroxide. Hydrated lime is similar to burnt lime in that it is powdery, quick-acting, and somewhat unpleasant to handle. The CCE value ranges between 120 and 135, depending on the purity of the burnt lime from which it is made. Approximately 0.75 ton of hydrated lime with a CCE of 135 is equivalent to one ton of Aglime with a CCE of 100 (Table 2).

## Marl

Marl is a natural, chalky material that is sometimes used as a liming material. Marl is found in beds as an unconsolidated mixture of materials composed of calcium carbonate, shell fragments, and impurities that are mainly sand, silt, and clay. Marl deposits often are found in the eastern or Coastal Plain region of Virginia, limestone valleys in the Appalachian region, and other Atlantic Coast states. The usefulness of marl as a liming material depends on its CCE, which ranges from 70 to 90, and the cost of processing. Marl is often plastic and lumpy and must be dried and pulverized before application. The reaction time of marl is the same as calcitic Aglime.

## Wood ash and power-plant ashes

Wood burning generates an ash material that contains oxides and hydroxides of calcium, magnesium, potassium, and sodium. These alkaline compounds are effective at neutralizing soil acidity. The burning of coal, gas, oil, or other biomass fuels in industrial boilers results in an ash material that is less alkaline than wood ash. Thus, wood and industrial ash can vary considerably in CCE. When wood ash is applied based on its CCE, it can be effective in neutralizing soil acidity. An additional benefit of using wood ash is that it can also supply other essential plant nutrients, especially potassium. **These materials must be carefully analyzed, as the potential exists for applying more soluble salts than plants can tolerate.** In addition, coal ash should be thoroughly tested for heavy-metal content prior to land application and for consistency of CCE value because of the potentially highly variable nature of coal. As a word of caution, both materials are alkaline and could cause crop damage if over-applied or misused. It is imperative that landowners follow the prescribed application rates based on their actual analysis and use common-sense approaches to prevent accidents and avoid environmental contamination.

## Cement-kiln dust or flue dust

Cement-kiln dust or flue dust is a very fine, calcium-based, alkaline material collected as a by-product from the manufacture of Portland cement. It may also contain some potassium, sulfate-sulfur, magnesium, and micronutrients. Cement-kiln dust is very fine and contains a high percentage of oxides and hydroxides as compared to Aglime, making it more reactive than Aglime. The CCE of cement-kiln dust can vary with typical values of 60 percent to 80 percent.

## Pelletized Aglime

Pelletized Aglime is manufactured from finely ground limestone formed into round pellets (approximately 0.16 to 0.20 inch in diameter) with a binding agent (Fig. 7). The pellets spread easier and eliminate dust during handling compared to conventional Aglime. Pelletized limestone is also expected to breakdown rapidly after contact with soil moisture and react rapidly to neutralize soil acidity in the area surrounding the pellet. This is due to the finely ground particles used in the manufacture of the pellets. Pelletized limestone is popular among homeowners for use on lawns and gardens. These materials are generally much more expensive than conventional Aglime sources due to the increased cost of processing. Research conducted in Virginia has demonstrated that pelletized dolomitic limestone is equally effective in maintaining soil pH as conventional limestone products. However, these materials are not as effective in raising the pH of very acid soils because the granules dissolve and react in a localized area. Since the materials are effective for surface applications to maintain soil pH values in an optimum range, they should be used as part of a regular liming



Fig. 7. Pelletized lime (#200 mesh ground limestone cemented into pellets that breakdown with soil moisture).

program that does not allow soil pH to drop to low levels, i.e. below 6.0.

### Suspension or fluid (liquid) lime

Fluid or suspension lime is produced by mixing very finely ground, high CCE value lime (typically 100 percent passing a 100-mesh sieve and 80 percent to 90 percent passing a 200-mesh sieve) with water (typically 50 percent) and a suspending agent, usually attapulgitic clay. The suspension is applied using a suspension fertilizer applicator, which can result in an excellent distribution pattern. With suspension lime, only small amounts of Aglime can be applied at one time (500 to 1000 pounds/acre of Aglime material), but due to the fineness of grind, the lime reacts rapidly in the treated soil. Due to the low rates of application, annual applications of suspension lime may be needed to maintain soil pH in the desired range. Suspension or fluid lime costs are typically two to four times higher than the cost of using dry Aglime. Current use of this product is limited because of cost, but it has been found to be a valuable product for liming selected areas, such as in apple orchards where only an area around the trees is limed.

