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Liming Materials and Management

Amy L. Shober, Karen L. Gartley, and J. Thomas Sims

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Introduction

Soil acidity, often measured as **pH**, plays a crucial role in plant health and overall soil productivity. Imagine the soil as a complex ecosystem that provides essential resources for plant growth. Just as humans thrive within a comfortable temperature range, plants have specific pH preferences for optimal development. When soil pH deviates significantly from a plant's ideal range, it can negatively impact several critical processes including nutrient availability, microbial activity, plant growth, and plant health. Understanding and managing soil acidity is therefore fundamental for successful gardening and agriculture, ensuring that plants have the best possible environment to thrive. For more information about measuring soil pH, refer to *Measurement and Management of Soil pH for Crop Production in Delaware* (available at http://www.udel.edu/0013466).

"Liming" is a way to make your soil less acidic. We do this by adding special minerals that are rich in calcium or both calcium and magnesium. When you add these materials, they help bring the soil acidity to a level that's just right for your plants to thrive.

How much lime you need, and how well the lime works, depends on a several factors including:

- the level of acidity (i.e., is the soil pH significantly lower than the optimum pH);
- the type of plants that will be grown (i.e., some plants prefer soil pH closer to neutral while others prefer more acidic environments);
- soil chemical and physical properties (e.g., organic material content, clay content);
- the type of liming material that will be used and how you plan to apply it.

What is "Lime"?

When people say "lime," they are technically talking about a specific material called calcium oxide (CaO). But in a broader sense, "lime" actually includes many different materials that contain calcium, or calcium and magnesium (Table 1). These liming materials can all be used to make the soil less acidic. Some common liming materials you might hear about include:

- **Calcium carbonate** ($CaCO_3$)
- **Calcium hydroxide** [$Ca(OH)_2$]
- **Dolomite** [$Ca{\cdot}Mg(CO_3)_2$] – this material contains both calcium and magnesium.
- **Slag** – usually a calcium silicate ($CaSiO_3$) material derived from metal refining.

Sometimes, other materials or industrial by-products can also be used as a liming material. These "alternative" liming materials could include wood ash, fly ash, treated biosolids (i.e., residuals from wastewater treatment), or dust from cement factories. People usually use these "alternative" materials if they are locally available and are cheaper to purchase than more traditional liming materials. These alternative materials often have smaller amounts of calcium or magnesium, and they might also add small amounts of other plant nutrients like phosphorus (P) or potassium (K). However, alternative liming materials may also contain unwanted impurities like heavy metals.

Table 1. Common liming materials that can be applied to the soil to raise the soil pH to levels that promote healthy soils and plant growth.

Material Name: Calcium Oxide **Common Names:** Unslaked lime; burned lime; quicklime **Chemical Formula:** CaO **Material Description:** Manufactured by heating calcitic limestone in a furnace in order to drive off carbon dioxide and some impurities. Purity of the final product is dependent upon the raw material. Highly caustic; very powdery; difficult to handle; highly reactive.
Material Name: Calcium hydroxide **Common Names:** Hydrated lime; slaked lime **Chemical Formula:** $Ca(OH)_2$ **Material Description:** Manufactured by hydrating calcium oxide. Highly caustic; very powdery; difficult to handle; reacts quickly in soil.
Material Name: Calcium carbonate (consolidated) **Common Names:** Agricultural limestone; calcite; calcitic lime; hi-cal lime **Chemical Formula:** $CaCO_3$ **Material Description:** Naturally occurring mineral with high-quality deposits are found throughout the world. Usually mined through open-pit techniques that use explosives to blast the rock into processible size. Collected limestone is then pulverized and ground to the desired fineness for application. Can be purchased in bulk or bagged supplies.
Material Name: Calcium carbonate (unconsolidated) **Common Names:** Marl **Chemical Formula:** $CaCO_3$ **Material Description:** Soft, unconsolidated deposits of $CaCO_3$ found in the soil or lake and stream stream beds. Frequently contains significant amounts of clays or impurities. Easily mined by dragline mined by dragline or power shovels and allowed to dry before sale and use.
Material Name: Calcium magnesium carbonate **Common Names:** Dolomite; dolomitic limestone; hi-mag lime **Chemical Formula:** $Ca{\cdot}Mg(CO_3)_2$ **Material Description:** Known as dolomite when Ca and Mg are present in equal proportions, dolomitic limestone when Ca and Mg are in other proportions. Naturally occurring material mined in the same way as $CaCO_3$. Slower reacting than $CaCO_3$.
Material Name: Calcium silicate **Common Names:** Slag; blast furnace slag; basic slag; electric-furnace slag **Chemical Formula:** $CaSiO_3$ **Material Description:** Industrial by-product of various manufacturing processes including the production of pig iron, steel, or elemental phosphorus from phosphate rock. Neutralizing values range 60-90%. Usually provides phosphorus in addition to liming benefits.
Material Name: Fluid lime **Common Names:** Suspended lime **Chemical Formula:** Dependent on liming agent used **Material Description:** Powdered lime (20 to 235 mesh) is mixed with or suspended in water or a liquid fertilizer solution. Provides an excellent distribution pattern. Makes small lime applications possible. Highly reactive due to fineness. More expensive than traditional liming practices.

