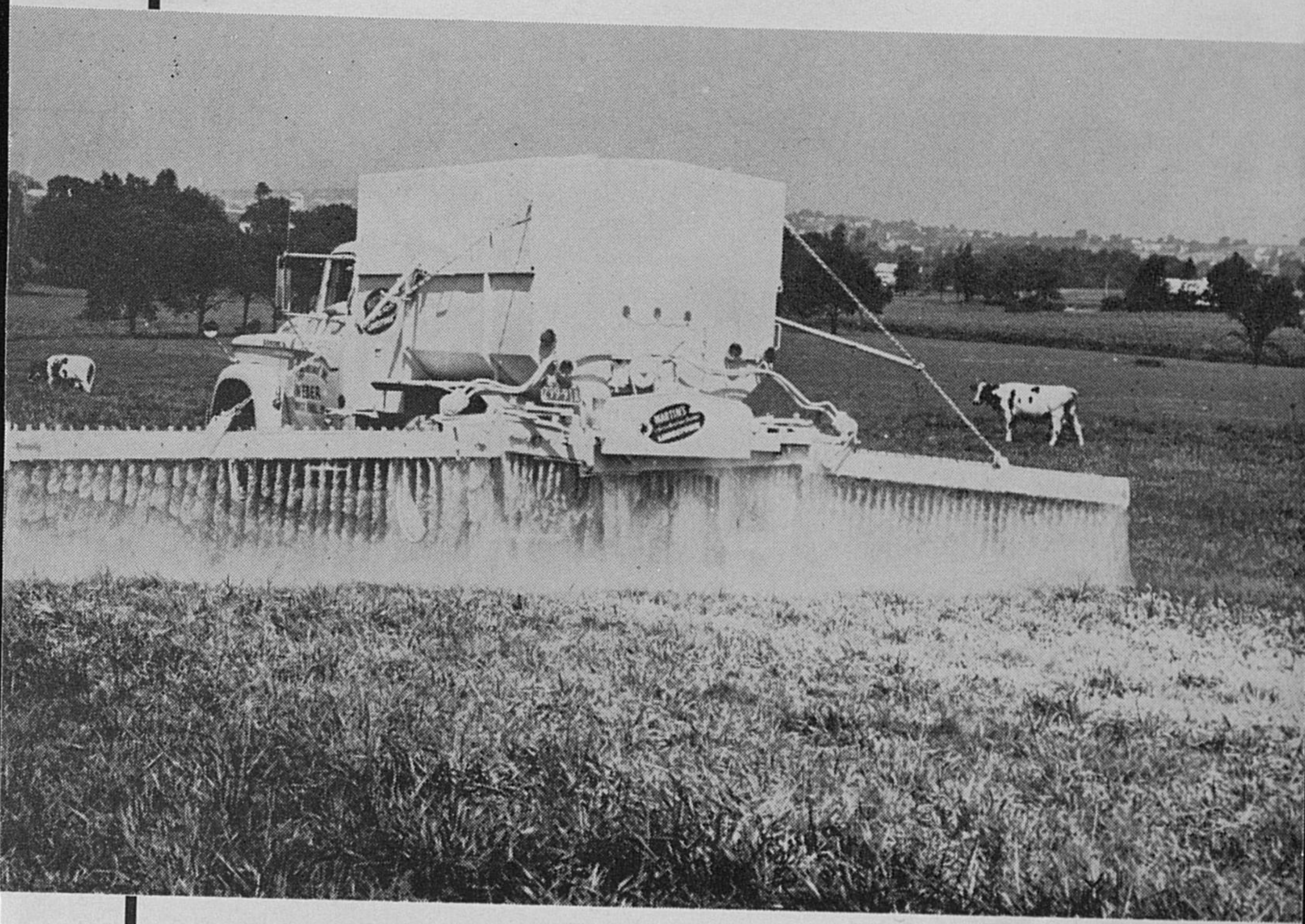

CONTROLLING SOIL ACIDITY

Why—When—Where

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NIVERSITY OF KENTUCKY | COOPERATIVE EXTENSION SERVICE
AGRICULTURE AND HOME ECONOMICS

Controlling Soil Acidity: Why - When - How

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UNIVERSITY OF KENTUCKY

Why Are Most Kentucky Soils Acid?

