



AGRICULTURAL LIME AND LIMING, PART 3: AGLIME PRODUCT SELECTION AND COMPARISON CALCULATOR USER GUIDE

Soil Acidification Series

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AGRICULTURAL LIME AND LIMING, PART 3: AGLIME PRODUCT SELECTION AND COMPARISON CALCULATOR USER GUIDE

By

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Abstract

Decreasing soil pH, also called soil acidification, is a growing concern in eastern Washington and northern Idaho. Researchers and farmers have measured soil pH values below 5.0 throughout the Palouse region, in particular. Decreasing soil pH has serious implications for the cropping systems of the Palouse.

This publication is part of a series on soil acidification and discusses the attributes used to perform calculations to characterize liming material, while the interactive utility provides a platform to compare up to three liming materials for their relative effectiveness, costs, and economic efficiency. The series begins with An Introduction, covering the fundamentals of soil pH and acidification, and continues with other fact sheets on more specific topics such as the influence of pH on pathogens and microbes, recommended varieties of specific crops, herbicide activity, crop nutrition, and liming.

Agricultural Lime and Liming is a three-part publication that introduces the basic principles of how and why calcareous amendments are land applied to elevate the pH of acid soils. Part 3 is a user's guide for the interactive online Agricultural Liming Material Selection and Comparison Calculator. This publication describes the attributes used to perform calculations to characterize liming material with instructions for the online calculator, which can compare up to three liming materials for the relative effectiveness, costs, and economic efficiency.

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Agricultural Lime and Liming, Part 3: Aglime Product Selection and Comparison Calculator User Guide

Agricultural Lime and Liming is a three-part publication that introduces the basic principles of how and why calcareous amendments are land-applied to elevate the pH of acid soils. It is also part of the companion series [Soil Acidification in the Inland Pacific Northwest](#).

Part 1 – [Introduction to Agricultural Lime and Liming](#). This section contributes to the discussion on the increasing incidence and severity of acid soils in the Inland Pacific Northwest (IPNW) and emphasizes: i) soil sampling and monitoring concepts to consider when managing acid soil conditions; ii) the role of soil testing; and iii) characterization of liming materials used to elevate pH of acidified soil.

Part 2 – [Laboratory Testing to Determine Lime Requirements](#). This section delves more deeply into variations among soil types and why laboratory testing is used to characterize soil pH. We define the term “lime requirement” and how it relates to soil buffering capacity. We also provide information on lime requirement test methods commonly performed by soil testing laboratories. A companion [Lime Requirement Worksheet](#) based on common buffer tests and base saturation is provided for reference.

Part 3 – Aglime Product Selection and Comparison Calculator User Guide. This is a user’s guide for the interactive online [Agricultural Liming Material Selection and Comparison Calculator](#). The publication describes the attributes used to perform calculations to characterize liming material, while the interactive utility provides a platform to compare up to three liming materials for their relative effectiveness, costs, and economic efficiency.

Introduction

Agricultural liming materials are applied as soil amendments to raise the pH of acidified soil (Collins 2012). Liming material characteristics, cropping system, and tillage practice are considered when calculating the appropriate application rate (Anderson et al. 2013). Liming materials vary in chemical purity, particle size distribution or fineness, and moisture content, while depth of soil incorporation varies with crop residue management systems and tillage practices (NRCS 1999).

The online [Agricultural Liming Material Selection and Comparison Calculator](#) is used to characterize liming materials, calculate agricultural lime application rates, and assess product pricing relative to application costs. Individual attributes listed in Table 1 are presented in the order provided in the Agricultural Liming Material Selection and Comparison Calculator and further described in the following sections of this document.

Lime Requirement

A lime requirement is determined by soil testing. Soil pH alone can be used as an indicator that a lime application is needed, but it does not provide enough information to determine an appropriate liming rate. More information on lime requirement tests and laboratory determinations is provided in [Agricultural Lime and Liming – Part 2. Laboratory Testing to Determine Lime Requirements](#).

