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Liming
minnesota soils

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About one-third of Minnesota's cropland could benefit from liming. Although not all of our soils are lime deficient, those that are differ greatly in the amounts of lime required. The content of lime varies in the many parent materials forming our soils, and the amount leached out by rainfall also varies. Other factors, such as vegetation, time, slope, and cultivation, also help bring about these differences in liming needs.

What Are the Benefits of Liming?

- Lime promotes the growth of favorable soil bacteria in acid soils.
- Lime helps nitrogen, phosphorus, and molybdenum become more available to growing plants.
- Lime neutralizes acidity produced by some fertilizers.
- Lime prevents soil acids, aluminum, manganese, and iron from becoming harmful to plants.
- Lime may improve the physical condition of many soils by promoting a crumblike structure.
- Lime may help to cut down on soil and water losses by improving soil tilth.
- Lime furnishes calcium and magnesium for plant growth.
- Lime lessens the possibility of insect and disease damage by promoting vigorous plant growth.

What Is Lime?

Agricultural lime is any material containing calcium or calcium and magnesium that, when properly applied, neutralizes soil acidity. Although gypsum contains calcium it is not a liming material because it does not correct soil acidity.

What Is Soil Acidity?

Soils are acid or alkaline depending upon the amounts of acid-forming elements (such as hydrogen and aluminum) or base-forming elements (such as calcium and magnesium) present. When acid- and base-forming elements are balanced, a soil is neutral and therefore has a pH of 7. As bases are removed by cropping and leaching, a soil becomes acid and may have a pH of 6 or lower. Adding lime to a soil reduces the activity of the acid-forming elements, and the soil becomes less acid.

Acid-forming elements are found in the soil water and attached to the clay and organic matter particles. A liming program attempts to neutralize these acid formers. This is why liming recommendations call for greater amounts of lime on fine-textured and high organic matter soils than on coarse-textured, sandy soils.

The extent of acidity or alkalinity in a soil can be determined with color indicators or, more accurately, with a pH meter. A pH of 7 (as for pure distilled water) indicates a neutral reaction. Sour milk and lemon juice which are acid substances have pH values well below 7. On the other hand, alkaline materials such as sea water and soap have pH values of about 8 and 9, respectively. The further the soil pH value falls below 7, the more acid the soil; the greater the pH value above 7, the more alkaline the soil. A soil testing pH 5 is 10 times more acid than one testing pH 6 and 100 times more acid than one testing pH 7. This is so because pH values are arrived at by the use of logarithms rather than simple arithmetic.

Measurements of soil pH reflect the active hydrogen in the soil solution. Since measuring this active acidity has caused some problems in making lime recommendations, another method, the SMP buffer test, is used to test for total acidity. Relationships between the SMP buffer test and the amounts of lime needed to raise the pH to 6.5 or 6.9 in major soils are known from greenhouse and laboratory studies.

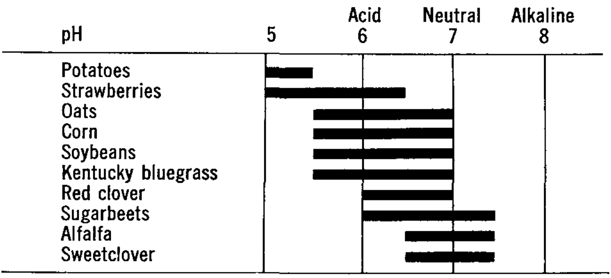
Do Crops Differ in Their pH Needs?

Because alfalfa and sweetclover require the highest pH, lime usually is recommended in amounts sufficient to meet the needs of these crops. Corn and soybeans are quite tolerant to a wide pH range in the soil.

Some specialty crops, such as potatoes, strawberries, and blueberries, require a low pH because of disease (i.e., potato scab) or nutritional problems at high pH levels. On very acid soils, potato growers sometimes apply as little as 200 or 300 pounds of lime per acre. Such applications furnish mainly calcium and magnesium to the crop and are not sufficient to lower soil acidity.

