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Not all Liming Materials are Created Equal

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Introduction

When a soil is too acidic for a given crop, liming to the appropriate pH is necessary to maximize yield potential and growth. Soil test summaries provided by the University of Arkansas System Division of Agriculture's Marianna Soil Test Laboratory (MSTL) during 2018 show that, on average, 15% of the soil samples from the Delta counties and 25% of the samples from the western Arkansas counties would have received a lime recommendation. Currently, agricultural lime (AGL) is recommended if the soil pH is lower than 5.8, except for legume crops that would receive a lime recommendation for soil pH lower than 6.3, commercial strawberries with a soil pH lower than 6.1, blueberries and acid group shrubs with a soil pH lower than 4.6, and commercial grape production when soil pH is below 5.5.

Why do Soils Become Acidic?

Soil pH is a measure of the concentration of hydrogen (H^+) ions. The higher the concentration of H^+, the more acidic pH is. Many of the soils found in the Ozark, Boston, and Ouachita Mountain regions of Arkansas are acidic because they have an acidic parent material. Continued use of nitrogen fertilizers is the principal reason why soils in the Delta region become acidic. In areas with a significant amount of rainfall, basic ions can be leached out of the exchange sites and be replaced by acidic ions. However, this process may take a long time.

Ammonium sulfate is the fertilizer that causes the most acidity on a weight basis, followed by urea and ammonium nitrate. It is the mineralization process that causes acidity, according to the reactions in figure 1. As seen in the equations, when ammonium sulfate is

Benefits of Liming Acidic Soils

- **Liming increases soil pH to a level where primary nutrients become more soluble and available for plant uptake, which reduces plant stress and increases plant resiliency.**
- **Nitrogen fixation for legume crops proceeds at a faster rate as bacteria survive better in soils with neutral pH.**
- **Liming materials may provide calcium and magnesium.**
- **The Cation Exchange Capacity of soil increases, reducing the risk of losing basic ions such as potassium.**
- **Some herbicides work better with a neutral soil pH.**
- **Liming reduces the toxicity of aluminum, iron, and manganese.**

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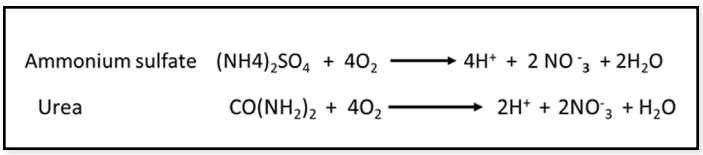

Figure 1. Mineralization reaction of ammonium sulfate and urea, and the resultant hydrogen ions generated.

applied to the soil, it produces twice as much acidity (H^+ ions) as does urea when applied to the soil (4 H^+ compared to 2 H^+). Irrigation groundwater with high pH and rich in Ca and Mg bicarbonates prevents the acidification of soils in some areas in Arkansas.

What is Considered a Liming Material?

According to the Arkansas Agricultural Liming Materials Act of 1969, "*the term 'liming material' means all or any form of limestone, lime rock, dolomite, marl, slag, by-product lime, brown lime, industry or factory refuse lime, and any other material moved, prepared, sold, or distributed primarily for correcting soil acidity.*"

By law, every AGL producer should provide information on liming materials sold in Arkansas, including the percentage Calcium Carbonate Equivalent (CCE), as well as the degree of fineness expressed as:

i. Minimum percentage passing through a ten (10) mesh sieve;
ii. Minimum percentage passing through a sixty (60) mesh sieve; and
iii. Minimum percentage passing through a one hundred (100) mesh sieve.

Several materials can increase the pH of soil. Table 1 shows some potential liming materials and associated properties. These materials' effectiveness to increase soil pH depends on their CCE and the material's fineness. The CCE is the neutralizing value of a specific liming material compared to pure calcium carbonate. A material with a CCE of 100% will neutralize the same amount of acidity as pure calcium carbonate, on a weight basis.

Table 1. Selecting Liming Materials and Associated Chemical Properties.