Liming Product Label

All agricultural liming materials sold in the state of Washington are regulated as fertilizers by the Washington State Department of Agriculture (WSDA) and possess a product label that contains a guaranteed analysis and other product information, i.e., trade name, company name, and company contact information (Figure 1).

Table 1. Liming material attributes for calculating agricultural liming material application rates

Factors	Abbreviations	Descriptions
Lime Requirement	lb CaCO ₃ per acre	Laboratory test to determine a lime application rate relative to the magnitude of acidity and buffering capacity of soil
Guaranteed Analysis	GA	Liming material calcium carbonate equivalent (CCE), concentrations of calcium carbonate and magnesium carbonate, and particle size distribution are listed on a product label
Purity	CCE	Calcium Carbonate Equivalent, %; determined as described by AOAC, reported on product label as part of a minimum guaranteed analysis
Particle size distribution	mesh size	Mesh size classes of product, where percentage of product passing three or more sieve sizes, 10-mesh, 60-mesh, and 100-mesh is reported on product label (Table 3)
Efficiency Factor	E-Factor	Percentage of target pH achieved with a complete chemical reaction for a given particle size fraction; percentage score is assigned to each size fraction; values range from 0% to 100%
Fineness Factor	F-Factor	Weighted sum of E-Factors; reported to the nearest whole percentage on a dry weight basis
Moisture Factor	M-Factor	Liming material net dry weight ÷ liming material net wet weight; ratio from 0.00 to 1.00
Lime Score	L-Score	ECCE x dry weight ratio
Tillage Factor	T-Factor	Desired depth of incorporation into soil ÷ laboratory assumed depth of incorporation into soil; ratio from 0.1 to 2.0
Product application rate	lb of product per acre	L-Score x T-Factor; adjusted lime requirement

The American Association of Plant Food Control Officials (AAPFCO) publishes uniform model laws to promote agreement among state departments of agriculture for animal feed, fertilizer, and soil amendment regulations. The AAPFCO model law for agricultural liming material was first published in 1971 (AAPFCO 2015), and it has been modified over time to account for advances in laboratory sciences and technologies. Their guideline suggests that an agricultural liming material label guarantee: i) the minimum concentrations of calcium and magnesium to be reported as calcium oxide [CaO], calcium carbonate [CaCO₃], magnesium oxide [MgO], and magnesium carbonate [MgCO₃]; ii) the particle size distribution or size fractions of a product, reported as mesh size; and iii) the chemical purity of a product reported as CCE.

Agricultural Lime

Guaranteed Analysis

Calcium (Ca)	38%
Calcium Carbonate (CaCO ₃)	95%
Calcium Carbonate Equivalent (CCE)	95%

Minimum percent material that will pass:

100 mesh	98%
60 mesh	100%
10 mesh	100%

Derived from:

Pulverized Calcitic Limestone

SuperGro Farm Supply
 HWY 9
 Homerville, WA 98001
www.supergrofarm.com

Net Weight: 50 pounds

Information regarding the contents and levels of metals in this product is available on the internet at:

<http://www.aapfco.org/metals.htm>

Figure 1. Ideal product label for liming materials. Provided by WSDA.

Terminology used to describe agricultural liming materials and labeling guideline interpretation are not the same across all states. For this reason, we provide agricultural lime and liming guidelines that are specific to the state of Washington. We use terminology and definitions to describe liming material characteristics such as purity, efficiency, and reactivity that are well defined in the textbook *Soil Fertility and Fertilizers: An Introduction to Nutrient Management* by Havlin et al. (2013).

Guaranteed Analysis

WSDA (2013) rules require that a product label specifies at a minimum:

- i. CCE, an indicator of chemical purity relative to 100% pure calcium carbonate;
- ii. Concentrations of calcium carbonate [CaCO₃] or magnesium carbonate [MgCO₃] on a percent dry-weight basis (% dw basis); and
- iii. The minimum percentage of a liming material that passes 100-mesh, 60-mesh, and 10-mesh sieves. (More information on particle size classification is described in later sections of this publication.)

