

Choosing between liming materials

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Liming agricultural land is an ancient practice. The benefits of liming have been recognized since Roman times, and agricultural experimental stations in the United States have conducted liming research trials since the late 1800s. However, questions are still being asked by dealers and farmers as to the differences between liming materials and how they might best be used.

A liming material is any compound capable of increasing soil pH by combining with hydrogen ions in the soil solution. Although most agricultural liming materials contain calcium, it is the negatively charged component of the compound, i.e. the carbonate (CO_3^-), which actually neutralizes the acidity. The most common liming material is crushed limestone (aglime); however, several other materials may be used in specialized situations or in areas where a by-product liming agent is produced.

Currently, a variety of liming materials are available to Wisconsin farmers. The materials differ in place of origin, amount of neutralizing power, and nutrients or other elements associated with the liming agent. These characteristics may influence the method and timing of the liming application and must be considered when deciding which material to use. Commonly used liming materials are briefly described below.

- **calcitic aglime**—a ground limestone composed mostly of calcium carbonate (CaCO_3).
- **dolomitic aglime**—a ground limestone containing a mixture of calcium carbonate and magnesium carbonate (CaCO_3 , MgCO_3).
- **hydrated or slaked lime**—a liming material composed of calcium hydroxide [$\text{Ca}(\text{OH})_2$] or a mixture of calcium and magnesium hydroxide.
- **quicklime or burnt lime**—a liming material containing calcium oxide (CaO) or a mixture of calcium and magnesium oxide.
- **marl**—a deposit of calcium carbonate (CaCO_3) derived from mollusk shells and mixed with silt and clay.
- **industrial by-products including slags, refuse sludges, and flue dusts**—these materials commonly contain a high percentage of calcium carbonate (CaCO_3), although the slags are mostly calcium and magnesium silicates (CaSiO_3 , MgSiO_3); flue dusts may contain a substantial quantity of oxides.

Neutralizing index

Lime quality is judged by how effectively it raises the soil pH to a desirable level within three years. Two properties of lime govern its quality: purity (percent calcium carbonate equivalent) and fineness (particle size). These two factors are used to calculate the neutralizing index, a measurement of the relative value of the liming material.

Chemical purity

The purity of an agricultural lime is expressed as its calcium carbonate (CaCO_3) equivalence. This is a measure of the amount of acid a given weight of the material will neutralize compared to pure calcium carbonate. Pure calcium carbonate has an equivalence of 100%; lime with higher magnesium content (dolomitic) will have a higher calcium carbonate equivalence because of the lower atomic weight of magnesium. By-product liming materials have a wide range of calcium carbonate equivalencies depending on their chemical composition. The calcium carbonate equivalents for several commonly used liming materials are listed in table 1. Typically, the higher the calcium carbonate equivalence, the more effective the product at neutralizing pH.

Fineness

The fineness of a liming material plays an important role in lime's effectiveness at neutralizing soil pH. This is because limestone dissolves slowly, so its effectiveness is limited to a small area around each particle. Increasing the surface area exposes more lime and increases its solubility. Reducing the radius of each

Table 1. Relative neutralizing value of some common liming materials containing no contaminants

Material	CaCO_3 equivalent (%)
Calcitic lime (CaCO_3)	100
Dolomitic lime [$\text{CaMg}(\text{CO}_3)$]	109
Hydrated (slaked) lime [$\text{Ca}(\text{OH})_2$]	136
Quicklime (CaO)	179
Slag (CaSiO_3)	86

particle by half increases the unit surface area by 50%. Finer grades of lime have a significantly larger surface area per unit weight of material than coarser grades. Table 2 shows the rate of change in soil pH over a 3-year period from lime applications of various particle sizes.