Figure 1 shows the pH ranges at which several field crops thrive on mineral soils. On peat and muck soils a pH of 5.5 to 6 is considered satisfactory.

Figure 1. Suitable pH ranges for various crops.



Acidity of Minnesota Soils

For convenience in making lime recommendations, the state has been divided into two general areas (see figure 2).

Area 1: Most subsoils are acid. These are mainly eastern Minnesota soils formed on lime-poor parent materials and/or under conditions of high rainfall. Most of the soils are acid in both surface and subsoil. Lime should be applied before legumes are seeded, except on fields that have been limed recently or on low spots high in lime. In this area, lime also increases yields of crops other than legumes, because it increases the availability of phosphorus and nitrogen.

Exceptions in this broad general area are high pH soils or soils with acid surfaces and high lime subsoils. These high pH subsoils are uncommon but can be identified with actual measurements or reference to soil survey.

Area 2: Few subsoils are acid. The two subareas in this category are (a) soils that are generally acid on the surface and (b) those that are neutral or alkaline.

Soils that are acid on the surface differ from area 1 soils in that the subsoils generally are neutral or alkaline. Crops, therefore, require less lime additions in area 2 than in area 1, even where the surface pH is the same for both areas.

Subarea A: Slightly acid to acid surface soils. Some of the subsoils may have high lime content at rather shallow depths, even though surface soils are acid. Crops on such soils may show little response to liming. In extreme southwestern Minnesota, the soils of the Moody-Kranzburg-Vienna association have an acid plow layer. Frequently, these soils have adequate lime in the subsoil. Lime is recommended only if it is difficult to establish stands of alfalfa, even though soil tests show medium or high levels of phosphorus or potassium.

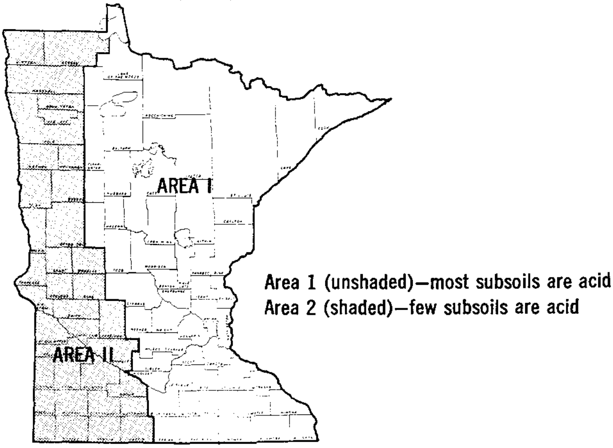


Figure 2. Reference map for lime recommendations.

Subarea B: Neutral or alkaline surface soils. These occupy a large section of western Minnesota. The soils often contain free lime in the rooting zone which sometimes causes "chlorosis" or yellowing in field crops and ornamentals. Liming is not recommended on these soils.

What Rates of Lime Are Recommended?

Several factors must be considered to arrive at a lime recommendation. These factors are: soil pH, SMP buffer index, soil texture, area in state (see figure 2), crop to be grown and the desired pH level. Table 1 shows the rates of lime recommended by the University of Minnesota Soil Testing Laboratory.

Liming rates given in table 1 refer to a plow layer of 6 inches. When a soil is plowed to a greater depth, heavier lime applications are needed to neutralize the acidity of this greater volume of soil. To make the plowing depth adjustment, multiply the basic limestone recommendation given in table 1 by a factor of 0.17 for each inch greater than the 6-inch plow depth. For example, lime rates needed for a 6-inch plowing depth have a multiplying factor of 1; for a 9-inch plowing depth the factor is 1.5 (3 inches x 0.17 plus the 6-inch factor of 1).

In laboratories where SMP buffer is not used, lime recommendations for soil-water pH are shown in table 1A.

When and How Should Lime Be Applied?

Acid soils in cropping systems that include a legume should receive lime 6 to 18 months before the new legume seeding is established. In other cropping systems, apply lime in the fall. It is better, however, to apply lime at the time of seeding than not at all.