Liming Material	Chemical Formula	Calcium Carbonate Equivalent (%)
Calcitic limestone	$CaSO_3$	95-100
Dolomitic limestone	$CaMg(CO_3)_2$	85-108
Hydrated Lime	$Ca(OH)_2$	120-135
Basic slag	$CaSiO_3$	50-70
Wood ash	Calcium, maganesium, and potassium oxides	20-60
Eggshells	Mainly calcium carbonate, phosphorus, and magnesium	56-74
Gypsum	$CaSO_4$ (calcium sulfate)	It does not raise the pH

Fineness is related to how small the lime particles are. The finer a limestone is ground, the faster it will react in the soil. The fineness of a liming material is determined by the percentage of material passing through a series of screens of different sizes. A 10-mesh sieve will retain particles larger than 2 mm in diameter. These particles have little effect on raising the pH of soil. A 60-mesh sieve will have 0.25 mm openings, while a 100-mesh sieve would have 0.15 mm openings. Under average conditions, lime particles in the 200-mesh size (0.07 mm) would typically react in about one month, while particles in the 100-mesh sieve may react in less than three months. It may take one year for particles passing a 60-mesh sieve to react with the soil. AGL contains particles of different sizes, with the fine particles reacting soon after application and the coarser particles (no more than 0.5 mm) giving it a longterm effect (> 1 year).

What is the Difference Between Calcitic and Dolomitic Limestone?

The difference between the two liming materials is that dolomitic limestone contains magnesium carbonate, in addition to calcium carbonate. A calcitic limestone will contain calcium carbonate only. Dolomitic limestone would be a good option for acidic soils, which are also low in magnesium and in pasture fields with a potential for grass tetany to be an issue. In some states, for a material to be referred as to "dolomitic limestone" it needs to have a minimum magnesium concentration. At this time in Arkansas, there is no minimum concentration of magnesium required.

Hydrated lime ($Ca(OH)_2$)

Hydrated lime (HL) can be made from mixing burnt lime (calcium oxide) with water. Calcium oxide is very toxic and difficult to handle. The resultant suspension would have a CCE about 25% higher than typical AGL. HL can also be made into a suspension by mixing AGL (with a high CCE) or powered hydrated lime with water and an additive to promote suspension. The low solubility of AGL limits the amount that can be maintained in suspension and consequently how much can be land applied. Typically, annual applications of HL are required to correct the acidity in a soil.

Basic Slag

Basic slag is a by-product of the steel

industry. Lime is normally mixed with iron ore to remove silicate, phosphorus, and other chemicals from the steel. The slag produced consists mainly of calcium and magnesium silicates, as well as calcium phosphate. The CCE of basic slag can range between 50% and 70%. Therefore, basic slag applied at the correct rates can raise the soil pH to desired levels.

Wood Ash

Wood ash also has liming properties. Once the wood is burned, oxides of calcium, magnesium, potassium, and sodium remain in the ashes. Depending on the wood source, the CCE can range between 20% and 60%. Wood ash is a material of low density (< 1 g/cc) so the application can be complicated if the material is wet or under windy conditions. Large applications of wood ash should be avoided due to potential salt accumulation.

What is the Relative Neutralizing Value?

The Relative Neutralizing Value (RNV), also known as Effective Calcium Carbonate Equivalent (ECCE) is an index of how effective a liming material is at raising the pH of a soil, and it can be used to compare different liming materials, unlike CCE alone. The RNV is calculated based on the CCE and the fineness of the material.

An AGL quality calculator is available online that allows the user to compare up to three potential liming materials. The calculator can be found at https://foragead-visor.uada.edu/AG-Lime-Calculator.html.

Can all Materials Containing Calcium and Magnesium Neutralize Acidity?

Not all products containing calcium and magnesium are effective as liming materials. As seen in the liming reaction in figure 2, the role of calcium is to replace the hydrogen (and other acidic cations) in the soil particle, so they are available to react with the accompanying ions carbonates ($CO3^{-2}$), hydroxides (OH^{-}), oxides (O^{-2}), or silicates ($SiO4)^{-4}$ to form water and insoluble minerals, thus

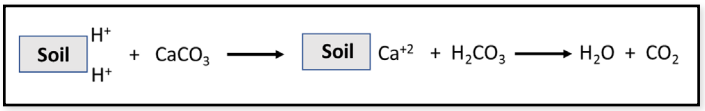

Figure 2. Reaction of calcium carbonate in soil.

reducing the acidity in the soil. Therefore, **it is not the calcium** molecule but rather the ion that accompanies the calcium or magnesium, which neutralizes the soil's acidity. Products such as calcium chloride, calcium sulfate (gypsum), and magnesium sulfate (Epsom salt) will not raise the soil pH.

