Liming Acid Soils

David A. Whitney
Extension State Leader
Agronomy Program

Ray E. Lamond
Extension Specialist
Soil Fertility and Management

Department of Agronomy

Soil pH is a criteria for assessing productive potential of soils. It is a measure of the relative acidity or alkalinity of soil. The acidity or alkalinity of a solution is determined by the proportion of hydrogen (H+) to hydroxyl (OH^-) ions. A soil pH of 7 is neutral, with soil pH below 7 being acid and above 7 being alkaline. The pH scale is logarithmic; that is, a 5.0 pH is 10 times more acid than a 6.0 pH and 100 times more acid than a 7.0 pH. Three soil pH ranges are of particular concern to producers: a pH below about 5.2 suggests the possible presence of exchangeable aluminum, a pH of 7.8–8.2 indicates the likely presence of free or excess calcium carbonates, and a pH greater than 8.5 points to high exchangeable sodium (sodic soil). Ignoring an extremely low soil pH can lead to severe yield reduction if lime is not applied, as illustrated in Table 1.

Nutrient availability and herbicide activity are influenced by soil pH. The availability of most nutrients is greatest at near neutral pH levels. The effectiveness of some herbicides is markedly affected by soil pH, and pH must be considered in herbicide selections and their rate of application. The following discussion addresses acid soils and liming.

Causes of Acid Soils

Acid soil conditions arise from several factors. Some soils are naturally acidic because of the parent material from which they form. Most acid soils exist, however, because of soil development and management. Climatic conditions during soil profile development affect water movement through soil. In areas with higher rainfall, greater leaching of basic cations results in lower soil pH, a relatively slow acidification process.

Removal of calcium, magnesium, potassium and sodium (basic cations) in the harvested crop also contributes to

Table 1. Effect of aglime rate on hard red winter wheat yields, pH and KCl-extractable Al 4 years after application in Kingman County.

Lime Rate	Four-year Average Yield	0–6" pH	KCl-Extractable Al
lb ECC/a	bu/a		ppm
0	15	4.6	102
3,000	39	5.1	26
6,000	38	5.9	0
12,000	36	6.4	0

Initial pH—4.7, Lime Requirement—12,000 lb ECC/a, KCl-Extractable Al—94 ppm
Source: Unruh, et. al., KS Fert. Res. Report of Prog., 1986 thru 1989

soil acidification. Total top growth removal has a greater impact on basic cation removal than grain removal only. Soil microorganisms cause soil acidification through biochemical processes such as the nitrification reaction of converting ammonium to nitrate (Figure 1). The use of nitrogen fertilizer in crop production has greatly accelerated the natural acidification process, but nitrification of nitrogen in organic matter, crop residue and manures also causes acidification

Table 2 shows the amount of calcium carbonate needed to neutralize the acidity from 100 pounds of nitrogen from common nitrogen fertilizer sources. The data indicate equal acidification from each pound of nitrogen in ammonium nitrate, urea, urea–ammonium nitrate solution (UAN) and anhydrous ammonia. Ammonium sulfate is much more acidifying because of the concurrent sulphate ion reactions in the soil.

Plant Response

Plant species vary in optimal soil pH for best growth. Some crops thrive in very acid or alkaline soils, but most agronomically important crops grown in Kansas do well on soils closer to a neutral pH (6.5—7.5). Legumes such as alfalfa, sweet clover and soybeans are among these crops because Rhizobia bacteria that fix nitrogen do best on neutral pH soils. Crops such as corn, sorghum, wheat and cool-season grasses tolerate a wider pH range, including moderate acidity as well as neutral pH conditions. With most Kansas soils having neutral to alkaline pH subsoils (except in the southeast), crops tend to be more tolerant of low surface soil pH compared with states to the east, where acid subsoils exist. General guidelines for when to lime based on soil pH are shown in Table 3.

The decision to lime should be made for the crop in the rotation least tolerant of low pH.

Figure 1. The breakdown of nitrogen-containing organic materials by soil microorganisms

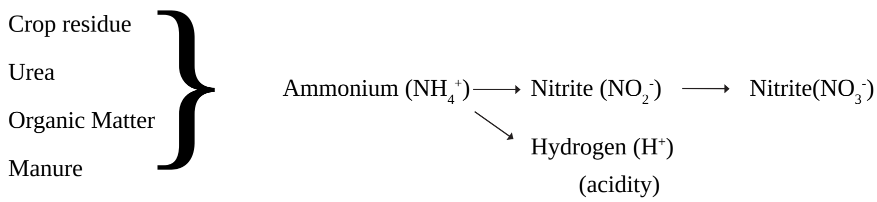

Table 2. Amount of calcium carbonate required to neutralize acidity created by common nitrogen fertilizer sources.

