AG-FO-3352
1988

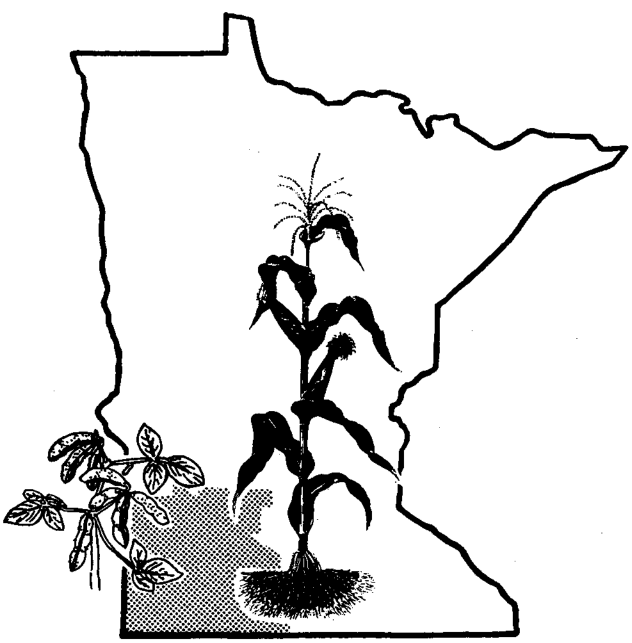
MANAGEMENT OF SOILS
IN **SOUTHWESTERN** MINNESOTA
A Correspondence Course

Unit 6: Soil Acidity and Liming

George Rehm

Objectives

- Understand the importance of liming in a crop rotation.
- Understand the long- and short-term benefits of proper lime use.
- Understand the cost effectiveness of various liming materials with special reference to the crop and the soil.



Minnesota Extension Service • University of Minnesota

UNDERSTANDING SOIL pH

Soil pH is nothing more than a numerical means of describing the degree of acidity in soils. The lower the number, the more acid the soil. If the pH of your soil is 7.0, you have a neutral soil (no acidity). If it is 6.0, your soils are slightly acid; if it is 5.0, your soils are quite acid. In the native condition, most soils in southwestern Minnesota have pH values of 7.0 or higher.

In general, soils are acid or become acid for the following reasons:

- The parent material on which the soils originally were formed was acid.
- Over the centuries, rainfall has moved calcium, magnesium, and potassium into subsoils, leaving the topsoil more acid.
- Crops remove calcium, magnesium, and potassium from the soil, leaving them more acid.
- Some fertilizers (especially nitrogen fertilizers) form acid in soils.
- Decomposition of organic materials such as crop residues and manure releases organic acids and other acid-forming substances that can make soils more acid.

OVERCOMING SOIL ACIDITY

The only way to overcome soil acidity is to add a liming material. Agricultural lime is any common calcium (Ca)/magnesium (Mg)-containing material that neutralizes soil acidity. However, not all Ca and Mg materials can be used as lime. Gypsum (calcium sulfate), for example, does not correct soil acidity. Magnesium sulfate is a material that contains Mg but does not neutralize soil acidity.

The amount of liming material needed to overcome soil acidity will depend on:

- The pH of the plow layer. The more acid the soil, the greater the lime requirement.
- The texture of the soil. Coarse-textured (sandy) soils generally require less lime to correct soil acidity than do fine-textured soils.
- The crops grown. A rate of lime to reach a pH of 6.5 is needed for best alfalfa yields. If a crop rotation does not include alfalfa, lime is not needed if the soil pH is 5.7 or above.

BENEFITS OF LIMING

If soils are acid, liming will:

- Promote the growth of microorganisms that aid in the breakdown of crop residues, manure, and other organic materials. This process releases nutrients in forms that are available to plants.
- Increase the availability of both soil and fertilizer phosphorus. Generally, phosphorus is most available to plants in a soil pH range of 5.7 to 7.0.
- Promote the growth of the bacteria that produce nodules on alfalfa, other forage legumes, and soybeans. These nodules supply the plant with nitrogen from the atmosphere. The bacteria grow best when soil pH is 6.5 or higher.

