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ENVIRONMENTAL SCIENCE AND TECHNOLOGY ● H.J. PATTERSON HALL ● COLLEGE PARK, MD 20742
PHONE (301) 405-1351 ● FAX (301) 314-2763 ● MCGRATHJ@UMD.EDU

Soil Fertility Management

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SOIL pH MANAGEMENT AND DETERMINING LIMING RATES

What is soil pH?

Determination of soil pH is a measurement of the acidity or alkalinity of a soil. The pH scale ranges from 0 (very acidic) to 14 (very alkaline). At pH 7, the soil is neutral, neither acidic nor alkaline. To help put the pH scale into perspective: lemon juice is very acidic (pH 2), vinegar is also acidic (pH 3), rainfall is slightly acidic (pH 5 to 6), pure water is neutral (pH 7), bicarbonate of soda is slightly alkaline (pH 8), milk of magnesia is quite alkaline (pH 10), and bleach is very alkaline (pH 13). Plant growth and plant nutrient availability from a soil are strongly influenced by soil pH.

What is the optimum soil pH?

The optimum soil pH varies for different crops. Most agronomic crops grow best in slightly acidic soil with pH between 6.0 and 6.5. Some crops, like alfalfa, perform best at a slightly higher soil pH, between 6.6 and 7.0. On the other hand, potato and sweet potato yields are optimized at a soil pH of approximately 5.2, and tobacco production is best at pH 5.6. Several horticultural species (azalea, rhododendron, and blueberry) perform best under even more acidic soil conditions.

How do I adjust soil pH?

Most of our farmland soils are acid generating soils and soil pH tends to decline over time. Therefore, in an effort to maintain an optimum soil pH for crop production, we amend our soils with liming materials that neutralize soil acidity. A liming material may be any substance that reduces the acidity of a soil. Typically, liming materials are oxide, hydroxide, or carbonate forms of calcium and/or magnesium. It is the oxide, hydroxide, or carbonate contained in the liming material, and *not* the calcium or magnesium, that acts to neutralize soil acidity. Different liming materials have different acid neutralizing capabilities.

Liming materials are most effective at neutralizing soil acidity when they are thoroughly incorporated and mixed with the soil of the plow layer (8 inches deep). For continuous no-tillage row crop production or for topdressing hay or pasture land, liming is still effective, but annual lime application rates should not exceed 1,500 pounds oxides per acre. (See discussion of total oxide content, below, and Tables 2 and 3.)

Lime effectiveness and the quantity of a liming material necessary to achieve a

desired adjustment in soil pH will vary by soil type, soil texture, and soil organic matter content. The impact of different soil types on liming recommendations is evident in Tables 2 through 5.

How is the acid neutralizing capability of different liming materials expressed?

The acid neutralizing capability of liming materials may be expressed in several ways. The most useful determination of neutralizing capability is the determination that permits the most simple and direct application of the recommendations provided by your soil testing laboratory.

The *calcium carbonate equivalent* (CCE) expresses the relative ability of a liming material to neutralize acid as compared to pure calcium carbonate (pure pulverized limestone). The CCE is determined by the chemical composition of the liming material. Table 1 presents average acid neutralizing values, expressed as CCE, for some common liming materials. The physical particle size of the liming material is sometimes used together with the CCE to determine the *effective neutralizing value* (ENV) of the liming material.

Often, the acid neutralizing potential of a liming material is determined from the *total oxide content* (calcium oxide plus magnesium oxide) of the liming material. The physical particle size of a liming material also may be used in conjunction with the liming material's oxide content to determine a lime application rate adjusted for lime fineness.

Any one of the above methods of expressing the relative acid neutralizing capacity of liming materials may be the most useful and convenient as you attempt to follow the liming recommendations of your soil testing laboratory. Purchased liming materials must be accompanied by a product description label that describes the acid neutralizing value of the material. Always refer to the labeled acid neutralizing information provided with the purchased liming material when making lime application rate decisions.

Table 1. Typical acid neutralizing value, expressed as calcium carbonate equivalent (CCE), of common liming materials and the quantity of each liming material necessary to achieve acid neutralization equivalent to one ton (2,000 pounds) of pure pulverized limestone.

