Liming Materials

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With the continuing pH decline of agricultural soils in northern Idaho, growers need to consider applying soil amendments to increase soil pH. Problems associated with increasing soil acidity are (1) aluminum toxicity, (2) phosphorus deficiency, (3) micronutrient toxicity problems, (4) molybdenum deficiency, (5) lack of or reduced microbial activity in the soil, and (6) reduced plant vigor and yield.

Applying liming materials to these highly acid soils is one way of increasing soil pH. This publication provides information about materials available for raising soil pH.

What is Lime?

Lime is any material that: (1) contains calcium (Ca) or magnesium (Mg) *and* (2) will neutralize soil acidity. For example, calcium carbonate ($CaCO_3$) is a liming material because it contains Ca and the carbonate portion of the material (CO_3) will neutralize soil acidity.

Liming materials include limestone, burned lime, slaked lime, marl, oyster shells, slag, cement plant flue dust, mine tailings, sugarbeet sludge, wood ashes, and paper mill lime sludge. Liming materials fall into the following four categories: carbonates, oxides, hydroxides, and by-product materials.

Gypsum—Not a Lime Material

Gypsum ($CaSO_4$) is not a liming material. Even though it contains Ca, gypsum cannot neutralize soil acidity. In addition to adding Ca, gypsum also supplies sulfur (S), an essential plant nutrient. Adding gypsum has little or no benefit for increasing soil pH.

Carbonates

Carbonates are the most widely available and most widely used liming materials. Carbonates are generally less expensive and easier to handle than other lime materials. Ground high grade limestone or calcitic limestone is nearly pure calcium carbonate ($CaCO_3$). This material is the most commonly used lime source. The major advantage is its relative low cost. Dolomitic limestone, or dolomite ($MgCO_3$+$CaCO_3$), is also a commonly used source. Dolomite usually costs a little more than calcitic limestone and changes the soil pH more slowly, but it has the advantage of containing Mg as well as Ca. Together, calcitic limestone and dolomitic limestone account for more than 90 percent of the lime used in the United States. Both materials are naturally occurring rocks that are mined in the Inland Pacific Northwest and ground for agricultural use. Calcium carbonate and dolomite are both mined.

Marl and oyster shells are also carbonate materials. Marl is a naturally occurring mixture of clays, carbonates of Ca and Mg, and shell remnants. Oyster shells are pure calcium carbonate but are important only in some coastal regions. Neither material is common in Idaho.

Oxides

Oxide liming materials are known by many names including burned lime, unslaked lime, and quicklime. Oxides are made by baking crushed calcitic limestone or dolomitic limestone in an oven or furnace, thereby driving off carbon dioxide (CO_2) to form a pure oxide (CaO

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or MgO). This material is of low molecular weight and reacts rapidly in the soil to raise the pH. Because CO_2 is driven off in the roasting process, oxides are the most efficient of all liming materials on a pound-for-pound basis.

Oxides are powdery, so they are sold in bags. Oxides are also caustic; that is, they react with moisture and are difficult to handle. In addition, their cost is high relative to carbonate materials because of the high energy requirement for CO_2 removal. One ton of calcium oxide has the neutralizing power of 1.8 tons of pure calcitic limestone.

Hydroxides

Hydroxides are simply oxide materials with water added. They are also known as hydrated lime, slacked lime, or builders lime. These materials are similar to oxides because they are powdery, quick acting, and unpleasant to handle. Hydroxides are also more expensive than carbonate materials.

By-Product Lime Materials

Several by-products of mining, refining, processing, and manufacturing processes are used as liming materials. Slags from blast furnaces and electric furnaces as well as fly ash and bottom ash from coal-burning plants are often applied as lime. In the West, you can use lime sludges from sugarbeet processing plants (sugar lime), paper mills, ore processing, and water-softening plants to raise soil pH. Wood ashes from wood stoves or fireplaces also may be used.

The quality of these by-products is quite variable as the purity is often low. This means that more than 1 ton of material provides the same neutralizing power as 1 ton of calcitic limestone. Many times the by-product materials contain unwanted or excessive amounts of materials such as sodium (Na), which can adversely affect soil properties or other elements that may be undesirable to crop production, human consumption, or both. Make sure you know the complete chemical analysis of by-product lime material before purchasing.

Material Comparisons

In general, carbonate materials account for more than 90 percent of the lime used in the United States. Factors favoring carbonates over oxides and hydroxides include (1) ease of handling, (2) lower cost, and (3) the availability of many more sources. Although smaller amounts of hydroxides and oxides are needed for raising soil pH, those two materials generally are used only when the grower requires a rapid pH change.

Quality of Lime

The two factors primarily affecting the quality of liming materials are chemical composition or purity and physical properties or particle size.

Chemical Composition—The purity of a liming material is measured by its Calcium Carbonate Equivalence (CCE). This is defined as the acid-neutralizing capacity of the material compared to pure calcium carbonate. In CCE comparisons, pure calcium carbonate has been assigned a value of 100. Other terms occasionally used—neutralizing value (NV) and neutralizing power (NP)—basically have the same meaning as CCE.

The relative CCE measurements of several liming materials are shown in table 1. Calcitic limestone has a CCE of 100. Dolomite has a slightly greater CCE than calcium carbonate due to the lower atomic weight of Mg compared to Ca. Oxide materials have the highest CCE values since CO_2 is removed in the burning process. Marl and by-product materials have low CCE values because of impurities.