- Furnish Ca and Mg (plant nutrients) to the crop. (However, for most soils in southwestern Minnesota the supply of both nutrients is already adequate for high yields.)
- Overcome or neutralize the acidifying effects of commercial fertilizers (especially nitrogen fertilizers) and manure.

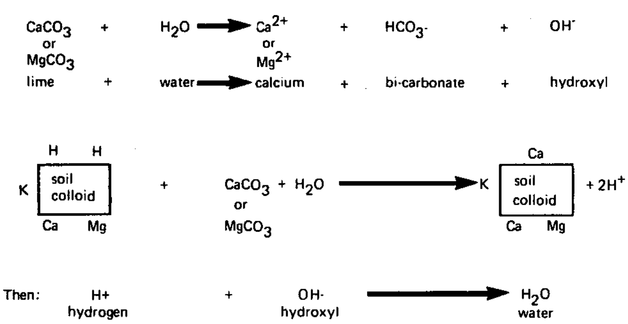
COST EFFECTIVENESS OF LIMING

Liming may be necessary for growth of long-lasting, high-yielding legumes such as alfalfa or sweet clover on some soils in southwestern Minnesota. Liming is the difference between being able to establish and maintain these crops and changing to more acid-tolerant crops such as red clover and grasses. The cost of lime must be spread over the length of the entire rotation rather than only the first year of establishment.

University of Minnesota research has shown that alfalfa generally will out-yield red clover by about 1.2 tons per acre the first two years after planting and by more than 2.3 tons per acre in the third and fourth years. The overall increased yield for four years will be about 7 tons per acre. In estimating the returns for liming, consider not only this higher yield but also the potential of having the alfalfa stand last for at least six years.

HOW DOES LIME WORK?

When lime is added to the soil, it dissolves in the soil solution. The Ca (or Mg) displaces hydrogen ions (acid) on the exchange sites, and this hydrogen then is neutralized by hydroxyl to form water:



LIMING MATERIALS

Liming materials usually are carbonates, hydroxides, or silicates of Ca and Mg. Some common liming materials are: calcium carbonate ($CaCO_3$), dolomitic limestone ($CaCO_3 \cdot MgCO_3$), hydrated lime ($Ca(OH)_2$), slag ($CaSiO_3$), marl, and waste lime from water-softening plants and sugar beet factories (Table 1).

Ground agricultural limestone or aglime may be either Ca-rich (calcitic) limestone, $CaCO_3$ (95 percent $CaCO_3$, 2 percent $MgCO_3$) or Mg-rich (dolomitic) limestone, $CaCO_3 \cdot MgCO_3$ (50 to 55 percent $CaCO_3$, 40 percent $MgCO_3$). Calcitic limestones and waste limes contain less than 2 percent Mg. Dolomitic limestones contain nearly 11 percent Mg.

Table 1. Approximate composition of various liming materials.

Material	Composition	Calcium Carbonate Equivalent
Limestone, calcitic	95% $CaCO_3$, 2% or less $MgCO_3$	100
Pelletized limestone, Ampel Co., Iowa	same as calcitic limestone	94
Limestone, dolomitic	50% $CaCO_3$, 40% $MgCO_3$	85-109
Hydrated lime	$Ca(OH)_2$	120
Marl	$CaCO_3$, clay, organic matter	60-80
Slags	$CaSiO_3$	60-90
Waste limes:		
sugarbeet	$CaCO_3$, 48% water	80
water softening	89.5% $CaCO_3$, 3.13% $Mg(OH)_2$ (33% solids, 66% water)	90
Filter cake sewage sludge	48 lb $CaCO_3$/wet ton	12

LIMESTONE QUALITY

Pure $CaCO_3$ is used as a standard for other liming materials in the evaluation of purity. The neutralizing value or purity of a liming material is expressed in terms of percent calcium carbonate equivalent (CCE, %).

The rate of reaction of a limestone in the soil varies with particle size and chemical composition. Limestone must dissolve in water to react with the soil, so fine particles will react most quickly.