Is Liquid Lime Effective at Correcting Acidity?

Liquid lime products are claiming to raise soil pH using considerably less volume than AGL. They may contain small amounts of calcium carbonate mixed with water. Such materials are suspensions of calcium carbonate which is not very soluble and needs to be constantly agitated to remain suspended. The math associated with the liming reaction shown in figure 2 is simple: one molecule of calcium is required to replace two hydrogen molecules. Liquid lime at the recommended rates by the suppliers (a few gallons per acre) will not contain enough calcium molecules to replace enough acidic ions to raise the soil pH to the desired levels.

Is Pelletized Lime Effective?

Pelletized lime (PL) is made from crushed lime, granulated, and made into pellets. Because it is made from fine particles, most of the material will react quickly with the soil. Most of the PL sold has a CCE of 90, which added to the fineness of the material, makes it a very effective liming source. However, there are some PL materials with a CCE under 90, which does not make it any better than typical AGL. Ease of application is one of the favorable characteristics of PL. However, the key disadvantage of PL is the cost added by the pelletizing process. Often PL is recommended at very low rates (300-500 lbs./a) suggesting it is as effective as recommended rates of ag lime. Research has shown that low rates of PL are not effective at increasing pH to recommended levels in low pH soils.

Table 2. Average Yield Response of Corn and Soybean to two Lime Sources Applied at the same ECCE (adapted from Mallarino and Haq, 2017) (n=3)

Crop	Rate of Effective Liming Material	Aglime	Pelletized Lime
	t/a	----------bu/a----------	
Corn	0	206a*	206a
	1	218b	219b
	2	223c	226c
	4	227c	228c
	8	228c	229c
Soybean	0	59.4a	59.4a
	1	65.6b	66.4b
	2	67.0b	66.5b
	4	67.2b	66.3b
	8	66.5b	66.5b

The high cost is probably the reason why PL is recommended at very low rates by the supplying companies.

As discussed earlier, the amount of lime to be used depends on the quality of the material, defined by the CCE, and the fineness. Also, enough calcium or magnesium needs to be added to displace the acidic molecules from soil particles so the accompanying ions can neutralize them, once in the soil solution. While PL may have a good CCE and be made of fine particles, it still needs to be applied at the correct rate.

In a study in Iowa (Mallarino and Haq, 2017), researchers compared the effect of varying rates of PL and AGL on the average yield of corn and soybean. Lime rates were applied based on supplying the same ECCE for both sources. The researchers reported that the PL material increased the pH faster and the final pH was higher for the PL (about 7.1), compared to AGL (about 6.7). However, no statistical yield difference was observed between the two lime sources or the two crops under study (Table 2). Corn yields were maximized with 1 t/a for both AGL and PL. Soybean yields were also maximized with the 1 t/a rate for both lime sources.

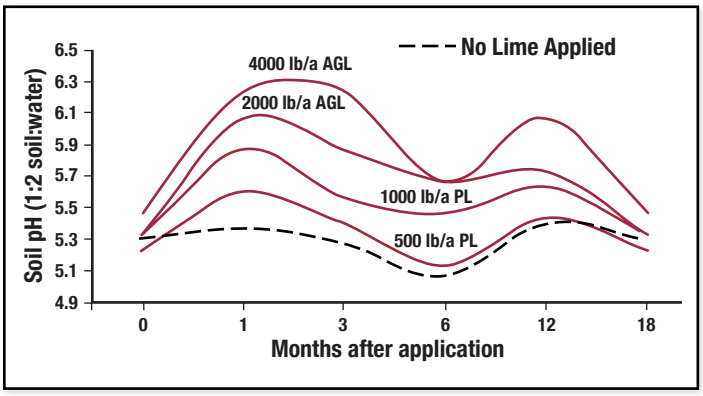

Figure 3. Average soil pH changes 18 months after application of several rates of Aglime (AGL) and Pelletized Lime (PL), on an acidic sandy loam in Fulton County. Soil pH was measured on a 1:2 soil: water mixture (n=3).