Liming material	Calcium carbonate equivalent (CCE)	Equivalent to one ton pure limestone
	%	*pounds*
Ground limestone, calcitic limestone, calcitic lime, calcite, hi-cal limestone, calcium carbonate	100	2,000
Burned lime, quick lime, unslaked lime, calcium oxide	178	1,120
Hydrated lime, builders' lime, slaked lime, calcium hydroxide	134	1,490
Dolomitic limestone, hi-mag limestone, calcium magnesium carbonate	95 - 109	1,830 - 2,100
Ground shells	80 - 90	2,200 - 2,500
Calcium silicate slag	70 - 80	2,500 - 2,860
Blast furnace slag, basic slag	67 - 75	2,670 - 2,990
Flue dust	96	2,080
Marl	40 - 90	2,220 - 5,000
Wood ashes	40	5,000

How do I use the total oxide analysis of a liming material to determine liming rate?

Total oxide content of a liming material is typically the sum of the percent calcium oxide (CaO) plus the percent magnesium oxide (MgO) contents. This information is usually stated on the label of purchased liming materials. Frequently, recommended liming rates are expressed in pounds per acre of oxides. Thus, if a soil test recommends lime application in pounds of oxides per acre, then the corresponding application rate of a given liming material would be:

$$\frac{\text{pounds oxides/acre}}{\%\text{ total oxides}} \times 100 = \text{pounds lime/acre}$$

Example 1, below, demonstrates the use of total oxide content to determine lime application rate. Calculated lime application rates should be rounded off to the nearest quantity practical for the spreading equipment to apply. Typically, agricultural lime application rates are approximated no closer than to the nearest 500 pounds / acre application rate.

Example 1*: A soil test analysis recommends the application of 2,000 pounds oxides / acre. Liming material #1 contains 29% CaO and 37% MgO. Liming material #2 contains 33% CaO and 8% MgO. What are the corresponding lime application rates for the two liming materials?*

Material #1

Total oxides = 29% CaO + 37% MgO
Total oxides = 66%

$$\frac{\text{2,000 lbs oxides/acre}}{66\%\text{ oxides}} \times 100 = \text{3,030 lbs lime / acre}$$

Apply 3,000 pounds lime / acre

Material #2

Total oxides = 33% CaO + 8% MgO
Total oxides = 41%

$$\frac{\text{2,000 lbs oxides/acre}}{41\%\text{ oxides}} \times 100 = \text{4,878 lbs lime / acre}$$

Apply 5,000 pounds lime / acre

How do I determine effective neutralizing capacity of a liming material?

The effective neutralizing capacity of a liming material is determined by the chemical composition of the liming material and the physical particle size, or fineness, of the material. The chemical characteristics are typically expressed as either the calcium carbonate equivalent (CCE) or total oxide content of the liming material. The finer the particle size, the more reactive the material. Coarse materials with large particles are much less reactive and much less effective at neutralizing soil acids.

Liming materials are graded for particle size, or fineness, by determining the percentage of the material that passes through each of a series of sieves with increasing mesh size (smaller openings). The calculated *fineness factor* uses the percent (by weight) of the material retained by an 8-mesh sieve, the percent retained by a 60-mesh sieve, and the percent that passes through a 60-mesh sieve. The material retained by the 8-mesh sieve is assumed to be not effective in neutralizing soil acidity for the following crop season. The material that passes through the 8-mesh sieve but is retained by the 60-mesh sieve is assumed to have 50% neutralizing effectiveness and that which passes through the 60-mesh sieve is assumed to be 100% effective at neutralizing soil acidity for the following crop season.

Particle size information should be used to adjust lime application rates. The fineness factor may be used to adjust the lime application based on total oxide content by correcting for the particle size of the liming material (*Example 2*).

Frequently, lime application rate recommendations are based on the assumption that pure calcium carbonate, CCE = 100%, will be used. Actual application rates should be corrected for the true CCE and particle size of the liming material.

The fineness factor may be used to modify the CCE of a liming material by calculating the *effective neutralizing value (ENV)* of the material (*Example 3*).

Liming recommendations

Recommended lime application rates based on the total oxide content of the liming material and initial soil pH, are presented in Tables 2 through 5, for agronomic crops having a target pH of 6.5, alfalfa with a target pH of 7.0, tobacco with a target pH of 5.6, and potato with a target pH of 5.2, respectively. These recommendations assume a fineness factor of 100%. Application rates of liming materials with fineness factors less than 100% should be adjusted as outlined in *Example 2*.

