Alaska Agronomy Technical Note 15
Liming Alaska Soils

Introduction
Liming materials are incorporated into the soil to increase pH. Lime applications are required on many soils in Alaska to (1) reduce aluminum toxicity, (2) increase P availability, (3) increase micronutrient availability, (4) increase soil microbial activity, and (5) overcome poor plant performance.

Lime contains calcium (Ca) or magnesium (Mg) and neutralizes acidity. Calcium carbonate (CaCO3) is the most commonly used liming material that contains plant available Ca and acidity neutralizing CO3 2- (see Alaska CES Publication FGV-00242A, *Soil Fertility Basics–pH).*

Gypsum (calcium sulfate, CaSO4) and calcium nitrate (Ca(NO3)2) are not liming materials. Although both materials add calcium to the soil, the sulfate and nitrate have little capacity to neutralize acidity.

Numerous materials come under the heading of lime including limestone, burned lime, slaked lime, marl, oyster shells, slag, wood ashes, mine tailings, and many more. There are four categories into which these materials are grouped. They are oxides, hydroxides, carbonates and by-product materials.

Carbonates
Carbonates are widely available and the most commonly used liming materials. Mined high-grade limestone or calcitic limestone, when ground, is almost pure calcium carbonate (CaCO3). This is an excellent liming material due to relatively low cost and availability. Dolomitic limestone (a combination of MgCO3 and CaCO3) is also widely used though usually more costly. Dolomite is important in areas with low soil Mg levels since this material provides both Ca and Mg.

Marls come from naturally occurring deposits of Ca and Mg carbonates, clay, and shell remnants and can be used to increase soil pH. Oyster shells are pure calcium carbonate which, when finely ground, increase soil pH.

Oxides
Quicklime, unslaked lime and burned lime are examples of oxide liming materials. Crushed calcitic or dolomitic limestone is oven- or furnace-burned which drives off CO2 forming pure oxide (CaO or MgO). These materials are the most efficient liming materials on a pound-for-pound basis and react rapidly with the soil to increase pH.

Oxides are powdery, caustic, and reactive with moisture so they are usually sold in bags. Due to the large amount of energy required to remove CO2, oxide materials are more expensive than carbonate materials.

Hydroxides
Hydroxides are hydrated oxides or simply oxides mixed with water. Common hydroxide limes include slaked lime, hydrated lime or builder's lime. Hydroxides react similarly to oxides in the soil and are also powdery and unpleasant to handle.

By-Product Materials
Mining, refining, processing, and manufacturing industries produce numerous by-products useful for increasing soil pH. Slags from blast and electric furnaces along with fly and bottom ash from coal burning plants are used in agricultural liming. Sugar beet processing plants use large amounts of lime in the sugar extraction process. This process generates lime sludge that is used as a liming material. Wood ashes from wood stoves and fireplaces can also be used to increase soil pH. Carbide lime from acetylene production is nearly pure Ca(OH)2 and an important lime source in Alaska. Probably the major problems with by-product lime sources involve variability in quality (purity) and fineness. Also, these materials may contain other elements or minerals which may be either toxic to plants or accumulate in the soil.

Pelletized Lime
Pelletized lime is finely ground agricultural limestone that is pelletized with the aid of clay or synthetic binders to produce pellets in the 5 to 14-mesh range. Usually, about 70 percent of the initial limestone, prior to pelletizing, passes through 100 to 200 mesh sieves. In contact with water pelletized lime "melts" to release the liming materials within the pellet. It may be spread with conventional spinner fertilizer spreaders, which makes it attractive to use for some producers. It is generally more expensive than ground agricultural limestone due to the cost of the pelletizing process.

Fluid Lime
Fluid lime generally consists of finely ground limestone, most of which will pass a 200-mesh screen, suspended in water at a ratio of about 50% water to 50% limestone. It would be almost impossible to apply such finely ground limestone as a solid material because of the dust problem. By mixing these finely ground limestone materials with water, fluid lime can be easily and accurately be applied using a sprayer. The main disadvantages of fluid lime are the added cost of application due to the 50% dilution of the liming material with water and the number of application trips across the field.

Lime Quality
Chemical composition (purity) and particle size are the two attributes which define the potential effectiveness of liming materials.

Chemical Composition
Calcium Carbonate Equivalence (CCE) is used to measure the relative effectiveness of liming materials and is a function of purity. The scale is designed to compare all liming materials to pure calcium carbonate, which is assigned a value of 100. CCE values for various liming materials are shown in Table 3. Note that marl, slags, sludges and wood ashes have considerably less acid-neutralizing power than the oxides, hydroxides or carbonates. This is due to the high level of impurities found in by-product lime sources.