Agricultural limestone is a mixture of many different sizes of particles. Particles larger than 8-mesh (mesh = the number of openings in a sieve per linear inch) have very little effect on the soil. Particles finer than 60-mesh size may dissolve completely and react with the soil within six months after application.

Up to 1976, liming materials sold in Minnesota under the federal cost-sharing program were inspected and had to meet Agricultural Stabilization and Conservation Service (ASCS) specifications for purity and fineness. Currently the state has no official inspection program, but limestone producers follow a voluntary quality control program. Most producers provide data on CCE, fineness, and percentages of $CaCO_3$ and $MgCO_3$ for their liming materials.

Minnesota has no state laws and regulations governing the sale of agricultural liming materials. The old ASCS minimum requirements for aglime (at least 80 percent must pass an 8-mesh sieve, and the aglime must have at least 80 percent CCE) still seem to prevail.

TOTAL EFFECTIVE LIMESTONE (ECCE)

The effectiveness of any limestone is based on its CCE and on its fineness. The total effectiveness, that is, the Effective Calcium Carbonate Equivalent (ECCE), is a combination of the two, expressed in percent. The following examples illustrate the effectiveness factors used in calculating the percent of limestone available based on fineness (Iowa method). Also shown are the calculations of ECCE and pounds of ECCE per ton of a limestone.

Basic equation: [(0.1 × % passing 4-mesh) + (0.3 x % passing 8-mesh) + (0.6 × % passing 60-mesh)] x (% CCE) = % ECCE

Example 1. (average aglime)

(0.1 × 100) + (0.3 × 92) + (0.6 × 39) = 61.0% (fineness factor)

CCE = 89%

total ECCE = 0.61 × 0.89 = 0.54

pounds of ECCE per ton = 0.54 × 2000 = 1080

Example 2. (finely ground aglime)

(0.1 × 100) + (0.3 × 90) + (0.6 × 55) = 70.0% (fineness factor)

CCE = 86%

total ECCE = 0.70 × 0.86 = 0.60

pounds of ECCE per ton = 0.60 × 2000 = 1200

Lime rates currently recommended in Minnesota are based on effectiveness of average agricultural limestone (39 percent passes through a 60-mesh sieve, 92 percent passes through an 8- mesh sieve, and a CCE of 89 percent). One ton of pure $CaCO_3$ is equivalent to 1.85 tons of such a limestone:

$$\frac{2{,}000 \text{ lb pure } CaCo_3}{1{,}080 \text{ lb ECCE/ton aglime}} = \text{1.85 tons aglime (see Example 1 above)}$$

In Iowa, lime recommendations are made in terms of 100 percent effective calcium carbonate (1000 lb/A ÷ 0.54 ECCE = 1850 lb/A aglime to be applied).

The ECCE provides a single value that can be used in comparing quality and cost of different aglimes. For example, an aglime with 1200 pounds of ECCE per ton (67% fineness × 90% CCE) sold in north-central Minnesota for $15/ton would cost 1.25¢/lb ECCE.

LIQUID, FLUID, OR SUSPENSION LIME

The rapid increase in popularity of solution and suspension fertilizers has stimulated interest in fluid lime. It usually consists of about 50 percent water or liquid nitrogen fertilizer (UAN, 28% N), 48 percent lime solids, and 2 percent attapulgite clay as a suspending agent. The calcitic limestone is finely ground and will pass a 60-mesh sieve and have a purity of at least 85% CCE. Usual applications add about 500 pounds per acre of lime solids. To apply 500 pounds per acre ECCE, 1225 pounds per acre or 80 gallons per acre (15 pounds per gallon) of total suspension would be required.

$$\frac{500 \text{ lb/A ECCE}}{0.85 \text{ CCE} \times 0.48 \text{ solids}} = 1225 \text{ lb/A}$$

Economics

If the fluid lime just described sold for $22 per ton, then:

$22 ÷ 630 lb ECCE = 3.5¢/lb ECCE

If an aglime sold for $15/ton with 1200 pounds ECCE per ton (67% fineness × 90% CCE), then $15 ÷ 1200 lb ECCE = 1.25¢/lb ECCE.