The reasons for "liming on time" (in the fall) are good ones:

1. Time is necessary for lime to dissolve and establish areas of "sweet" soil which are favorable to the early growth of young plants.
2. Delivery and spreading problems associated with soft fields and spring road restrictions are often avoided.

Spread lime uniformly for best results. Make sure that each application strip is lapped sufficiently to avoid alternating good and poor strips in the following year's crop. While this may seem unimportant at first, on large fields these strips may add up to several acres of poor alfalfa.

Work lime into the seedbed. Disking or harrowing followed by plowing distributes lime throughout the plow layer and will still be within easy reach of seedling roots. Be sure to follow this rule: **Lime, disk or harrow**, then plow. This is especially important on strongly acid soils being limed for the first time. Plowing, without disking,

Table 1. Rates of ground agricultural limestone needed to raise soil pH of 6-inch plow layer to an indicated level

Where SMP buffer applies (Soil-water pH values below 6.0)	Amount of limestone			
	To raise soil-water pH to 6.5		To raise soil-water pH to 6.9	
	Area 1	2	Area 1	2
SMP buffer index	Tons per acre*			
6.8	3.0	2.0	5.0	NR†
6.7	3.0	2.0	5.0	NR
6.6	4.0	2.0	6.0	NR
6.5	4.5	2.0	6.5	NR
6.4	5.0	2.5	7.0	NR
6.3	5.5	2.5	7.5	NR
6.2	6.0	3.0	8.0	NR
6.1	6.5	3.0	8.5	NR
6.0	7.0	3.5	9.0	NR
5.9	7.5	3.5	9.5	NR
5.8	8.0	4.0	10.0	NR
5.7	8.5	4.0	10.5	NR
5.6	9.0	4.5	11.0	NR
Where SMP buffer does **not** apply (Soil-water pH values of 6.0 and higher)				
Mineral soils				
Soil-water pH				
6.5	0‡	0	2‡	NR
6.4	0	0	2	NR
6.3	3	0	5	NR
6.2	3	0	5	NR
6.1	4	0	6	NR
6.0	4	2	6	NR
Organic soils (peats and mucks)§				
Soil-water pH				
5.4	2	2	2	2
5.3	2	2	2	2
5.2	2	2	2	2
5.1	2	2	2	2
5.0	2	2	2	2
4.9	3	3	3	3
4.8	3	3	3	3
4.7	4	4	4	4
4.6	4	4	4	4
4.5 and lower	5	5	5	5

* Rates based on total effectiveness of average limestone having 38 percent passing through a 60-mesh sieve, 90 percent passing through an 8-mesh sieve, and having a neutralization value of 90 percent. One ton of pure calcium carbonate is equivalent to 1.85 tons of such a limestone.
† NR= Not recommended.
‡ Lime rates at soil-water pH 6.0 or above need not be applied where alfalfa is not grown in the cropping system.
§ Only limed to pH 5.5.

Table 1A. Rates of ground agricultural limestone needed to raise soil pH of 6-inch plow layer to satisfactory level when SMP buffer is not used.

Soil-water pH	Needed lime, tons per acre	
	Area 1	Area 2
6.5	0	0
6.4	0	0
6.3	3	0
6.2	3	0
6.1	4	0
6.0	4	2
5.9	4	2
5.8	5	2.5
5.7	6	3
5.6	6	3
5.5	6.5	3
5.4	7	3.5
5.3	7	3.5
5.2 or less	8	4

turns the lime under but does not thoroughly mix it with the soil. Topdressing established stands of alfalfa seldom gives satisfactory results until the lime is incorporated through subsequent tillage.

Which Liming Materials Are Common in Minnesota?

Ground agricultural limestone may be either calcitic (calcium carbonate) or dolomitic (a mixture of calcium and magnesium carbonates) in nature. Most limestone quarried in Minnesota is dolomitic. Sandy and many organic soils sometimes are poorly supplied with magnesium. In these cases, the magnesium in dolomitic limestone may be beneficial to plants.

