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Liming Materials

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The continued pH decline (increasing soil acidity) in agricultural soils in northern Idaho has created the need to consider the application of soil amendments to increase soil pH. Problems associated with acid soils include: (1) aluminum toxicity, (2) phosphorus deficiency, (3) micronutrient toxicity problems (boron, copper, manganese, zinc), (4) lack of or reduced microbial activity in the soil and (5) poor plant growth.

One method of increasing soil pH is by applying liming materials to these highly acid soils. This publication provides information about available materials that can be used to raise 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, it cannot neutralize soil acidity. In addition to adding Ca, gypsum also supplies sulfur (S), an essential plant nutrient. Additions of gypsum have little or no benefit for increasing soil pH.

Carbonates

Carbonates are the liming materials most widely available and most widely used. Ground high grade limestone or calcitic limestone is nearly pure calcium carbonate ($CaCO_3$). This material is the most commonly used lime source. Its major advantage is its relative low cost. Dolomitic limestone or dolomite ($MgCO_3CaCO_3$) 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 over 90% of the lime used in the United States. Both materials are naturally occurring rocks that are mined and ground for agricultural use.

Marl and oyster shells are also considered carbonate materials. Marl is a naturally occurring mixture of clays, carbonates of Ca and Mg and remnants of shells. Oyster shells are pure calcium carbonate but are important only in 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 roasting crushed calcitic limestone or dolomitic limestone in an oven or furnace, thereby driving off carbon dioxide (CO_2) to form a pure oxide (CaO 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 caustic, 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 is equivalent to 1.8 tons of pure calcitic limestone.

Hydroxides

Hydroxides are simply oxide materials to which water has been 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, lime sludges from sugarbeet processing plants (sugar lime), paper mills and water softening plants may be used 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 is needed to provide 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.

Material Comparisons

In general, the carbonate materials account for over 95% 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 fact that many more sources are available. Although smaller amounts of hydroxides and oxides are needed to raise the soil pH, those two materials are generally used only when a rapid pH change is required.

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.

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
Oxides	CaO or MgO	150-179
Hydroxides	$Ca(OH)_2$ or $Mg(OH)_2$	120-136
Marl	$CaCO_3$•X*	60-90
Slags	$CaSiO_3$•X*	50-90
Sludges	$CaCO_3$•X*	30-80
Wood ashes	X*	30-50

*X indicates impurities of unknown nature.

Physical Composition — Agricultural limestone, produced by crushing limestone rock, will have a range of particle sizes. Crushed limestone will usually be fine enough to pass a U.S. Standard No. 8 sieve (which has 8 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. Note in Table 2 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.

Idaho has a fertilizer law that states 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% of the lime material should pass a 10-mesh sieve and 50% should pass a 60-mesh sieve. At least 20% 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 insufficient amounts of lime are applied, the benefit from the added lime may be negligible. Likewise, if all the lime material applied is coarse (low mesh number), several years may be needed to realize the pH benefit.

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 lime is not dissolved but is suspended in solution. Known as fluid or liquid lime, this suspension consists of 50% water, 48% lime solids and 2% clay to maintain a suspension. The material used in this suspension should pass a 100-mesh sieve. Advantages of using liquid lime include: (1) good uniformity of application, (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% water, making the cost relatively high per unit of lime actually applied. A maximum of only 500 lb lime/acre can be applied in this manner because of economic considerations.

Time of Application

Lime can be applied any season that the cropping sequence permits. Ideally, the lime should be uniformly applied and mixed into the soil to a depth of 4 to 6 inches. Lime is not mobile in soils and will only change the pH where it comes in contact with the soil. When a carbonate material is applied, soil pH will change 6 to 12 months later. Often the benefit will appear in the second crop after liming.

Conservation tillage presents special problems when liming. Lime should be applied at the time maximum soil disturbance occurs to allow the best distribution of lime in the soil profile.

Lime Requirement Soil Test

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

Rates of Lime to Apply

Rates of lime commonly applied to acid agricultural soils range from 1 to 2 tons per acre. Soils are usually limed to a pH of 6.0 to 6.1. A lime requirement test is necessary to determine the correct amount of lime to apply because over-applications may result in decreased soil productivity. In addition to soil pH, soil texture, amount of clay, 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 uniformly spread lime in the field. Normal fertilizer applicators are not satisfactory. Consequently, liming costs are often increased by the need for additional equipment and/or custom applications.

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.

Lime particle size (mesh)	Soil pH		Relative effectiveness	
	Calcitic limestone	Dolomitic limestone	Calcitic limestone	Dolomitic 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

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