In another study, soil pH changes (1:2 soil: water) were measured after lime application in February 2016, to an acidic sandy loam in Fulton County, Arkansas (Figure 3). The data shows soil pH changes during the 18 months after surface application. The AGL used had an RNV of 77 while the PL had an RNV of 64. In this particular case, the AGL used was of better quality than the PL source (17% higher RNV). Although both sources were applied at different RNV rates, the data shows that when the AGL was applied at a rate of 2,000 lb/a, the increase in soil pH was consistently 0.2-0.3 pH units higher than when PL was applied at an equivalent rate of 1,000 lb/a. Even with the typical fluctuation in soil pH observed during the year, a rate of 4,000 lb/a AGL created a soil pH increase

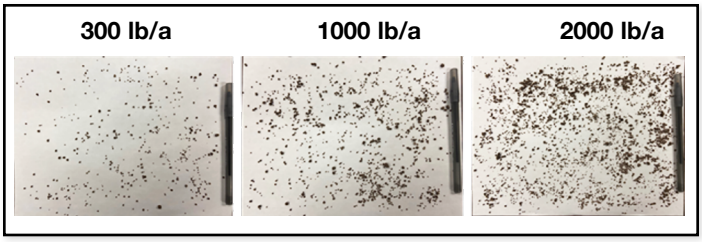

Figure 4. Relative difference in the amount of ground cover by different rates PL.

that was as much as 0.6 units higher than the 1,000 lb/a pelleted lime rate used. When 500 lb/a PL was applied, no obvious effect on soil pH was observed.

Tillage is an effective way of incorporating ag lime into the root zone and should be considered during field preparation or pasture renovation. Calcium carbonate is not very soluble, so it does not move down into the soil profile much once applied. Therefore, incorporating the lime material with tillage (if possible) and ensuring an even distribution of the material is very important. Figure 4 depicts a simulation of the distribution of PL rates equivalent to 300 and 1,000 lbs and 2,000 lbs of PL. The advantage of using AGL is obvious; more surface area will be covered, allowing the liming material to contact more soil particles.

Liming soils to raise soil pH is a chemical reaction and can take place year-round, but ideally, lime should be applied 6-12 months ahead of the crop to be grown to have a significant effect on soil pH. It can take upward of 12-18 months for applied lime to fully react and maximize soil pH change.

Key Points

- The only way to compare lime sources is to use the Relative Neutralizing Value (RNV) also known as Effective Calcium Carbonate Equivalent (ECCE) of the products, which is determined by the Calcium Carbonate Equivalent (CCE) and the fineness of a material.
- It is not the calcium or magnesium, but the accompanying ion (carbonates [CO_3^{-2}], hydroxides [OH^-], oxides [O^{-2}], or silicates [SiO_4]$^{-4}$) that determines if a material is effective at neutralizing soil acidity.
- Liquid lime products, applied at rates of a few gallons per acre, will not raise soil pH to desired values.
- Pelletized lime is made from fine particles; thus, it will react quickly with the soil, but not quicker than agricultural lime applied at rates of equal RNV.
- Pelletized lime is effective at raising the soil pH, but

only when applied at the correct rates based on the Relative Neutralizing Value.

- There is an Ag lime quality calculator available at https://www.uaex.uada.edu/farm-ranch/animals-forages/forage-software/limestone-calculator.aspx that facilitates the calculation of the RNV of up to three samples.

References

Mallarino and Haq. 2017. Evaluation of Agricultural Lime and Pelleted Lime to Increase Soil pH and Crop Yield. Iowa State University Extension. https://www.agronext.iastate.edu/soilfertility/info/Mallarino-Haq%20Aglime-Pelleted%20lime%20article%20NC%20fert%20conf%202017.pdf (Accessed Feb. 24, 2022).

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