### Lime-stabilized biosolids

Biosolids in certain municipal wastewater treatment plants are treated with calcium oxide or hydroxide to raise the pH of the biosolids above pH 12 to kill pathogens. These biosolids contain unreacted calcium hydroxide and can be valuable liming materials. Regulations require that biosolids be analyzed for their respective CCE value and applied at rates not to exceed the lime requirement for the soil to which the biosolids are applied. The effectiveness of these materials in neutralizing soil acidity is directly proportional to the CCE value of the biosolids.

### By-products

There are a number of by-products used as soil amendments and many of these contain alkaline compounds that can neutralize soil acidity and add calcium and magnesium to a soil. When amendments containing alkaline compounds are applied to soils, they should be analyzed for CCE values to determine their contribution to soil lime requirements, and soil pH should be monitored to prevent excessive soil pH levels. Excessive soil pH values can result in micronutrient deficiencies, especially Mn and Zn in the Coastal Plain region, and Zn in the Piedmont and Valley regions.

## State Regulations

Under the Virginia Agricultural Liming Materials Law, all liming materials distributed in Virginia must be approved and registered for sale annually. Each package or lot sold must show the registered brand name and guaranteed analysis. Items in the analysis include: whether burned or unburned; the minimum percentage of calcium carbonate, magnesium carbonate, calcium oxide, and magnesium oxide; and the percentage of ground limestone passing certain mesh sizes. These mesh sizes are used to define pulverized limestone and agricultural ground limestone, the two types of Aglime sold in Virginia. These two types of Aglime are distinguished based on the particle sizes summarized in Table 4. In addition, agricultural liming materials are also required to meet minimum calcium carbonate equivalent (CCE) requirements as listed in Table 5.

Table 5. Minimum calcium carbonate equivalent (CCE) for agricultural liming materials marketed in Virginia. (The Virginia Agricultural Liming Materials Act, Code of Virginia Section 3.1-126.1)

Liming Material	Calcium Carbonate Equivalent (CCE)
Ground Limestone	Not less than 85%
Burnt (Burned) Lime	Not less than 140%
Hydrated Lime	Not less than 110%
Shells	Not less than 85%

### Effective neutralizing value

The effective neutralizing value (ENV) is used to express Aglime effectiveness based on the combined effect of chemical composition, purity (CCE), and particle size or fineness of grind. ENV values are required labeling for liming materials distributed in Virginia. The ENV for a specific liming material is determined by multiplying the CCE by factors based on the fineness of grind of the limestone, using the following formula:

$$ENV = \frac{(A + B + C) \times CCE}{100}$$

Where:

CCE = calcium carbonate equivalent (%)

A = (% by weight passing a 20-mesh sieve - % by weight passing a 60-mesh sieve) x 0.4

B = (% by weight passing a 60 mesh sieve - % by weight passing a 100-mesh sieve) x 0.8

C = (% by weight passing a 100-mesh sieve) x 1.0.

If applied to supply equivalent amounts of ENV per acre, all liming materials should have an equal effect on crop yield.

## Liming Material Selection

Often great care is taken to determine the proper amount of lime needed for a field based on soil testing, but a poor job is done in selecting and applying lime. For many years, ground agricultural limestone or Aglime has been the primary liming material used in Virginia. However, as illustrated in Table 1 there are a number of products that can be used to increase soil pH. Factors to consider in selecting a liming material include available lime sources in the area, the length of time between application of lime and planting of the crop, degree of soil acidity, the need for magnesium, value of the crop, and the intensity of cropping.

Whether to use a slow- or a quick-acting liming material can be a difficult and confusing decision. The time between the application of lime and planting the crop can be helpful in answering this question. If lime can be applied three to six months ahead of planting, then more coarsely ground limestone can be used. Aglime works best when applied in this manner. However, the fine particles (percent passing 100-mesh) in Aglime will react very quickly and yield benefits will be seen even if lime is applied at the time of planting. Research conducted in Virginia by P.M. Bertsch and M.M. Alley on Coastal Plain soils, showed that extractable soil calcium and magnesium increased more rapidly with suspension limestone applications as compared to conventional Aglime. However, after 16 weeks, pH and exchangeable calcium and magnesium levels were nearly the same for the two liming materials. Moreover, corn yields responded equally to suspension and conventional ground Aglime. These data clearly illustrate that Aglime meeting Virginia specifications immediately reacts with soil acidity and does produce a crop response even when lime is applied at the time of planting (Fig. 8).