If, for example, we compare pure calcitic limestone (molecular weight=100) with pure calcium oxide (molecular weight=56), we see that 56 pounds of calcium oxide will neutralize the same amount of acid as 100 pounds of calcitic limestone. How much more effective then is 100 pounds of CaO than the same quantity of $CaCO_3$? This is demonstrated quite easily by the following proportion:

$$\frac{56}{100} = \frac{100}{X}$$

$$X = 179$$

$$CCE = 179$$

Table 1. Relative (CCE) values for different liming materials.

Material	Composition	CCE
Calcitic limestone	$CaCO_3$	98-100
Dolomitic limestone	$CaMg(CO_3)_2$	100-109
Calcium oxide	CaO	179
Magnesium oxide	MgO	250
Hydroxides	$Ca(OH)_2$ or $Mg(OH)_2$	120-136
Marl	$CaCO_3 \cdot X^*$	60-90
Slags	$CaSiO_3 \cdot X^*$	50-90
Sludges	$CaCO_3 \cdot X^*$	30-80
Wood ashes	X^*	30-50

*X indicates impurities of an unknown nature.

Physical Composition—Agricultural limestone, produced by crushing limestone rock, will range in particle size. Crushed limestone will usually be fine enough to pass a U.S. Standard No. 8 sieve (which has eight wires per inch and openings of 0.0937 inches on each side). The effect of particle size is shown in table 2. The finer the particle size (larger mesh number), the greater the soil pH change after 1 year. Table 2 shows that in about 3 years, the pH would be the same in all soils receiving lime. Note also that at the end of 1 year, the dolomite limestone finer than 100 mesh size increased soil pH more than the calcium carbonate. This would be expected since dolomite has a higher CCE value of 109.

Idaho has a fertilizer law requiring that the percentages of lime passing 10-, 60-, and 100-mesh sieves must be specified for any agricultural limestone. Although there are no provisions in the law as to percentages passing the sieves, for the best results minimum percentages of at least 90 percent of the lime material should pass a 10-mesh sieve and 50 percent should pass a 60-mesh sieve. At least 20 percent should pass a 100-mesh sieve. A liming material containing a range of particle sizes has the advantage that the small particles rapidly react to raise the soil pH, the medium-sized particles will react in 12 to 36 months, and the large particles will neutralize acidity over the longer term. If you apply insufficient amounts of lime, the benefit from the added lime may be negligible. Likewise, if all the lime material applied is coarse (low mesh number), the pH benefit may not be realized for several years.

Fluid Lime

Lime is usually applied to the soil as a solid material, but it can be applied in liquid form as a suspension. Lime is relatively insoluble in water; thus, it is not dissolved but is suspended in solution. Known as fluid or liquid lime, this suspension consists of 50 percent water, 48 percent lime solids, and 2 percent clay to maintain a suspension. The material used in this suspension should pass a 100-mesh sieve. The advantages of using liquid lime include (1) good application uniformity,

Table 2. The influence of lime particle size on soil pH change 1 year after application. Two tons of lime were applied to all treatments except the control.

	Soil pH		Relative effectiveness	
Lime particle size (mesh)	Calcitic limestone	Dolomitic limestone	Calcitic limestone	Dolmitic limestone
No lime (check)	5.0	5.0	0	0
4-8	5.0	5.0	5	8
20-30	5.6	5.5	54	39
40-50	5.9	5.8	74	65
60-80	6.3	6.2	96	84
100	6.5	6.6	100	100

(2) high quality lime material (mesh size), and (3) quick soil pH change. Using liquid lime also gives the operators the opportunity to apply N solutions in the same suspension. The major disadvantage of liquid or fluid lime is that it is 50 percent water, making the cost relatively high per unit of lime actually applied. A maximum of only 500 pounds of lime per acre can be applied in this manner.

Time of Application

Apply lime any season that the cropping sequence permits. Lime must be uniformly applied **and** mixed into the soil 4 to 6 inches deep. Lime is not mobile in soils and will only change the pH where it contacts the soil. When a carbonate material is applied, soil pH will change within 6 to 12 months. Often the benefit will not appear until the second crop after liming.

Conservation tillage presents special problems when liming. Apply lime when maximum soil disturbance occurs to allow the best distribution in the soil profile. Applying lime to the soil surface without incorporating it will not significantly change soil pH.

Lime Requirement Soil Test

Soil tests help determine the amount of lime required to raise soils to a desired pH. Perform a lime requirement test on all soils with a pH of 5.1 or lower. Soil pH is more critical for legumes such as alfalfa, lentils, and peas than for cereals. Consequently, for soils testing less than pH 5.5, perform a lime requirement test where legumes are grown. Numbers obtained from lime requirement soil tests are often meaningless when soil pH values exceed 5.6.

Several different lime requirement tests have been developed to determine the amount of lime needed for improving crop yields. The two tests that work best on northern Idaho soils are SMP and Woodruff. Have your laboratory select one of them.

Rates of Lime to Apply

In Idaho, application rates for acid agricultural soils commonly range from 1 to 2 tons of lime per acre. Soils are usually limed to a pH of 6.0 to 6.1. A lime requirement test is necessary for determining the correct amount of lime to apply because over-applications may decrease soil productivity. In addition to soil pH, soil texture, clay content, cation exchange capacity (CEC), base saturation, and other factors affect the amount of lime needed. A lime requirement test considers all these factors.

Applying Lime

Special applicators are required to spread lime in the field uniformly. Normal fertilizer applicators are not suitable because of lime's range in particle size. Consequently, liming costs are often increased by the need for additional equipment, custom applications, or both.

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