In fact, based upon data such as those shown in table 2, Wisconsin and several other states have adopted a step-like scale to distinguish the effectiveness of various lime particle sizes over a 3-year period (figure 1). The Wisconsin system assumes that material that is held on an 8-mesh screen is ineffective. That which passes through an 8-mesh sieve but is held on a 20-mesh screen is 20% effective; and that which passes through a 20-mesh screen but is held on a 60-mesh is 60% effective; and those that pass through a 60-mesh sieve is 100% effective over a 3-year period.

Dolomite versus calcite

The choice between a calcitic and dolomitic liming material should be based on availability, price, and agronomic effectiveness. As stated before, calcitic limestone is made up of calcium carbonate, whereas, dolomitic limestone is a mixture of calcium and mag-

nesium carbonate. Dolomitic limestone reacts somewhat more slowly with acid soils than does calcitic lime. However, as shown in figure 2, at the fineness to which agricultural limestone is usually ground, and with the typical reaction times of two to three years, there is relatively little difference between the two materials. A study at Spooner, WI, compared the relative effectiveness of dolomitic and calcitic aglime (neutralizing index 80-89) over a 2-year period. The results, in table 3, show no significant difference in pH between the two liming materials at any given rate or year. Alfalfa yields from these plots were also similar. Other Midwestern studies comparing the two materials have shown that in the few cases where calcitic lime was more effective, its effectiveness usually could be attributed to a somewhat more rapid reaction with the soil.

Some people suggest that calcitic limestone should be used instead of dolomitic limestone, claiming that the calcium to magnesium ratio of many Wisconsin soils is too narrow (excess magnesium present). However, research conducted at the University of Wisconsin examined the effectiveness of both products on soils with Ca:Mg ratios varying from 2 to 8. Researchers found no significant effect on crop yield

Table 2. Effect of various rates of dolomitic lime sizes on the pH of Withee silt loam

Fraction (mesh size)	Soil pH ^a			
	1 mo	1 yr	2 yr	3 yr
0 ton/a lime				
—	4.96	5.18	5.23	5.30
2 ton/a lime				
20-40	5.04	5.39	5.70	5.91
40-60	5.12	5.52	5.82	6.05
60-100	5.18	5.64	5.94	6.03
< 100	5.44	5.58	5.97	6.03
6 ton/a lime				
8-20	4.98	5.28	5.78	6.10
20-40	5.17	5.66	6.15	6.40
40-60	5.29	5.81	6.40	6.50
60-100	5.33	5.95	6.48	6.60
< 100	5.73	6.19	6.59	6.61
16 ton/a lime				
8-20	5.41	5.66	6.24	6.47
20-40	5.35	5.99	6.50	6.71
40-60	5.56	6.10	6.63	6.81
60-100	5.70	6.21	6.73	6.82
< 100	6.17	6.45	6.97	6.98

^aEach value represents the average of three replicates.
Adapted from Love et al. (1960)

Figure 1. Effectiveness of aglime at various particle sizes (mesh size)

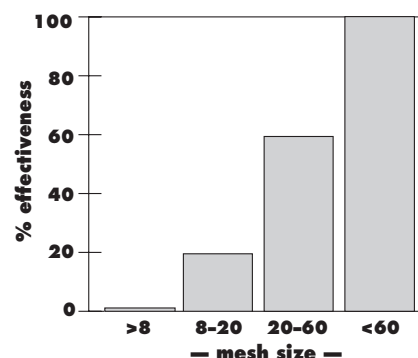
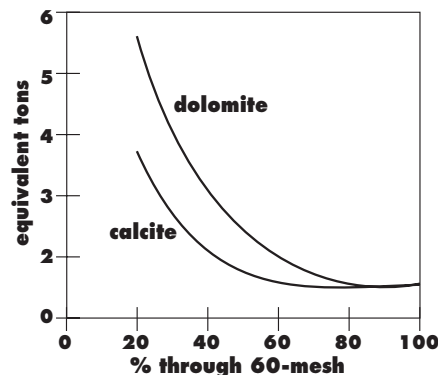


Figure 2. Influence of fineness of limestone on the relative effectiveness of calcitic and dolomitic limestone



Barber (1973). Reproduced with permission of the American Society of Agronomy, Inc.

or quality. Due to the added cost and the limited difference, these researchers do not recommend the application of gypsum or calcitic limestone simply to increase Ca:Mg ratios. For a more detailed discussion on this issue, see Extension publication *Soil Calcium to Magnesium Ratios—Should You be Concerned?* (A2986).