Remember, even the most precisely calculated lime application rate is only as accurate as the spreader used to apply the lime. Check the calibration of spreader equipment regularly. Take time to verify the application rate of custom applied lime.

Soils can be over-limed as easily as they can be under-limed. Both over-liming and under-liming can reduce yields. A program of routine soil testing can help manage soil pH, maximize crop yields, and minimize input costs.

Prepared by:

Frank J. Coale

Soil Fertility/Nutrient Management Specialist

Department of Natural Resource Sciences and Landscape Architecture

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Example 2: *Liming material #1 from Example 1 has the following sieve analysis: 95% passes through an 8-mesh sieve and 81% passes through a 60-mesh sieve. What is the adjusted application rate of liming material #1 after correction for particle size?*

% retained by 8-mesh sieve: 100% - 95% = 5%
% retained by 60-mesh sieve: 95% - 81% = 14%
% passing through 60-mesh sieve: = 81%

***Calculated fineness factor*:**
5% retained by 8-mesh x 0% effectiveness = 0%
14% retained by 60-mesh x 50% effectiveness = 7%
81% passing 60-mesh x 100% effectiveness = 81%
Fineness factor = 0% + 7% + 81% = 88%

Application rate of liming material #1 corrected for particle size:

3,000 lbs lime/acre x 100 = 3,409 lbs lime / acre
88% fineness factor
Apply 3,500 pounds lime / acre

Example 3: *Calculate the effective neutralizing value (ENV) of an agricultural limestone that has a CCE = 90% and a sieve analysis of: 98% passes through 8-mesh sieve and 76% passes through 60-mesh sieve. What is the correct lime application rate if a soil test recommends applying 3,000 lbs lime/acre, assuming a liming material with CCE=100% and ENV=100%?*

% retained by 8-mesh sieve: 100% - 98% = 2%
% retained by 60-mesh sieve: 98% - 76% = 22%
% passing through 60-mesh sieve: = 76%

***Calculated fineness factor*:**
2% retained by 8-mesh x 0% effectiveness = 0%
22% retained by 60-mesh x 50% effectiveness = 11%
76% passing 60-mesh x 100% effectiveness = 76%
Fineness factor = 0% + 11% + 76% = 87%

ENV = CCE x Fineness factor = 90% x 87% = 78.3%

Application rate corrected for ENV:
3,000 lbs/acre recommended rate x 100 = 3,831 lbs/acre
78.3% ENV
Apply 4,000 pounds lime / acre

Table 2. Recommended application rates for liming materials based on total oxide content for most agronomic crops. Target soil pH = 6.5. Recommendations presented by soil texture and region within Maryland.*

Initial soil pH	Loamy Sand All Regions	Sandy Loam All Regions	Loam Coastal Plain	Loam Piedmont & Mountain	Silt Loam & Clay Loam Coastal Plain	Silt Loam & Clay Loam Piedmont & Mountain
	Pounds per Acre of Total Oxides					
6.5	0	0	0	0	0	0
6.4	0	0	0	0	0	0
6.3	0	0	0	0	0	1000
6.2	0	0	1000	1000	1000	1000
6.1	0	1000	1000	1000	1000	1500
6.0	500	1000	1000	1000	1000	2000
5.9	500	1000	1000	1500	1000	2000
5.8	500	1000	1500	1500	1500	2500
5.7	500	1000	1500	2000	1500	3000
5.6	1000	1500	1500	2000	2000	3500
5.5	1000	1500	2000	2500	2000	3500
5.4	1000	1500	2000	2500	2000	4000
5.3	1000	2000	2000	3000	2500	4500
5.2	1500	2000	2500	3000	2500	4500
5.1	1500	2000	2500	3500	3000	4500**
5.0	1500	2500	2500	3500	3000	4500**
4.9	1500	2500	3000	4000	3000	4500**
4.8	2000	2500	3000	4000	3500	4500**
4.7	2000	3000	3500	4000**	3500	4500**
4.6	2000	3000	3500	4000**	3500**	4500**
4.5	2000	3000	3500	4000**	3500**	4500**

* For continuous no-tillage or for topdressing hay or pasture land, lime application rates should not exceed 1,500 pounds total oxides / acre / year. Soil pH should be measured within one year of lime application to determine the quantity of additional lime needed.