Advantages

The advantages of fluid lime are:

- It is very finely ground and reacts with the soil quickly.
- It is ideal for soils under minimum tillage to neutralize acidity from crop residues and shallow urea applications.
- It can be mixed and spread with liquid N fertilizers, potassium (K), Mg, and sulfur (S), saving an extra hauling and spreading trip.
- Renters with a one-year lease may prefer fluid lime because of speed, economy, and convenience.

Disadvantages

The disadvantages of fluid lime are:

- Large pH changes are not possible with small amounts.
- It may require application every year.
- The cost may be greater than aglime, especially on a long-term basis.
- It cannot be used with phosphorus fertilizers.

WHICH LIMESTONE IS BETTER—CALCITIC OR DOLOMITIC?

In some parts of Minnesota where soil Ca is low relative to Mg levels, some advisors recommend adding calcitic instead of dolomitic limestone to raise the Ca level. However, Minnesota limestone is primarily dolomitic, so this means hauling in calcitic aglime from Iowa or Michigan. Transportation costs can make calcitic aglime quite expensive.

Field trials have been conducted in a part of Wisconsin with a low (4:1) Ca/Mg ratio to find out whether the extra expenditure for calcitic aglime is valid. Calcium was supplied as gypsum (calcium sulfate), and Mg as magnesium sulfate, to vary the ratio of Ca to Mg. Alfalfa was grown to determine benefits from various ratios that resulted. One experiment was conducted on a Theresa silt loam with a Ca/Mg ratio of 4 to 1 before treatment—a Ca/Mg ratio of 7.5 to 1 is thought by some to be desirable. The Ca/Mg ratio was markedly altered, but there was no significant influence on alfalfa yield. The researchers concluded that adding Ca to change the ratio is not necessary.

Lime experiments on acid soils in several other states showed very little difference between dolomitic and calcitic lime. Various Minnesota trials have not revealed a Ca deficiency, nor is there evidence that adding Mg-containing materials is detrimental.

Continuous use of dolomitic limestone is not expected to result in excess Mg relative to Ca since proportional plant uptake, greater leaching of Mg ($MgCO_3$ is ten times more soluble than $CaCO_3$) and fixation prevent such a buildup. In fact, there should be more concern for inducing magnesium deficiency with a low-Mg liming material than Mg toxicity with dolomitic limestone. The Mg in dolomitic limestone may be beneficial to plants on sandy and organic soils. For most soils where dolomitic limestone is available locally, there is no justification for "importing" calcitic limestone. When an acid soil requires liming, choose the most economical liming material. Do not apply Ca-rich limestone or gypsum to Minnesota soils simply to increase the Ca/Mg ratio.

DETERMINING THE NEED FOR LIME

It's relatively easy to determine the amount of lime needed for crop production. A representative soil sample is mixed with water and the pH is recorded. If this measured value is less than 6.0, a portion of the soil sample collected is then mixed with a buffer solution. The pH of the soil and buffer solution mixture is recorded. The amount of lime needed is determined from this second reading.

There is no way to determine lime needs without a soil sample. This sample should be collected six months or more before the legume crop is seeded to allow ample time for the lime to react with the soil.

HOW AND WHEN TO APPLY LIME

Lime should be broadcast and mixed into the plow layer. Because lime is only effective where it is placed, thorough mixing by plowing and disking is extremely important, especially on strongly acid soils being limed for the first time. The University has documented many cases in which poor mixing of lime resulted in poor stands and poor yields of alfalfa.

Apply lime 6 to 12 months prior to seeding alfalfa to give it time to neutralize soil acidity. If lime cannot be applied during this period, it can be applied even just before seeding to establish adequate stands. If lime is needed and not applied, crop production will not be optimal.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Patrick J. Borich, Dean and Director of Minnesota Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Minnesota Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, religion, color, sex, national origin, handicap, age, veteran status, or sexual orientation.