The degree of soil acidity can be important in deciding which liming material to use, especially for acid-sensitive crops such as alfalfa, sweet clover, trellis tomatoes, and certain other vegetables. In strongly acid soils, it may be desirable to use pulverized lime or one of the burnt or hydrated limes. These liming materials will benefit crops and reduce the level of soil acidity more quickly. Though the cost per acre may be somewhat greater, improved crop performance may result

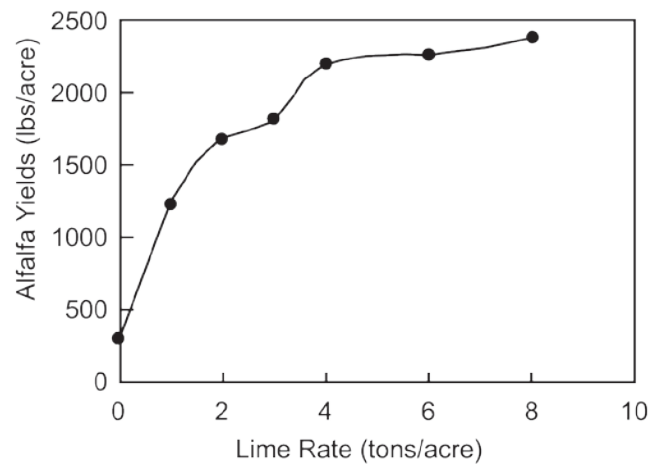


Fig. 8. First-cutting alfalfa yields as influenced by lime rate on a Frederick silt loam soil in Montgomery County. Lime was applied at the time of planting at rates ranging from 0 to 8 tons/acre (M.M. Alley, *Agronomy Journal* 73:687-689).

in higher net income. The value of the crop should be considered in determining what lime source to use, especially for those crops that are acid-sensitive or have a critical pH requirement. Aglime has its maximum effect in a period of one to three years. Suspension, burnt, and slaked lime have their maximum effect in three to six months if the lime is properly mixed with the soil.

## Lime Application

### Frequency

Cropping intensity is a factor in a liming program as it usually influences liming frequency. Where more crops and/or greater yields are being produced, more calcium and magnesium are removed from the soil. Also, the application of ammonium and urea types of nitrogen fertilizers increases the need for lime. The natural nitrification process of these fertilizers produces acid and tends to speed the acidification of soils. A soil test every two or three years will reveal the need for lime. Fig. 9 shows the effect of different rates of lime on several soils over a period of 38 months. In these studies, the maximum increase in soil pH occurred within approximately two years after the lime application. Sandy soils generally require less lime at any one time than silt or clay soils to increase pH by a given amount. Sandy soils, however, usually need to be limed more frequently.

A liming material should spread easily to achieve a uniform application over the entire field. Aglime meeting Virginia specifications generally spreads easily and evenly. However, liming materials exposed to rainfall in outdoor stockpiles and containing a relatively high moisture content can “cake” and not flow uniformly



through the applicator, resulting in non-uniform application patterns. Research conducted in Virginia by M.M. Alley demonstrated that Aglime meeting Virginia's requirements should handle easily and spread evenly when using commercial twin-spinner spreading equipment.

## Applying Lime

Lime moves slowly in soil; consequently, lime works most efficiently when mixed to tillage depth. Also, as soil pH increases, lime particles dissolve more slowly. Uniform application and thorough incorporation of Aglime are helpful to a good liming program. The one exception to this "tillage rule" is a continuous "no-tillage" system for grain crops and alfalfa.

Research with no-tillage corn and forages has shown that surface-applied lime has been effective in reducing soil acidity in the surface two to four inches of soil, especially in fields that have been limed to the tillage depth in previous years. The mulch layer in no-till fields maintains more optimum moisture conditions in the surface soil. This helps lime dissolve faster and speeds the neutralization of soil acidity in the surface layers. Fig. 10 shows alfalfa yields on a Davidson soil in Virginia as affected by incorporated and non-incorporated limestone applications. In this study, high