Note that Oregon State Department of Agriculture rules for lime materials (Horneck et al. 2007) are different than those of the WSDA and further outlined in the NRCS publication *Liming to Improve Soil Quality in Acid Soils*.

Purity

Chemical purity is sometimes referred to as the relative neutralizing power or neutralizing value of a liming material. CCE is a measure of the reactivity of chemical constituents in the liming material relative to pure calcium carbonate.

Two lime sources dominate the agricultural market: processed calcitic limestone and dolomitic limestone. Pure calcitic limestone contains up to 40% calcium (% dw basis) and less than 8% magnesium, with a CCE or purity rating of up to 100%. Pure dolomitic limestone is more reactive than calcitic limestone, contains 18% to 23% calcium and 8% to 12% magnesium (% dw basis) with a purity rating or CCE of up to 109% to 118%. Refer to Table 2 for a list of typical CCE values for various agricultural liming materials.

The reaction rate for the same particle size class of calcite versus dolomite is not the same. For example, the reaction rate of dolomite limestone is slightly slower than that of calcitic limestone, even though the purity rating of pure dolomite is higher than that of pure calcite. The source of liming material can be identified by evaluating the concentrations of calcium and magnesium (Table 2). In the next section, we will describe how this difference affects the E-Factor.

Table 2. Relative neutralizing power and mineral content of agricultural liming materials

Liming Materials	CCE (range)	[Ca] (%)	[Mg] (%)
Calcitic Limestone	95 to 100	23 to 40	0 to 8.0
Dolomitic Limestone	109 to 118	18 to 23	8.1 to 12
Calcium Oxide	178	71.5	0
Calcium Hydroxide	135	54.1	0
Calcium Sulfate	0	29.4	0

Particle Size Classification and Mesh Sizes

WSDA rules stipulate that an agricultural liming material label provides particle size information specified as a minimum percentage of liming material that passes US Standard mesh sizes: 10-mesh, 60-mesh, and 100-mesh sieves (Table 3). The amount of material that passes each sieve size is weighed and recorded, and the percentage of material passing each sieve size is calculated and reported on a percent dry weight basis.

Table 3. US Standard mesh size of sieves for determining particle size distribution of liming materials*

Sieve Sizes	Openings per inch	Opening diameter	
		(inch)	(mm)
10-mesh	10	0.0790	2.000
20-mesh	20	0.0331	0.850
40-mesh	40	0.0165	0.425
60-mesh	60	0.0098	0.250
80-mesh	80	0.0070	0.180
100-mesh	100	0.0059	0.150
200-mesh	200	0.0029	0.074

*Based on International Standards Organization (ISO) 565:1990
 – Test sieves – Metal wire cloth, perforated metal plate and electroformed sheet – Nominal sizes of openings.

Characterizing Liming Materials

Efficiency Factor

An E-Factor indicates the relative ability of liming material to elevate soil pH. Liming material particle size, purity, and time in years or months affect efficiency (Figure 2). Liming materials with a 100% CCE consisting of very fine particles smaller than 100-mesh can provide 100% of the desired change in pH in less than one year. Large particles that are held on a 40-mesh sieve provide between 40% and 80% of the desired change in one year. An E-Factor score (indicated as a percentage) is assigned to each size fraction and can range from 0% to 100%.

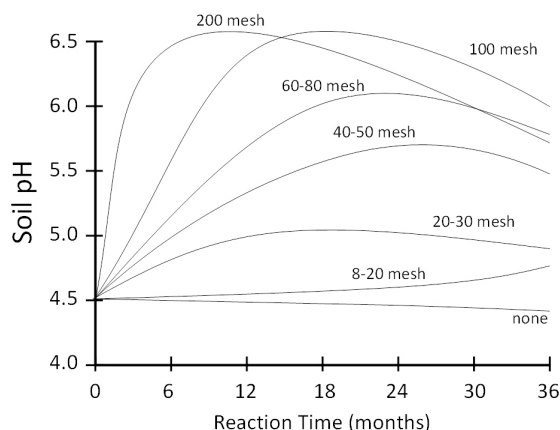


Figure 2. Relative reaction times for different mesh sizes of calcitic limestone. Adapted from Havlin et al. (2013).