Although dolomitic limestone reacts somewhat more slowly with the soil, it has the advantage of supplying magnesium as well as calcium. On some Wisconsin soils, such as sands, where high rates of potassium have been used or where soil magnesium levels are naturally low, the additional magnesium in dolomitic lime may be beneficial.

Liquid versus dry

The use of lime suspensions has been suggested for cropping situations where very even lime distribution or very fast reaction is recommended, such as in no-till cropping. Liquid lime is made by suspending fine lime (usually finer than 100-mesh material) in either water or fluid fertilizer. Typical application rates are much lower than those used for conventional dry lime. Very fine liming materials will react quickly if

Table 3. Effect of lime rate and source on soil pH one and two years after application at Spooner, WI

Rate of application (ton/a)	Calcitic lime	Dolomitic lime
———— soil pH ————		
1 year after application		
2	6.21	6.24
4	6.56	6.48
2 years after application		
2	6.02	6.04
4	6.30	6.24

Adapted from Schulte and Kelling (1987)

Table 4. Changes in soil pH as a function of time and soil amendment added to a Withee silt loam

Amendment	Rate	Months				
		0	2	10	26	48
		———— soil pH ————				
None	0	5.0	5.0	4.8	5.1	5.1
Aglime (90-99)	1	5.0	5.0	5.1	5.2	5.4
	2	5.0	5.1	5.1	5.4	5.4
	4	5.0	5.2	5.4	5.9	5.9
	16	5.0	5.8	6.2	6.7	6.9
Papermill lime sludge	3	5.0	5.8	6.0	5.8	6.0
	10	5.8	6.8	6.8	7.0	7.2

Primary tillage performed annually. Maximum pH reached at 48 months; thereafter, pH declined. Peters and Schulte, Univ. of Wis., unpublished data.

thoroughly mixed into the soil. Liquid lime suspensions should not be used as a substitute for timely applications of agricultural limestone, but they can be used to provide small increases in soil pH on land where aglime application cannot be justified. Examples include liquid applications on rented land or applications intended to counteract the acidification of soil from nitrogen applications in no-till corn production. The cost of liquid lime application should be compared to the cost of larger dry lime applications which contain an equivalent amount of finer material plus coarser material that provides residual effects.

Management and effectiveness

Limestone dissolves extremely slowly, allowing it to neutralize soil acidity only in the solution immediately surrounding each lime particle. The only way to speed the process is by using finer particles and distributing them evenly throughout the soil. If lime is mixed thoroughly with the soil, the soil pH will rise within a few weeks after liming. The pH continues to increase very slowly until another tillage operation redistributes the lime particles, bringing them into contact with more acid soil. Limestone continues to cause a distinct rise in pH following tillage operations up to four years after application (table 4).

In some cases, it has been suggested that topdressing liming materials may serve as an effective short-term management tool on previously established forages or as a necessary technique where no-till is being used. Wisconsin field studies indicate that while topdressed lime does move downward through the soil system, the rate of movement is quite slow—less than 1 inch per year. In one study, varying rates of 20-40 mesh dolomitic lime was applied to a Plano silt loam near Arlington, WI. Soil pH was measured in 3-inch increments to a depth of 18 inches after 24 years. The higher the rate of application, the higher the pH at all depths sampled (table 5).