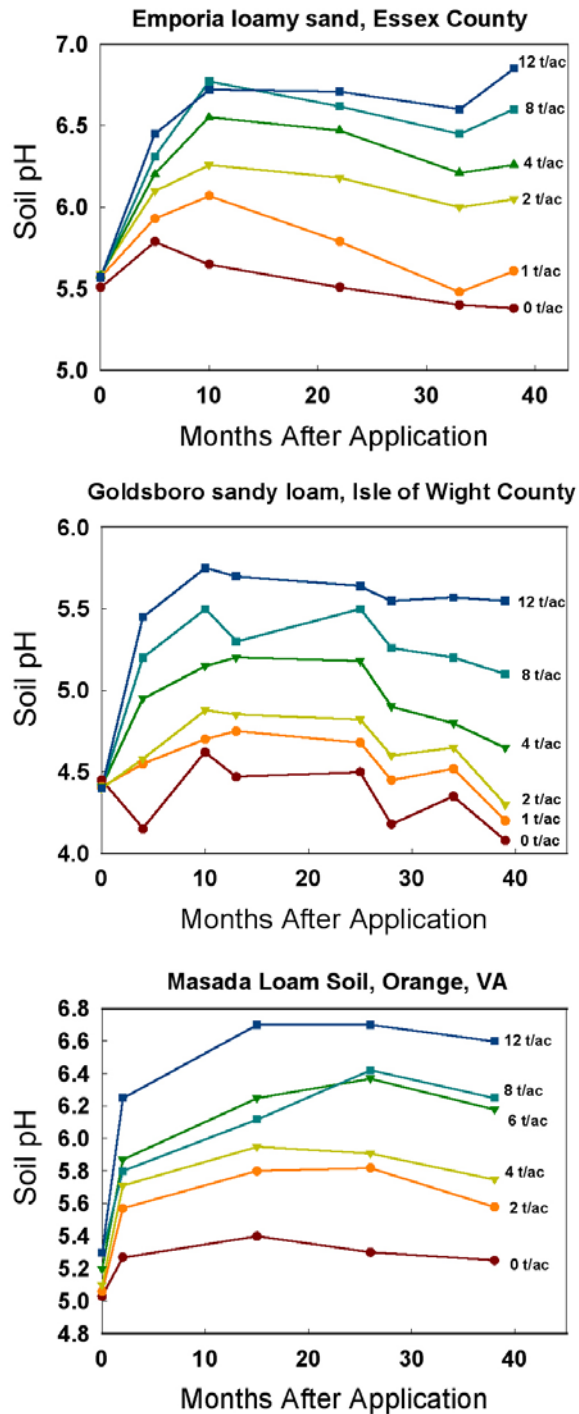


Fig. 9. Change in soil pH with time in various soils as affected by the rate of dolomitic limestone applied (S.M. Nagle, M.S. Thesis, Virginia Tech).

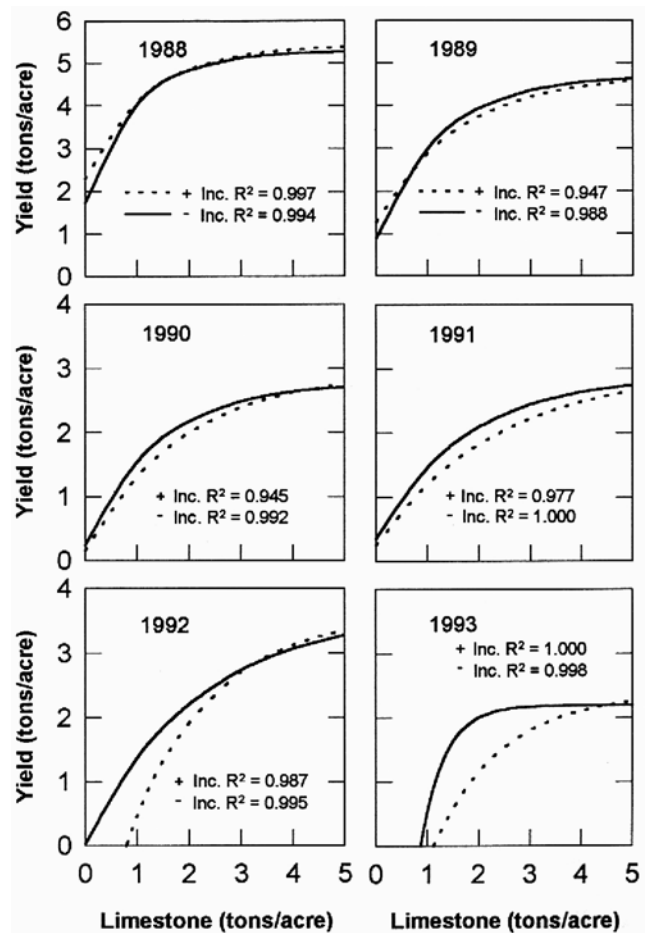


Fig. 10. Total seasonal alfalfa yields as influenced by the rate incorporated (dashed lines) and non-incorporated Aglime applications. Limestone treatments were imposed on Nov. 26, 1986, and alfalfa was planted on Aug. 26, 1987 (Wolf et al., *Journal of Production Agriculture* 7:490-494).

alfalfa yields were sustained from non-incorporated as compared to incorporated Aglime after six growing seasons. When switching from conventional tillage to no-till, a good management strategy would be to incorporate the recommended rate of Aglime to tillage depth during the final primary tillage operation prior to making the conversion to no-till.