Why Control Soil Acidity?

Need Lime?

What Kind Should Be Used?

How Much Is Needed?

When and How Should Lime Be Applied?

Can Soils Be Overlimed?

You will find answers to these questions in this publication.

* * *

Is soil acidity limiting crop yields on *your* farm? If so, proper use of liming materials to correct soil acidity will increase your profits. A sound liming program is essential to successful soil management. The use of lime is one of the oldest farm management practices, but many farmers do not understand why it is needed nor do they realize the benefits that can be derived from its wise use.

WHY ARE MOST KENTUCKY SOILS ACID?

A soil is acid when acidic elements (hydrogen and aluminum) have replaced the basic elements such as calcium, magnesium, and potassium. Soils that were formed from rocks low in basic minerals were acidic from the time they were formed. On the other hand, those soils derived from rocks medium to high in basic minerals always become acidic when rainfall and temperature conditions are similar to those in Kentucky. In such climates there is a slow but constant formation of carbonic acid from soil water and carbon dioxide given off by plant roots and microorganisms in the soil. At first, this acid is used up in dissolving and removing calcium, magnesium and other base-forming cations from the soil. These elements, in turn, may be used by plants or lost in the water which leaches through and drains from the soil. When the soil becomes more and more acid, the acid will actually dissolve part of the soil particles. Appreciable quantities

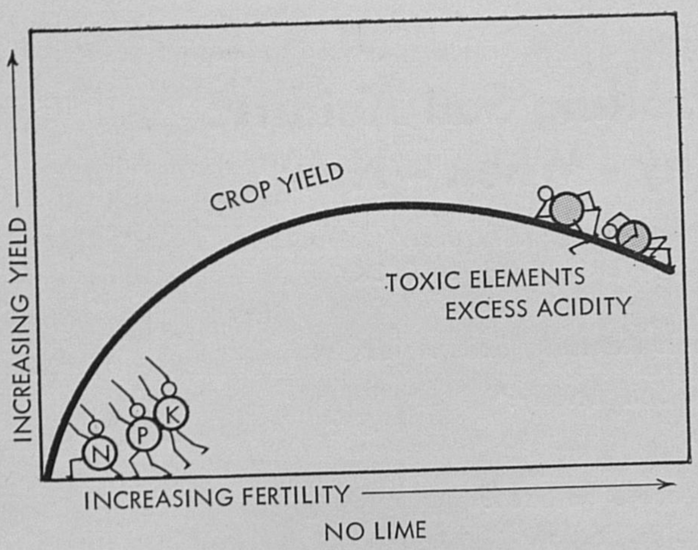

Fig. 1.— On strongly acid soils toxic elements and excess acidity will limit crop yields even though there is an abundance of available introgen, phosphorus and potassium.

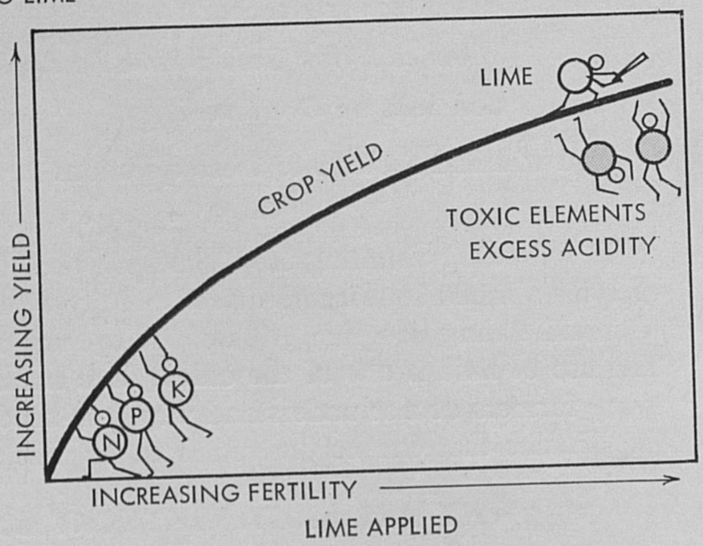

Fig. 2.— Liming strongly acid soils reduces the soil acidity and the solubility of toxic elements, thereby increasing crop yields.

of aluminum and manganese are dissolved and are taken up by plants growing on such soils.