How Well Does Lime Work?

Not all liming materials are equally good at making the soil less acidic. We measure how effective a liming material is by its "neutralizing value", or how much acidity the liming material can react with. The neutralizing value depends on two main things:

1. **Chemical composition:** Different materials react differently with acid in the soil. For example, while liming materials contain Ca or Ca and Mg, it is actually the carbonate, oxide, or hydroxide components that neutralize acidity. In general, oxides and hydroxides are generally more effective than carbonates.
2. **Purity:** Liming materials often contain impurities that do not neutralize acidity. The higher the concentration of impurities, the less effective the liming material will be.

To make it easy to compare different liming materials, we use a rating system called the **calcium carbonate equivalent (CCE)**. This system compares every liming material to pure calcium carbonate ($CaCO_3$), which is given a CCE value of 100%.

- If a material has a CCE value **greater than 100%**, it has more neutralizing power than pure calcium carbonate at making soil less acidic. You would need less of this material to get the same results.
- If a material has a CCE value **less than 100%**, it is not as effective as pure calcium carbonate. You would need to use more of this material to achieve the same result.

The neutralizing values of some pure liming materials are shown in Table 2. Keep in mind that the CCE values listed for pure materials in Table 2 might be a bit higher than what is in the actual products you buy because agricultural liming materials usually have some impurities (e.g., clay).

Table 2. Calcium carbonate equivalent (CCE) value of some common liming materials (purse forms only).

Material	CCE (%)
Calcium oxide	179
Calcium hydroxide	136
Calcium magnesium carbonate	109
Calcium carbonate	100
Calcium silicate	60–90

Fineness of Liming Materials

The "neutralizing value" is not the only thing that makes lime work well. The **size of the lime particles**, or how finely the material is ground, is also very important.

Imagine trying to dissolve a big sugar cube versus a spoonful of granulated sugar in water. The granulated sugar dissolves much faster because it has more surface area touching the water. It's the same with lime in your soil. The smaller the lime particles, the more surface area they have. This means they can react more quickly with the acid in the soil and raise the soil pH faster. Bigger particles, on the other hand, take a much longer time to neutralize acidity.

We usually describe the fineness of limestone by saying what percentage of the material can pass through a certain size screen. For example, particles that pass through a screen with 8 to 10 holes per inch (i.e., 8 to 10 mesh) are considered "coarse." But particles that can pass through a screen with 80 to 100 holes per inch (i.e., 80 to 100 mesh) are "very fine."

Very fine lime works the fastest, but there is a trade-off. The finer the material, the more it costs because it takes more work to grind it down. Finer materials can also be a bit trickier to spread. They might clump up in the spreader, or some of the fine dust could blow away. Because of these trade-offs, most of the liming materials sold for farms and gardens are a mix of both fine and coarse particles.

This kind of mix helps raise the soil pH within a reasonable amount of time (e.g., a few months), while also keeping the cost down. A summary of typical limestone particle size criteria is shown in Table 3.

Table 3. Specifications of particle size distribution for commercially sold limestone.

Particle Size Criteria	Particle Size Distribution	
	Agricultural Grade Limestone	Granular Limestone
	——— % of Particles ———	
Passing a 20-mesh sieve	95	95
Passing a 60-mesh sieve	60	40
Passing a 100-mesh sieve	50	30

Other Types of Limestone You Might Find

You might also see two other types of limestone sold, often for lawns and gardens:

- **Granular limestone:** This type has a higher percentage of larger particles. It's a bit slower to work than the regular agricultural lime, but it's much easier to spread. It usually works just fine for most needs.
- **Pelletized limestone:** This is made from very finely ground limestone that's been mixed with a binding agent that helps the fine lime particles stick together in small pellets. Once you spread it on the soil, water dissolves the binding agent that holds the pellets together, and the fine lime is released. This type of lime is very easy to apply and works very well at raising soil pH.

Comparing the Efficacy of Liming Materials

When we want to compare how well different types of agricultural lime will work, we look at two main things: the **fineness factor** and the **effective calcium carbonate content**.

Let's focus on the **fineness factor (ff)** first. This number tells us how good a liming material is at reducing soil acidity based *only* on the size of its particles. The fineness factor does not consider the neutralizing value of the material.

In the United States, liming materials are sorted into three general classes based on their particle size (Table 4). Each class is given an "effectiveness rating" that shows how easily particles of that size will react with the acid in the soil. We calculate the fineness factor using this formula:

$$ff = (\%_{class1} \times ef_1) + (\%_{class2} \times ef_2) + (\%_{class3} \times ef_3)$$

Where:

- **ff:** This is the fineness factor itself, shown as a percentage.
- **$\%_{CLASS\ X}$:** This is the percentage of the liming material that falls into a specific particle size class (Class 1, Class 2, or Class 3).
- **ef_X:** This is the effectiveness rating for that specific particle size class.

Basically, the higher the fineness factor (ff), the more effective the liming material will be at making your soil less acidic.

Table 4. Effectiveness factors of limestone fineness classes.