The E-Factor of larger particles of unclassified materials is not clearly documented. Unclassified materials are typically byproducts that contain oxides, hydroxides or carbonates, and varying amounts of contaminants which vary in particle size. Many, but not all, byproducts suitable for use as a liming material are water soluble and will pass through a 100-mesh sieve. In contrast, contaminants that do not pass through the sieves will decrease the efficiency and effectiveness of unclassified liming material.

Mahler (1994) developed liming material efficiency data based on a one-year reaction time for each of the seven sieve size classes (Table 4). It is relevant to note that states do not always assume a one-year liming material reaction period. For example, efficiency data from Oregon State University assumes a reaction period of four to five years. This results in a high E-Factor for larger particle sizes than with the Mahler method which is based on a one-year reaction time (Mahler 1994; Horneck et al. 2007; NRCS 1999).

Table 4. Examples of E-Factors for calcitic and dolomitic limestone* and for unclassified liming materials, such as fly ash and recycled, crushed roadbed concrete

Sieve Size	E-Factors		
	Calcite	Dolomite	Unclassified
100-mesh**	100%	99%	100%
80-mesh	100%	96%	80%
60-mesh	96%	85%	60%
40-mesh	81%	68%	40%
20-mesh	56%	45%	20%
10-mesh	30%	24%	10%
< 10-mesh	0%	0%	0%

*Adapted from Mahler (1994).

**WSDA rules stipulate that liming material labels must include, at a minimum, particle size data on 100-, 60-, and 10-mesh sieves (shown in bold).

Formulas used to calculate an E-Factor based upon the source of liming material (calcitic, dolomitic, and unclassified) are provided in Table 5. Calculated E-Factors are rounded to the nearest whole percentage. For additional reading, refer to Product Effectiveness in the Liming Materials section of [Agricultural Lime and Liming – Part 1. Introduction to Agricultural Lime and Liming.](#)

Table 5. Equations to determine the E-Factor of liming material particle size fractions*

Liming Materials	E-Factor Equations**	P-Value	R ²
Calcitic	$-0.0134 \times MS^2 + 2.36 \times MS - 2.5$	0.0116	0.9884
Dolomitic	$-0.0077 \times MS^2 + 1.78 \times MS - 0.87$	0.0013	0.9987
Unclassified	$1.0 \times MS$	N/A	N/A

*Adapted from Mahler (1994).

**MS = mesh size (e.g., 10, 60, 100)

Fineness Factor

An F-Factor is the weighted sum of E-Factors for a liming material, reported as a whole number with values ranging 0% to 100%. The F-Factor decreases as the relative amount of larger particles in a liming material increases. The formula to perform the calculation is provided in Equation 1.0. The F-Factor addresses the effectiveness of the liming material by accounting for particle size, and it is used to adjust the CCE to provide the effective calcium carbonate equivalent (ECCE), as in Equation 1.1.

$$\text{F-Factor} = E_{10} \times R_{10} + E_{60} \times R_{60} + E_{100} \times R_{100}$$

Equation 1.0

$$\text{ECCE} = \text{F-Factor} \div 100 \times \text{CCE}$$

Equation 1.1

where:

E = E-Factor for each sieve size class; subscripts 10, 60, and 100 indicate sieve mesh sizes (Table 3), decimal ratio percentage,

R = percentage of liming material retained on sieve,

CCE = calcium carbonate equivalent, %, and

ECCE = effective calcium carbonate equivalent, %.

Relative Time for Soil Reaction

The relative time needed to achieve complete chemical reaction is proportional to liming material particle size distribution and dependent upon soil incorporation, soil moisture status, and level of soil acidity (Havlin et al. 2013). An approximation of reaction time for a given product is provided in the calculator. For calculation purposes, we assume that a liming material is thoroughly mixed into an acidified soil, and soil moisture status is high enough to sustain a chemical reaction.