When possible, lime should be mixed to tillage depth. On moderately acid soils (pH 5.2 to 5.7), a single application of lime made either before or after tillage will usually give good results. For strongly acid soils (pH 5.0 and below) that have very high lime requirements, it may be desirable to apply one-half of the lime before tillage and the remaining half after tillage. A disc-harrow can be used for mixing lime with the soil. This method is more practical for high-value crops or for crops particularly sensitive to acid soil conditions in relatively small areas. For large areas that have high lime requirements, i.e. three to four tons per acre, it is probably best to apply one-half of the required lime in a first-year application, and then apply the other half of the lime the second year. Most benefits during the first year of crop growth will be obtained from the first application, and the cost of liming can be spread over two years.

The uniform application of lime is just as important as selecting the right type and amount of lime for a given situation. Careless application can result in a loss of income and may create problems with some areas in the field being under-limed and other areas being over-limed. Though soils are limed to correct the acid condition that has developed over time, soils can be over-limed. This often happens when applications overlap too much in the spreading operation or if there is uneven distribution for other reasons. Factors that affect the pattern of distribution by bulk lime spreaders (Fig. 11) include the rate of application per acre, driving speed, steadiness of the speed, and equal distribution of lime by the spreader.

Usually, it is best to apply no more than two tons of Aglime per acre at one time with bulk spreaders. Higher rates tend to overload the spinners and result in non-uniform application. This results in over application directly behind the truck. To prevent double applications, equipment should be well calibrated to determine the proper spreading swath and operated to reduce overlap during a spreading operation. Proper training for operators and using devices such as foam markers or GPS-controlled parallel swathing equipment (i.e. *Lightbars*) are crucial to maximizing the economic return from lime treatments.

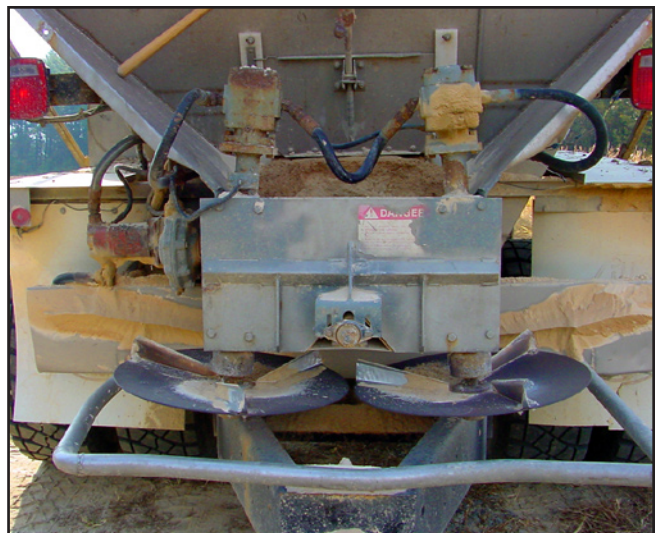


Fig. 11. Commonly used "twin-spinner" apparatus for bulk spreading of Aglime (Photo, courtesy of Matt Lewis, Virginia Cooperative Extension).

Calibration is critical for proper rate of application and must be done on a regular basis. Growers should insist on current calibration of the spreaders used to apply lime for them, and should have a set of calibration pans and scales for calibrating their own spreaders.

## Timing

The best time to lime is any time that a lime need has been determined. Aglime can be applied anytime between the harvest of a crop and the planting of the next. Lime is usually broadcast on the soil surface and then incorporated into the soil during tillage operations. In conservation tillage systems and on pastures and hay fields, surface applications can be made whenever soil conditions allow spreaders to enter the fields. Lime is a product for all seasons.

- Lime can be applied in early spring for all crops. Spring applications are excellent for fall crops since there will be adequate time for significant soil pH adjustment. However, spring-planted crops will also benefit from spring applications of lime because fine particles will react rapidly with soil acidity. *Limestone applications should never be postponed in the belief that limestone reaction will be slow.* Aglime meeting Virginia's specifications will react immediately with soil acidity and increase crop yields.
- Summer is a good time to lime pastures, especially those scheduled for fall fertilization and renovation.
- Fall applications of Aglime are good for spring-planted crops such as corn, cotton, and soybeans since this

will allow adequate time for the lime to reach and neutralize acidity in the soil. An application of good-quality Aglime can adjust the soil pH adequately in 45 to 60 days.

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Originally published as:

McCart, G.D., G.W. Hawkins, and G.R. Epperson. 1970. *Lime for Acid Soils, what to use and how to apply*, Extension Division, Virginia Polytechnic Institute and State University Publication 405.