Table 5. Changes in soil pH 24 years after application of 20-40 mesh lime

Soil depth (inches)	Rate of application (ton/a)			
	0	8	16	32
———— soil pH ————				
0-3	5.2	6.0	6.6	7.0
3-6	5.2	6.4	7.0	7.1
6-9	5.3	6.5	7.0	7.2
9-12	5.2	6.2	6.6	7.0
12-15	5.1	5.7	6.3	6.8
15-18	5.1	5.4	5.8	5.8

Adapted from Schulte and Kelling (1983)

Relative worth of liming materials

To evaluate the relative worth of a liming material, first you'll need to determine how much lime is needed per acre and then you'll need to calculate how much it will cost. Knowing the cost per acre gives you a good starting point for evaluating various materials, but other factors may also influence your decision about which is the best liming material for your situation.

Step 1. Use table 6 to determine equivalent amounts. Because the soil test report only gives results based on liming materials with neutralizing indexes of 60-69 and 80-89, you may need to refer to table 6 to compare different materials. For example, if the soil test report indicates that you need 4 tons/a of 60-69 lime but you're interested in using 70-79 lime, you would need to read across the fourth row of the table to the column marked 70-79. In this case, only 3.5 tons of 70-79 lime are required.

Step 2. Compare the cost per acre. Multiply the rate (ton/a) by the cost (\$/ton) to determine the cost per acre. If the 60-69 material costs \$12/ton and you need to apply 4 tons/a, the total cost would be \$48 per acre (4 tons/a × \$12/ton). By contrast, the equivalent amount of the 80-89 material, 3.1 tons/a, at \$15/ton would cost only \$46.50 per acre (3.1 tons/a × \$15/ton). In this case, the more expensive material is the better buy.

Step 3. Factor in other considerations. Several other considerations which are difficult to quantify economically may also influence your purchase decision. For example, if you'll be planting an acid-sensitive crop like alfalfa immediately after liming or if you're liming a no-till field, you may wish to select a finer material to neutralize the soil acidity sooner to benefit the crop. Or, you may decide that the convenience of using a lime suspension, or application in combination with a fertilizer or pesticide outweighs the cost considerations. However, this should be considered a temporary measure as the low levels of lime applied will only neutralize a small amount of soil acidity. Conversely, even though very coarse (8-mesh) lime particles have a zero neutralizing value assigned to them, and intermediate sizes have a limited neutralizing value, there is still some benefit in applying them since research has shown that these particles will continue to react for more than 20 years. Another factor to consider is the source of the material. Locally available material normally will cost significantly less than other materials because transportation is a large part of the total cost of aglime. You'll need to weigh all of these factors to make an economically sound decision on what type of liming material to buy.

Table 6. Aglime conversion table for different neutralizing index (NI) zones

Lime rec. (60-69 NI) ^a (ton/a)	— Zones of lime quality according to NI values —						
	40-49	50-59	60-69	70-79	80-89	90-99	100+
	— ton/a lime to apply —						
1.0	1.4	1.2	1.0	0.9	0.8	0.7	0.6
2.0	2.9	2.4	2.0	1.7	1.5	1.4	1.2
3.0	4.3	3.5	3.0	2.6	2.3	2.1	1.9
4.0	5.8	4.7	4.0	3.5	3.1	2.7	2.5
5.0	7.2	5.9	5.0	4.3	3.8	3.4	3.1
6.0	8.7	7.1	6.0	5.2	4.6	4.1	3.7
7.0	10.1	8.3	7.0	6.1	5.4	4.8	4.3
8.0	11.6	9.5	8.0	6.9	6.1	5.5	5.0
9.0	13.0	10.6	9.0	7.8	6.9	6.2	5.6
10.0	14.4	11.8	10.0	8.7	7.6	6.8	6.2

^aSoil test recommendations are made for lime having a neutralizing index value of 60-69 and 80-89.

To convert a recommendation for 60-69 lime to a liming material with a different grade, read across the table to the appropriate column.

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