Sieve size fractions that pass an 80-mesh sieve are assumed to fully react within nine months, size fractions between 40-mesh and 80-mesh between 12 and 18 months, and size fractions between 10-mesh and 40-mesh to fully react after 24 months, while fractions larger than 10-mesh are assumed to be non-reactive. Refer to Table 2 for an illustration of the relative change in soil pH achieved by particle size fraction for a calcitic liming material.

Moisture Factor and Lime Score

An L-Score adjusts the product application rate to account for product moisture content (Anderson et al. 2013). Liming materials are applied on an as-received moist basis, whereas the liming material label reports guaranteed nutrient concentrations and product purity on a dry-weight basis. The moisture content for liming materials as with all soil amendments is calculated and reported on a wet-weight, or as-received moist, basis (ww basis). This is unlike soil moisture which is calculated and reported on a dry-weight basis.

Liming material moisture content can be determined by drying a sample in an oven set at 212°F for approximately 24 hours and measuring the change in weight due to moisture loss (Equation 2.0). The moisture factor (M-Factor) is the total solids or dry-weight ratio of the liming material (Equation 2.1). An L-Score is calculated by multiplying the M-Factor by ECCE (Equation 2.2).

$$\text{Moisture Content (\%)} = [(1 - \text{net dw} \div \text{net ww}) \times 100]$$

Equation 2.0

$$\text{M-Factor} = [1 - (\text{Moisture Content} \div 100)]$$

Equation 2.1

$$\text{L-Score} = [\text{M-Factor} \times \text{ECCE}]$$

Equation 2.2

where:

net ww = as-received moist sample weight, weight of undried sample minus tare,

net dw = oven-dried sample weight minus tare, and

tare = weight of sample drying vessel

Tillage Factor

Depth of soil incorporation for a liming material will vary with tillage practice. Typically, a laboratory lime recommendation (lime requirement) assumes an eight- or six-inch acre furrow slice (AFS) of soil as a reference depth of soil incorporation. The actual depth of soil incorporation may not be the same as the reference depth, so a T-Factor is used to account for this difference.

For example, if the assumed depth of soil incorporation provided by the laboratory is a six-inch AFS, but the actual depth of soil incorporation by tillage or earthworm activity is only three inches, then the application rate would be lowered by fifty percent and calculated by dividing the actual three-inch depth by the reference six-inch depth, with a resulting ratio of 0.5 (Equation 3.0). The T-Factor is also used to account for depth to zone or strata of acidification when adjusting a liming material application rate for direct-seed or minimum tillage systems.

$$\text{T-Factor} = (\text{actual depth of incorporation}) \div (\text{laboratory-reference depth})$$

Equation 3.0

Liming Material Application Rate

The final calculation for determining a liming material application rate is completed by multiplying the L-Score by the T-Factor (Equation 4.0).

$$\text{Application Rate} = \text{L-Score} \times \text{T-Factor}$$

Equation 4.0

Liming Material and Application Costs

Liming material cost is directly related to product fineness and purity. As product quality increases (high CCE and high F-Factor), so does the price. Transportation and application costs are also significant in the IPNW as most lime sources are not locally available.

Case Study Comparing Three Liming Materials

Three liming materials with distinct chemical and physical characteristics are characterized to illustrate how each product can be applied and achieve the same goal, albeit at different costs. The examples provided in Table 6 represent three materials potentially available in eastern Washington. Liming material price and guaranteed analysis vary. Lime requirement, product specifications, and transportation and application costs also vary. Actual product specifications, pricing structure, and costs should be verified by the user.

Considerations

Liming materials vary considerably in purity, fineness, and price. Finely ground limestone with a particle size of 100-mesh and finer react very quickly in an acidified soil under moist conditions. Ground limestone with a full range of particle sizes from coarse to very fine require higher application rates and more time to achieve the desired change in soil pH. Prilled and pelletized liming materials are finely milled calcitic or dolomitic limestone whose particles are bound together by water-soluble lignosulfonates to form small pellets or prills. Liquid-suspended liming materials consist of very fine particles of calcite or dolomite mixed with up to 70 parts water and a small amount of clay as a dispersant. Examples of liming material types licensed by the WSDA for sale in the state of Washington are provided in Appendix 1.