WHY CONTROL SOIL ACIDITY?

No doubt the most widely recognized reason for applying lime to soils is to adjust the acidity to a level desirable for production of a particular crop or cropping sequence. The other principal reason is to supply calcium and magnesium (both chemical elements are essential for plant growth and for promoting the growth and functioning of the many important microorganisms present in productive soils).

The control of soil acidity is essential for maximum crop production since the degree of soil acidity affects the availability of certain elements in soils. In acid soils, such elements as aluminum and manganese are particularly soluble and also may be present in sufficient quantity to be toxic to plants. Consequently, when liming materials are applied, soil acidity is reduced and the solubility of toxic substances is reduced sufficiently to prevent crop injury. On the other hand, when acidity is reduced by liming, the phosphorus, molybdenum, calcium and magnesium are made more available to crop plants. In addition, fixation of atmospheric nitrogen by bacteria is encouraged, which in turn makes more nitrogen available to the growing crop. Maximum returns from fertilizer dollars cannot be realized unless acidity is controlled through the judicious use of lime.

Lime is not fertilizer. Actually lime sets the stage for efficient crop use of the nitrogen, phosphorus, potassium and trace elements present in the soil. Unless the acidity problem is corrected first, maximum crop yield can never be obtained, regardless of how much fertilizer is used. One of the major benefits of lime comes from its ability to change manganese and aluminum to less soluble forms that are no longer injurious to crops. An additional benefit of the lime comes from its prevention of phosphorus from being "fixed" as aluminum and manganese phosphates, which are relatively unavailable to plants. For that reason, the phosphorus already present in the soil and that added as phosphorus fertilizer are used more efficiently by plants grown on limed soil. Lime makes conditions favorable for growth of microorganisms that fix nitrogen, decompose crop residues, convert ammonium to nitrates, and at the same time it chemically discourages growth of harmful fungi and many plant diseases.

NEED LIME?

Recent summaries of soil test results indicate that at least three-fourths of the fields used for crop production in Kentucky are too acid for maximum production of most crops, particularly the valuable legumes. Proper use of good liming materials can counteract this excess acidity and result in higher yields, when used in conjunction with recommended fertilization practices (Fig. 3).

You can get additional information about the lime needs of a particular field by taking a representative soil sample, along with cropping and liming history of the field, to your county agent for a soil test.

The need for lime is most commonly determined by measuring the degree of soil acidity which is expressed in *pH* values. The pH scale ranges from 0 to 14 and is really a shorthand expression of the amount of active acidity (concentration of active hydrogen ions) in the soil.

Fig. 3. — The effect of liming on the growth of corn. (The plot on the left received lime.) Both plots were treated with nitrogen, phosphate and potash.

Notice from the pH scale that pH 7.0 is neutral, whereas all values higher than 7.0 are alkaline and any pH value below 7.0 is acidic (Fig. 4). These numbers are logarithms; consequently, there is *10 times* more acidity at pH 5 than at pH6, which means that more lime is needed to make a one unit pH change when the pH values are low.