Marl is a loose material composed mostly of calcium carbonate and varying amounts of silt, clay, and organic matter. The state's most extensive marl deposits are in northern Minnesota. The value of marl is determined by its quality and costs of digging, drying, and spreading. Marl contains little or no magnesium.

Blast-furnace slag is a byproduct in the manufacture of pig iron. Unlike limestone and marl, its calcium and magnesium are silicates rather than carbonates. Furnace slag is as effective a liming material as ground limestone of similar quality.

Less popular liming materials include **refuse lime** (from water-softening plants, sugar beet factories, and acetylene plants), and **slaked** (hydrated) **lime.**

Table 2. Equivalent amounts of liming materials

Material	Amount
Ground agricultural limestone	1 ton
Marl	2 cubic yards
Papermill and sugarbeet refuse lime	2 cubic yards
Water-softening process lime	2 cubic yards
Blast-furnace slag	1 ton
Slaked lime (1,400 pounds)	¾ ton

How Are Liming Materials Valued?

The two things determining the value of agricultural liming materials are neutralizing value and fineness of grinding. Pure calcium carbonate is used as the standard for other liming materials. The neutralizing value or the purity of a liming material is expressed in terms of its calcium carbonate equivalent (C.C.E.). Pure calcium carbonate is given a C.C.E. of 100 percent. A limestone made up of 95 percent calcium carbonate and 5 percent sand and clay impurities has a C.C.E. of 95 percent. Limestone sold to Minnesota farmers generally varies from 80 to 98 percent C.C.E. Marl and refuse limes should have at least 70 percent C.C.E.

To be effective, limestone first must dissolve in the soil. Because calcium and magnesium carbonates do not readily dissolve, their effectiveness also depends greatly on particle size.

Agricultural limestone is a mixture of many different sized particles. Particles larger than 8-mesh (about ⅛ inch in size) have very little effect on the soil pH (table 3). On the other hand, particles finer than the 60-mesh size may dissolve completely and react with the soil within 6 months after application. The use of a 60-mesh sieve (mesh size indicates the number of openings per linear inch) gives a good indication of the particle size distribution of agricultural limestone. The 8-mesh sieve is used to control the upper limit on the amount of coarse

Table 3. Relative efficiency of various dolomitic limestone particles

Particle size (mesh)	Relative efficiency
4-8*	5
8-20	13
20-40	27
40-60	55
60-100	78
Finer than 100	100

* Particles that pass through a 4-mesh sieve but are held on an 8-mesh sieve.

limestone particles that may occur in the product. Limestone should be ground finely enough so that at least 80 percent passes through an 8-mesh sieve, and about 40 percent passes through a 60-mesh sieve.

Liquid lime is finely ground limestone suspended in water. Because of the fineness its reaction in the soil is more rapid than regular agricultural limestone. Over a few years time, however, quantities added must be the same as with agricultural limestone in order to bring soil pH to the desired level.

What Effect Does Fertilization Have on Liming Needs?

Most nitrogen fertilizers used today are acid forming. Since the application rates of fertilizers have generally increased, the need for neutralizing this acidity becomes more important. Also, with the higher rates of fertilizer there has been an increase in crop yields which further increases the removal of base formers (calcium and magnesium). It would appear that limestone should be applied in the amounts needed to at least neutralize both of these acidifying effects (fertilizers and base removal by crops).

To calculate the amount of limestone needed, the following guideline can be used. About 2 pounds of limestone are needed to neutralize the acidity produced by 1 pound of nitrogen in the form of anhydrous ammonia. Therefore, about 300 pounds of limestone are needed to overcome an application of 150 pounds of nitrogen. When crop removal is also considered, a 1-ton rate of lime should be applied about every 5 years to counteract the added acidity. This does not apply on soils that are alkaline in nature.

What's Next?

Good liming practices require you to know the pH level and the lime requirements of your soil. A soil test is your best guide. Collect soil samples and send them to the University's Soil Testing Laboratory or take them to a private laboratory near you. For a small fee you will receive information on both the lime and fertilizer needs of your crops.

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