Physical Composition
Since agricultural limestone is produced by crushing limestone rock, particle sizes vary. Particle size is important because it is related to acid-neutralizing activity. Finely ground materials (smaller particle size) react more rapidly in soil than coarse ground materials (large particle size). Most ground limestone will pass a U.S. Standard No. 8 sieve (8 wires per inch, each opening 0.0937 by 0.0937 inches) and as much as 40% passes a 100 mesh sieve. As a rule, remember the higher the sieve number the finer the grind of the limestone.

Lime Requirement
The lime requirement is the amount of lime needed to increase soil pH to a desired level. The amount is determined by testing the soil. Lime recommendations are established by comparing individual soil test values to values from calibration experiments. Crops differ in their sensitivity to soil acidity so soil testing for lime should be crop specific. A combination of water pH and SMP buffer index is used for making lime recommendations in Alaska. Optimum crop soil pH ranges are shown in Table 2.

Application Rate
Lime application rates are typically much higher than fertilizer application rates. Soils should be limed to a pH of 6.0 to 6.5 for the best crop production. At a minimum, soils should be limed to meet the lowest pH level shown in Table 2, however, maximum benefits from liming will not be obtained and/or sustained from liming to meet minimum levels. Table 4 is provided for use with SMP buffer soil test information. Simply find the SMP buffer value for each soil sample in the first column, then follow horizontally across to either of the lime requirement columns, tons/acre. Use these recommended amounts of lime to increase soil pH to approximately 6.5. If surface applying lime, apply no more than two and one-half tons per acre per year. Up to four tons per acre may be applied if the lime is worked into the soil. In situations where soil pH is extremely low and a large amount of lime is recommended, it may be a good idea to spread the cost over two to three years by annually applying one-third or half of the lime needed.

Application Timing
To adjust soil pH lime must ‘react’ in the soil following application. Since water is required for lime to react with the soil, effects of a lime application will be slower in a dry soil. It often takes a year or more before a response can be measured even under perfect conditions. However, a response may be observed within weeks of the application when soil pH is extremely low.

It is important to apply lime immediately after the growing season or crop removal to allow lime to react and begin to correct the soil pH before the next growing season. Fall application of liming materials prior to soils becoming frozen is recommended in Alaska. Whenever possible, tillage should be used as a tool to incorporate lime six inches into the soil. When lime is worked into the soil, a larger portion of its surface area is exposed to the soil allowing for faster reactivity. Lime applied on the soil surface does not react as fast as lime incorporated by tillage but is generally the only option for perennial pasture systems. Surface-applied lime moves into the soil at a slow rate. It is similar to non-mobile nutrients in its movement in the soil. Even though it is best to incorporate lime whenever possible, it is still important to surface-apply lime to correct the soil acidity problem in established pastureland and no-till cropping systems.

The reactivity time also depends on the type of lime used. Liming materials differ widely in their neutralizing powers due to variations in the percentage of calcium and/or magnesium. Usually, liming materials with a high calcium carbonate equivalent (CCE) tend to neutralize soil acidity faster than those with a low CCE. The coarseness of the liming material will also influence how fast the lime will react. The finer the liming material the quicker the liming material will take affect.

Application Methods

Finely ground liming materials are difficult to handle and apply evenly. Even with the best calibration techniques for liming equipment it is difficult to apply exact amounts of agricultural lime. Most application techniques and spreaders will result in applications that fall within 500 lbs per acre. There are two types of lime spreaders, spinner and full-width or boom spreaders.

The most common application method for lime is by spinner spreader. Unfortunately, this application method can also be the poorest when considering lime application calibration and distribution. Double spinners are better than single spinners; however, all normally apply more lime immediately behind the spreader than to the sides. In practice, rates are adjusted by checking the spreader pattern, overlapping the pattern, and double spreading, making the second pass at right angles to the first. If done properly, this is an acceptable way to apply lime.

Lime can be more evenly applied using full-width or boom spreaders. Full-width spreaders allow lime to fall to the ground by gravity. The rate is determined by the size of the openings in the box and by ground speed. Boom spreaders use drag chains, augers, or pneumatic pressure to move lime out the booms and drop it on the ground. If adjusted properly, both types of spreaders are vastly superior to the spinner type. The main limitations to their use are the high initial cost and more complex operation. Most growers will likely continue to spread lime using spinner spreaders, but if you choose that method you should be aware of the limitations and take every precaution to see that the lime is evenly spread.