** The amount of oxide recommended probably will not be enough to raise soil pH to 6.5, but is the maximum amount that should be applied in one application. Soil pH should be measured within one year of lime application to determine the quantity of additional lime needed.

Table 3. Recommended application rates for liming materials based on total oxide content for alfalfa seedbed preparation. Target soil pH = 7.0. Recommendations presented by soil texture and region within Maryland.*

Initial soil pH	Loamy Sand All Regions	Sandy Loam All Regions	Loam Coastal Plain	Loam Piedmont & Mountain	Silt Loam & Clay Loam Coastal Plain	Silt Loam & Clay Loam Piedmont & Mountain
	Pounds per Acre of Total Oxides					
7.0	0	0	0	0	0	0
6.9	0	0	0	0	0	0
6.8	0	0	0	0	0	1000
6.7	0	0	1000	1000	1000	1000
6.6	0	1000	1000	1000	1000	1500
6.5	500	1000	1000	1000	1000	2000
6.4	500	1000	1000	1500	1000	2000
6.3	500	1000	1500	1500	1500	2500
6.2	500	1000	1500	2000	1500	3000
6.1	1000	1500	1500	2000	2000	3500
6.0	1000	1500	2000	2500	2000	3500
5.9	1000	1500	2000	2500	2000	4000
5.8	1000	2000	2000	3000	2500	4500
5.7	1500	2000	2500	3000	2500	4500
5.6	1500	2000	2500	3500	3000	5000
5.5	1500	2500	2500	3500	3000	5000**
5.4	1500	2500	3000	4000	3000	5000**
5.3	2000	2500	3000	4000	3500	5000**
5.2	2000	2500	3500	4500	3500	5000**
5.1	2000	3000	3500	4500	4000	5000**
5.0	2000	3000	3500	4500**	4000	5000**
4.9	2500	3000	4000	4500**	4000	5000**
4.8	2500	3500	4000	4500**	4500	5000**
4.7	2500	3500	4000**	4500**	4500	5000**
4.6	2500	3500	4000**	4500**	4500**	5000**
4.5	2500	3500	4000**	4500**	4500**	5000**

* For topdressing established alfalfa, lime application rates should not exceed 1,500 pounds total oxides / acre / year. Soil pH should be measured within one year of lime application to determine the quantity of additional lime needed.

** The amount of oxide recommended probably will not be enough to raise soil pH to 7.0, but is the maximum amount that should be applied in one application. Soil pH should be measured within one year of lime application to determine the quantity of additional lime needed.

Table 4. Recommended application rates for liming materials based on total oxide content for tobacco. Target soil pH = 5.6. Recommendations presented by soil texture and region within Maryland.

Initial Soil pH	Loamy Sand All Regions	Sandy Loam All Regions	Loam All Regions	Silt Loam & Clay Loam All Regions
	Pounds per Acre of Total Oxides			
5.6	0	0	0	0
5.5	0	0	0	0
5.4	0	150	200	200
5.3	150	250	250	300
5.2	200	300	350	400
5.1	250	400	450	500
5.0	300	450	550	600
4.9	350	550	650	700
4.8	400	600	700	750**
4.7	450	700	750**	750**
4.6	500	750	750**	750**
4.5	550	750**	750**	750**

** The amount of oxide recommended probably will not be enough to raise soil pH to 5.6, but is the maximum amount that should be applied in one application. Soil pH should be measured within one year of lime application to determine the quantity of additional lime needed.

Table 5. Recommended application rates for liming materials based on total oxide content for potato and sweet potato. Target soil pH = 5.2. Recommendations presented by soil texture and region within Maryland.

Initial soil pH	Loamy Sand All Regions	Sandy Loam All Regions	Loam		Silt Loam & Clay Loam	
			Coastal Plain	Piedmont & Mountain	Coastal Plain	Piedmont & Mountain
	Pounds per Acre of Total Oxides					
5.2	0	0	0	0	0	0
5.1	0	50	100	100	100	200
5.0	100	150	200	250	200	350
4.9	150	250	250	350	300	550
4.8	200	300	350	500	400	700
4.7	250	350	450	600	500	900
4.6	300	450	550	750	600	1100
4.5	350	550	650	850	700	1300