- Liming material selection should be based on material and application costs, tillage system used to incorporate the liming materials, and time to achieve a desired change in soil pH.
- Characterize liming materials to identify the least expensive option to achieve the desired neutralizing effects to elevate pH of an acidified soil.
- The potential effect of applying byproducts with reported levels of contaminants should be considered while planning liming material applications.

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Table 6. Example of liming material attributes to specify three liming materials

Lime Requirement*	2,000 lb/acre	2,000 lb/acre	2,000 lb/acre
Ag Lime Products	Sugar Beet Lime	Ground Dolomitic Limestone	Liquid Suspended Calcite
Guaranteed Analysis (%)**			
Calcium	18.0	21.8	37.5
Magnesium	0.1	11.6	0.5
CaCO ₃	45.0	55.0	94.0
MgCO ₃	0.4	40.2	1.7
CCE	77	105	94
Percentage passing mesh size fractions (%)			
Pass 10-mesh**	100	100	100
Pass 20-mesh	100	99	100
Pass 40-mesh	99	98	100
Pass 60-mesh**	83	95	100
Pass 80-mesh	80	90	98
Pass 100-mesh**	78	85	96
F-Factor ÷ 100	0.90	0.96	1.00
ECCE = CCE × F-Factor ÷ 100	0.693	1.008	0.940
Moisture Content (% ww basis)	8.5	1.0	65.0
M-Factor (ratio)	0.915	0.990	0.350
L-Score = ECCE × M-Factor	0.63	1.00	0.33
Actual Depth of Incorporation (in)	3.00	3.00	3.00
Reference Depth of Incorporation (in)	6.00	6.00	6.00
T-Factor	0.500	0.500	0.500
Product Application Rate = Lime Requirement ÷ L-Score × T-Factor			
Product Application Rate (lb/acre)	1587	1000	3030
Relative Time for Soil Reaction			
Less than 9 months	80	85	96
12 to 18 months	19	13	4
More than 24 months	1	2	0
Non-reactive Fraction	0	0	0
Number of Acres	100	100	100
Itemized Prices			
Product Price (\$/ton)	50	85	285
Application Fee (\$/acre)	10	10	10
Transportation Fee (\$/ton)	15	15	15
Total			
Total Product (tons)	0.79	0.50	1.52
Application Cost (\$)	10.00	10.00	10.00
Transportation Cost (\$)	11.90	7.50	22.73
Product (\$)	39.67	37.50	431.78
Total Cost of Application (\$)	61.57	55.00	464.51

*Lime requirement is determined by laboratory testing and reported on a soil test report. Contact your soil testing laboratory for assistance.

**Guaranteed analysis and mesh size information for liming materials sold in Washington State are reported on the liming material product label.

Appendix 1

Examples of agricultural liming materials potentially available in eastern Washington. *Source: WSDA.*

Agricultural Liming Materials	Elemental Ca (%)	Elemental Mg (%)	CaCO ₃ (%)	MgCO ₃ (%)	CCE (% dw basis)	Screen Analysis (% passing mesh sizes)					Moisture (% ww basis)
						10	20	40	60	100	
Sugar Beet Lime	18	0.1	45	0.4	77	100	100	99	83	78	8.5
Ground Calcitic Limestone	37.5	0.5	94	1.7	94	100	99	98	95	85	1.0
Ground Dolomitic Limestone	21.8	11.6	55	40.2	105	100	99	98	95	85	1.0
Liquid Suspended Calcite	37.5	0.5	94	1.7	94	100	100	100	100	96	65.0
Liquid Suspended Dolomite	21.8	11.6	55	40.2	104	100	100	100	100	96	65.0
Prilled or Pelletized Calcite	37.5	0.5	94	1.7	94	100	100	100	95	92	1.0
Prilled or Pelletized Dolomite	21.8	11.6	55	40.2	104	100	100	100	95	92	1.0



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