Table 2. **Optimum Crop Soil pH Ranges**

	Optimum pH range[1]		Optimum pH range[1]
alfalfa	6.5 - 8.0	lettuce	5.8 - 7.0
apples	4.8 - 6.5	lupine	5.5 - 7.0
apricots	4.8 - 6.5	oats	5.5 - 7.0
barley	6.5 - 8.0	parsnips	5.3 - 6.8
beets	5.8 - 8.0	peas	5.8 - 6.8
blackberries	5.7 - 6.5	peppers	5.3 - 6.8
blueberries	4.0 - 4.8	potatoes	4.9 - 6.2[2]
broccoli	6.0 - 7.5	pumpkins	5.3 - 7.5
brussels sprouts	6.0 - 7.5	quackgrass	5.5 - 6.5
cabbage	5.8 - 8.0	radishes	5.8 - 7.0
carrots	5.3 - 6.8	rape	6.0 - 7.5
cauliflower	5.8 - 7.0	raspberries	5.7 - 6.5
celery	5.8 - 7.0	red fescue	5.5 - 6.5
cherries	4.8 - 6.5	reed canary grass	6.0 - 7.0
chinese cabbage	6.9 - 7.5	rhubarb	5.8 - 7.0
chives	5.8 - 7.0	rutabagas	5.3 - 6.8
clover,		rye	5.0 - 7.0
alsike	5.5 - 7.5	snap beans	5.3 - 6.8
red	6.0 - 7.5	spinach	5.8 - 7.5
white	6.0 - 7.5	strawberries	4.8 - 6.5
cucumbers	5.3 - 6.8	squash	5.3 - 7.5
currants	5.8 - 8.0	timothy	5.5 - 7.5
gooseberries	5.8 - 8.0	tomatoes	5.3 - 7.5
horseradish	5.8 - 7.0	turnips	6.0 - 7.0
kentucky bluegrass	5.5 - 8.0	wheat	6.0 - 8.0
		vetch	5.5 - 7.0

[1] These ranges are estimates only; they are for mineral soils (not mucks or peats).

[2] Potatoes grown at the upper end of this range may be more susceptible to potato scab than those grown at lower pHs.

Source: Walworth, J. L. 1992. *Soil Fertility Basics*. University of Alaska, Cooperative Extension Service Publication100G-00242A.

Table 3. Calcium Carbonate Equivalence (CCE) values of various liming materials.

Liming Material	Chemical Composition	CCE
Calcitic limestone	$CaCO_3$	98 - 100
Dolomitic limestone	$CaMg(CO_3)_2$	100 - 109
Hydroxides	$Ca(OH)_2$ or $Mg(OH)_2$	120 - 136
Oxides	CaO or MgO	150 - 179
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 unknown impurities.

Source: Mahler, R.L. and R.E. McDole. 1986. Liming materials. University of Idaho Current Information Series No. 787.

Pull-type lime spinner spreader.

Boom type Lime Spreader.

Table 4.

Appendix 2
From
Lime Requirements Indices of Alaskan Soils by Thomas Loynachan
Agricultural Experiment Station
School of Agriculture and Land Resources Management
University of Alaska
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Suggested agricultural lime additions for SMP buffer pH for Alaskan soils. This appendix is based on the data of Shoemaker, et al.(1) as adjusted by equation C Table 4 of the text and considering a liming factor of 1.8. Values are expressed as tons of agricultural-grade lime[1] required to adjust soil pH to the indicated pH based on an acre 6-inch volume of soil.

SMP Buffer pH	**Final Soil pH**		
	6.0	**6.5**	**7.0**
	Tons per Acre	Tons per Acre	Tons per Acre
6.9	0	0	0
6.8	0.3	0.5	.6
6.7	0.7	1.0	1.2
6.6	1.1	1.4	1.7
6.5	1.5	1.9	2.3
6.4	1.9	2.4	2.9
6.3	2.3	2.9	3.5
6.2	2.7	3.3	4.0
6.1	3.1	3.8	4.5
6.0	3.5	4.3	5.2
5.9	3.9	4.8	5.8
5.8	4.2	5.2	6.3
5.7	4.6	5.8	6.9
5.6	5.0	6.2	7.4
5.5	5.5	6.8	8.0
5.4	5.9	7.2	8.6
5.3	6.2	7.6	9.2
5.2	6.6	8.2	9.8
5.1	7.0	8.6	10.4
5.0	7.4	9.2	11.0
4.9	7.8	9.6	11.6
4.8	8.2	10.2	12.1

[1] Amounts of lime are based on agricultural-grade limestone (95% through a 8-mesh and 40% through 100-mesh sieve, and 90% Calcium Carbonate equivalent).

(1) Shoemaker, H.E., E.O. McLean, and P.F. Pratt. 1961. Buffer methods for determining lime requirement of soils with appreciable amounts of extractable aluminum. Soil Sci. Soc. Amer. Proc. 12:141-142.