Class	Criteria	Effectiveness Rating
1	Percentage retained on an 8-mesh sieve	0
2	Percentage passing through the 8-mesh sieve but retained on a 60-mesh sieve	50
3	Percentage passing through a 60-mesh sieve	100

The second important measure we use to compare lime materials is the **effective calcium carbonate content (ECCC)**. This ECCC is a measure of the true power of a liming material to make your soil less acidic. The ECCC combines both the **neutralizing value** (how much acid it can neutralize, shown as the CCE) and the **fineness factor** (how quickly it will work based on particle size). We calculate ECCC using the formula:

$$\textbf{ECCC} = \textbf{CCE} \times \textbf{ff}$$

Where:

- **ECCC:** This is the effective calcium carbonate content.
- **CCE:** This is the calcium carbonate equivalent (how strong it is).
- **ff:** This is the fineness factor (how quickly it works).

In simple terms, if you have two liming materials that work at the same speed (meaning they have the same fineness factor), the one with a higher CCE will be better at neutralizing soil acidity.

How to Apply Liming Materials for Best Results

The success of your liming plan is not just about the material itself; it also depends on *how* you apply the liming material. The most important things to consider with lime applications are: 1) **where you put the lime**, 2) **how evenly you spread it**, and 3) **when you apply it**. Thinking about these factors carefully will help your liming program work best.

Where to Put the Liming Material

Where you put the lime makes a big difference in how well it can mix with the soil and neutralize the acid.

- **Mixing it into the soil:** When you mix the lime into the soil (this is called "incorporation"), it makes much better contact with all the acid soil particles. This makes the liming material work better and faster to change the pH.
- **Spreading it on top of the soil:** Sometimes, you can only spread lime on the soil surface (e.g., established lawns, pastures, or crops like alfalfa). Surface applications will still reduce soil acidity, but it happens much slower because the lime is not directly mixed with all the acid soil. If you are applying the lime on the soil surface and you need a large amount to neutralize the soil acidity, you might need to split it into several smaller applications a few months apart. Splitting applications helps to prevent damage to your plants from direct contact with too much lime. When lime is mixed into the soil, plant damage from high rates is much less likely because the lime is not touching the plants directly.

Spreading Liming Materials Evenly

It is very important to spread lime as evenly as possible over the area. If you do not spread the liming material evenly, some spots might still be too acidic, while others might get too much lime. Uneven

applications can lead to problems like plants not getting enough nutrients in some areas or even getting damaged in others. If you have ever seen a "striped lawn" where some parts are greener than others, that can be a sign of uneven lime application. How evenly you spread the lime largely depends on the equipment you use and how skilled the person operating it is.

For large areas (like athletic fields or farms):

- **Drop spreaders:** These spread lime very evenly but are slower, hold less lime, and need another vehicle (like a truck or tractor) to pull them.
- **Auger driven spreaders:** These apply liming materials almost as evenly as drop spreaders and hold more lime, but they are also a bit slow.
- **Spinner spreaders:** These are commonly used by professionals because they can spread lime quickly over a large area. However, they do not always spread as evenly, and some lime can blow away as dust. Spinner spreaders are probably the most common choice.

For home lawns and gardens: You can use similar application methods as used for larger areas, but on a smaller scale.

- **Push-type drop spreaders:** These give the most even application.
- **Spinner spreaders:** These are the next best for evenness.
- **Spreading by hand:** This application method results in an uneven lime application; as such, we do not recommend spreading by hand.

No matter what equipment you use, take your time and be careful to cover the area evenly. When you are using a lot of lime, you can usually see the white path left behind your spreader. For smaller amounts, it can be harder to see where lime has been applied, so pay extra attention. Also, be careful when turning at the edges of your lawn to avoid putting too much lime in one spot.

When to Apply Lime

The timing of your lime application is the third important factor. It usually takes several months for lime to make the desired change in soil pH.

- Because of this lag time, it is often best to apply lime several months *before* you plan to plant. This is especially true if you are growing a plant that is very sensitive to soil pH, like alfalfa.
- For spring planting, applying lime in the **fall** is usually the most effective.
- Applications in the winter or early spring are less effective but can still work if you only need a small change in soil pH.
- If you need to apply a lot of lime over several treatments, start in the early fall. This way, most of the lime is applied before the spring growing season begins.

Summary

By understanding the different **types of liming materials**, their **neutralizing value**, and how **particle size** and **application techniques** affect their performance, you will be well-equipped to make informed decisions for your soil. A healthy soil pH is a key ingredient for thriving plants and a successful garden or crop.

About the Authors

Amy L. Shober (corresponding author), Professor and Extension Specialist, University of Delaware, Newark, DE (ashober@udel.edu)

Karen Gartley, Director, University of Delaware Soil Testing Program, Newark, DE

J. Thomas Sims, Professor (retired), Environmental Soil Management, University of Delaware, Newark, DE

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Peer Reviewers

Nicholas Adams, Extension Agent, University of Delaware Extension, Newark, DE

Lyndsie Mikkelsen, Extension Agent, University of Delaware Extension, Georgetown, DE