Fertilizer Material	N Conc.	$CaCO_3$ per 100lb N
	%	lb
Ammonium nitrate	34	180
Urea	46	180
Anhydrous ammonia	82	180
Urea-ammonium nitrate solution	28-32	180
Ammonium sulfate	21	535

Source: NCSA Aglime Facts Book, 1981

Determining Rate of Lime

Soil acidity can be thought of as two types: active or soil solution acidity measured by soil pH, and reserve or exchangeable acidity. Reserve acidity depends on several factors, such as amount and type of clay, amount of organic matter, and soluble aluminum concentration in the soil. Thus, two soils may have the same soil pH, but different lime requirements. Several approaches are used to determine lime needs. A chemical test involving a buffer solution (SMP Buffer) is used by the KSU Soil Testing Lab to determine the amount of effective calcium carbonate (ECC) necessary to raise the soil pH to a desired level. This buffer solution reacts with the soil to neutralize both active and reserve acidity. The change in the pH of the buffer solution has been calibrated for lime rate. This procedure has proven reliable for determining lime needs in Kansas soils.

The amount of lime to achieve a desired pH also depends on the depth of incorporation, the amount of soil mass to neutralize. Most recommendations are based on neutralization of two million pounds of soil, which is a depth of about 7 inches over an acre for medium-textured soils. If lime is incorporated deeper, more lime will be needed (Table 4). Conversely, if lime is incorporated shallower, less lime will be needed.

Lime Sources and Quality

The Kansas Agricultural Liming Materials Act defines agricultural liming materials as products whose calcium and magnesium compounds are

Table 3. Soil pH guidelines for liming for various crops in eastern and western Kansas

	Area of the state	
Crop	Eastern	Western
	- - - - - - - - -pH	- - - - - - - - -
Legumes	<6.4	<6.0
Nonlegumes	<6.0	<5.5

Table 4. Adjustment factor for aglime rate for incorporation depth.

Incorporation Depth (inch)	Adjustment Factor
3	.43
5	.71
7	1.00
9	1.29
11	1.57

Table 5. Common liming sources, their composition and calcium carbonate equivalence

Liming Material	Composition	Typical CCE (%)
Limestone (calcitic)	$CaCO_3$	80-100
Dolomitic lime	$CaCO3•MgCO_3$	80-100
Marl	soft $CaCO_3$ with clay & organic matter impurities	70-90
Burnt lime	CaO	150-179
Hydrated (slaked) lime	$Ca(OH_2)$	120-136
Municipal & industrial lime wastes	$CaCO_3$ with impurities	80-100

Table 6. Calculation of the fineness factor.

Size of Material	Percent of Material		Effectiveness Factor	Effectiveness
> 8 mesh	______ (10)*	×	0	0 (0)*
8-60 mesh	______ (40)	×	0.5	______ (20)
< 60 mesh	______ (50)	×	1.0	______ (50)
			Fineness Factor (FF)	______ (70)

*Values for example calculation

capable of neutralizing soil acidity. This definition allows materials in addition to calcium carbonate ($CaC0_3$) to be considered as lime sources. Liming sources do not include gypsum ($CaSO_4$) which is a neutral salt that will not directly change soil pH.

The calcium carbonate equivalence (CCE) of a liming material is the acid-neutralizing capacity, expressed as the percent by weight relative to pure calcium carbonate ($CaC0_3$). Pure calcium carbonate has a CCE of 100. Table 5 lists the typical CCE concentration of some common liming materials.

The effectiveness of a liming material in correcting soil acidity depends not only on purity, but also on fineness of the material. Fineness of grind is important for calcium and/or magnesium carbonate materials because carbonate materials have a very low solubility in water. A greater surface area associated with finely ground material will speed their dissolution and reaction. Considerable research has been done on particle-size effect on soil acidity neutralization. Based on this research, effectiveness ratings for various particle-size ranges have been established as a fineness factor.

The calcium carbonate equivalence (purity) and the fineness factor for a material are multiplied to arrive at an effectiveness rating for the material, called effective calcium carbonate (ECC).

ECC = fineness factor × calcium carbonate equivalence

As an example, suppose a lime quarry has 86 percent CCE limestone rock crushed to a fineness factor of 70. This liming material would be 60 percent ECC (70 × .86 = 60.2).