The pH alone does not denote the amount of liming material required to make the desired adjustment in soil reaction or pH. If it

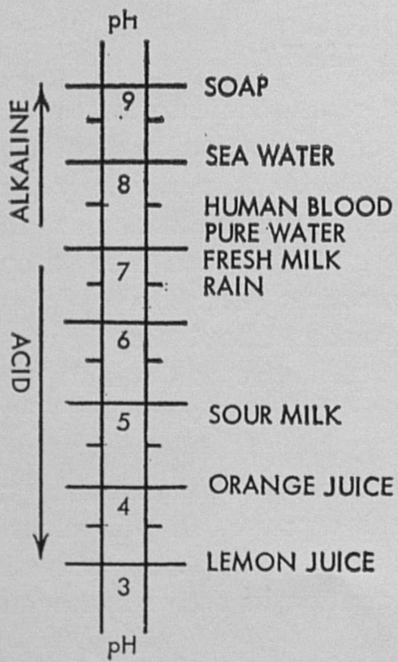

Fig. 4.— pH scale. (See text for explanation.)

were, all soils would require the same amount of lime to make the same change in pH. Such is not the case. The amount and type of clay, as well as the amount of organic matter in the soil, affect the amount of lime required to bring about any particular change in soil reaction.

Coarse lime particles dissolve more slowly in soils than fine particles, and complete dissolution of either may take as long as four or five years. Therefore, the pH of a soil a year or two after lime has been applied is not a good indicator of the need for additional lime to promote better crop yields. In other words, the pH value may indicate that more lime is needed than is actually the case, since some of the lime from the last application may still be reacting. To insure an accurate estimate it is important to complete the cropping and liming history questionnaire when you send in a soil sample.

The pH difference among soils due to rates of lime (Table 3) has been statistically different, in almost every case, but crop yields (corn on the Pembroke and Ladino clover on the Grenada) have not been increased by the use of more than 1.5 tons of lime. This comparison would suggest that only a small amount of lime was necessary to raise the pH enough to lower the solubility of aluminum, manganese, and other toxic substances to the point that they were not injurious to the crops and that the active hydrogen neutralized by the additional lime was not a limiting factor. For these reasons, soil texture and past liming history must be considered, as well as pH values, in order to make good liming recommendations.

WHAT KIND SHOULD BE USED?

The three main points for judging a liming material are: 1) the total capacity to correct soil acidity; 2) the rate at which it makes the change; and 3) the relative cost of the correction. Ground limestone, because of its wide distribution and relatively low cost, is commonly used as a standard liming material and other materials may be compared with it. Limestone for use as a liming material should have a neutralizing value of at least 80 percent of that of pure calcium carbonate. The limestones in Kentucky are dominantly calcic (calcium carbonate) with neutralizing values ranging from 85 to 95 percent.

Dolomitic limestones contain considerable amounts of magnesium carbonate and have slightly higher neutralizing values than calcic limestones. At present, there is no experimental evidence that the dolomitic limestone is more effective on most Kentucky soils than calcic limestone, but if the cost is the same the dolomitic limestone should be used, if available.

Marl is being used in some sections of the state as a liming material. Most of the marls contain some magnesium and have neutralizing values of 40 to 70 percent. This soft limestone material is good for use in liming soil, on the basis of neutralizing value, if its cost is comparable to ground limestone.

Other materials which may be economical in some particular situations are burned lime, hydrated (slaked) lime, and basic slag (byproduct of the steel industry).

Table 1.— Comparable neutralizing rates of liming materials

Liming Material	*Neutralizing Value*	*Comparable Weights*
Ground Limestone ($CaCO_3$)	90%	2,000 lb
Hydrated Lime [$Ca(OH)_2$]	133%	1,300 lb
Burned Lime (CaO)	180%	1,000 lb
Basic Slag (calcium silicate)	85%	2,500 lb
Marl (mainly $CaCO_3$)	50%	3,600 lb

The quality of limestone is also dependent upon the size of the individual particles, which is expressed in terms of the number of openings per inch of the screen, through which the material will pass. Neutralizing value of the lime is fairly constant for a given quarry. However, one should be concerned about the particle size of the lime, since it largely governs the rate of reaction of the material once it is applied to the soil.