If the soil test results showed the need for 3,000 lb/a of ECC, then the farmer would need to apply 5,000 lb/a of 60 percent ECC aglime (3,000 ÷ .6 = 5,000) to meet this need.

Crushed or ground limestone, commonly referred to as aglime, is the most common liming material spread in Kansas. The ECC of this material typically ranges from 50–65 percent. Other sources of lime are fluid and pelleted lime.

Fluid or liquid lime is prepared by mixing finely ground calcium carbonate with water and a suspending agent (attapulgite clay) so the material can be spread with a suspension fertilizer applicator. The lime used in making the suspension must be of very fine particle size, or by-product from water treatment or other industries using finely crushed lime. Fluid lime suspensions as spread are generally no more than 50–60 percent solids. The main advantages claimed for the fluid lime are a more uniform spread and a quicker reaction because the fine-particle size allows greater soil-lime contact. Suspension fertilizer application equipment is limited to spreading 1,000–2,000 pounds of fluid per acre; therefore, fields with high lime needs will need multiple applications or applications over several years to raise the pH to near neutral.

Pelletized lime (granular) is prepared by adding a binding agent to aglime to obtain a granular material suitable for application with dry granular fertilizer equipment. Pelletizing of lime cuts down on dust and perhaps allows a more uniform spread. The pelletizing process, however, does add significantly to cost. Pelletizing does not increase effectiveness when compared with aglime at an equal rate of ECC.

When selecting a lime source, remember that all liming materials are equal in final neutralization of

Table 7. Effect of rate and source of lime on soil acidity neutralization 8 months after application.

Source	Depth, inch	ECC Rate (lb/a) 0	1,250	2,500	5,000
		- - - - - - - - pH - - - - - - - - -			
Aglime	0-3	5.1	6.0	6.6	6.8
	3-6	4.9	5.2	5.5	5.8
Fluid	0-3	—	6.4	6.5	7.2
	3-6	—	5.2	5.5	5.8

Lime applied in mid-July and incorporated by one disking and field cultivating.

soil acidity if applied at the same rate of ECC. Thus, cost per unit of ECC applied should be the major consideration in selecting a source. Other factors such as uniformity of spread and speed of reaction (on very acidic soils) should also be considered. Local availability of liming materials also can be a major factor.

Application Considerations

Aglime has a very low solubility in water and, therefore, requires thorough incorporation and time for reaction to fully effect neutralization of soil acidity. Data from a field study in Table 7 illustrate the effects of incorporation on neutralization. A disking and field cultivation were not effective in incorporation of lime to much more than 3 inches. The data also show no difference between aglime and fluid in acidity neutralization.

Tillage system and nitrogen application method should be considered in assessing lime need and establishing lime application rate and incorporation method. With reduced and no-till seedbed preparation and surface application of nitrogen, acidity problems may develop in the surface 2–3 inches of soil. Therefore, soil samples should be taken in 2- or 3-inch increments and lime rate adjusted for the soil mass involved (Table 4). Where a moldboard plow is used every few years, soil samples should be taken to plow depth and lime applied to neutralize the acidity in the soil mass involved. Ideally, soil samples should be taken every 2–3 years and soil acidity problems identified before the soil pH has decreased to a critically low level. This allows lime to be applied and incorporated with normal tillage operations.

Important Points to Remember

- A soil pH of 7.0 is neutral with a pH of 6.0 being 10 times and a pH of 5.0 being 100 times more acidic
- Most agronomically important crops in Kansas do best on soils mildly acidic to slightly alkaline. Legumes are more sensitive to low pH than nonlegumes.
- Soil pH indicates whether a soil should be limed. An additional test (buffer pH) of the soil must be made to accurately predict the lime rate.
- Lime recommendations from the KSU Soil Testing Lab are reported as the amount of effective calcium carbonate (ECC) needed to neutralize two million pounds of soil or roughly a 7-inch deep layer over an acre of a silt loam soil.
- The quality of liming material is expressed as ECC rating, which is a combination of purity (calcium carbonate equivalence) and fineness factors.
- All liming materials are equal in final neutralization of soil acidity when applied at the same rate of ECC and incorporated similarly.
- Thorough incorporation and time for reaction are necessary to fully effect neutralization of soil acidity.
- Soil testing every 2-3 years allows producers to monitor soil pH and initiate liming before a critically low pH exists.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-1065 March 1993