Table 2.— A guide to the reactivity of lime in respect to particle size

Particle Size	*Soluble Within 3 Years*
Larger than 4 mesh (¼ in.)	0
4-8 mesh	10%
8-20 mesh	30%
20-60 mesh	60%
Passing a 60 mesh screen	100%

In the absence of a set of screens to check the particle size of the lime, a visual comparison can be made as in Fig. 5 below.

Considerable experimental data have been accumulated concerning the desired particle size in agricultural limestone. The larger material may be effective over a longer period of time, but the more fine material it has, the more rapidly the soil acidity will be corrected.

Ground limestone should have a neutralizing value of at least 80 percent, with at least 80 percent of the particles passing a 10-mesh screen and 40 percent passing a 60-mesh screen.

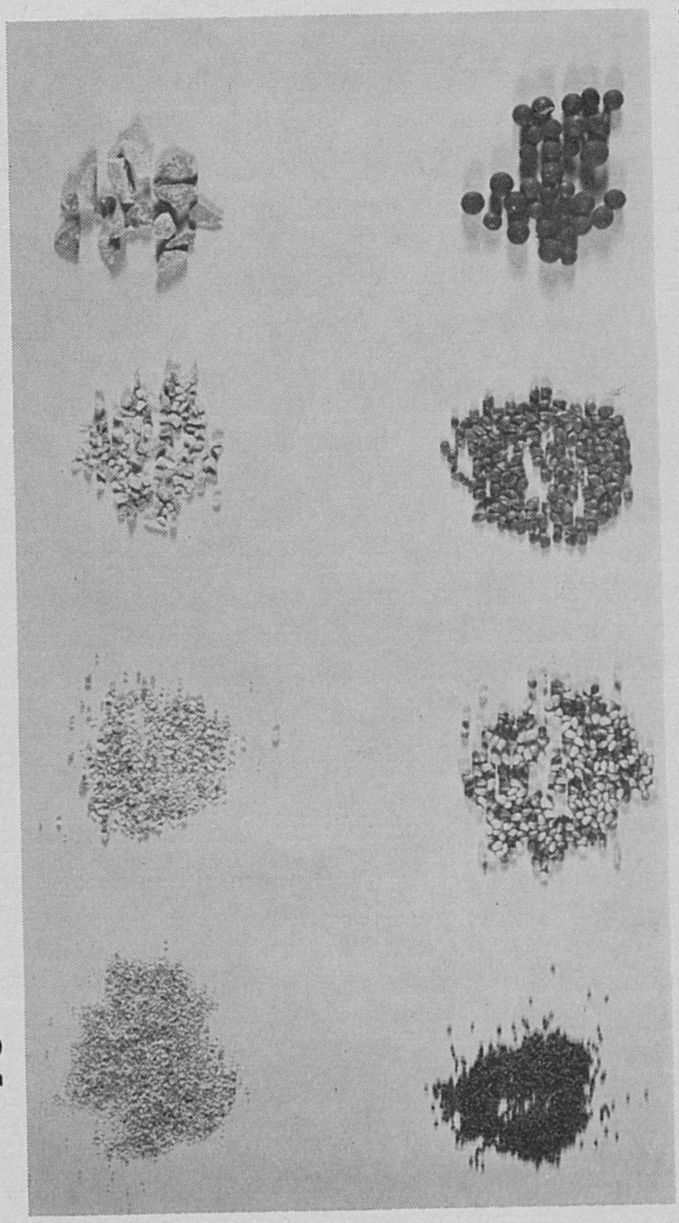

Fig. 5.— A comparison of various sized particles of ground limestone with crop seed of various sizes.

HOW MUCH IS NEEDED?

The amount of lime required depends on the kind of liming material used, the texture of the soil, the organic matter present in the soil, the depth to which the soil is plowed, and the particular crop and cropping sequence to be followed.

An intimate knowledge of how certain soils react to applied lime is necessary before a prediction can be made of the amount of lime required to raise the pH to a desired level. For instance, laboratory determinations of the amount of pure calcium carbonate necessary to change the pH from 5.5 to 7.0 have been made for several soils of the state. Mercer silt loam and Loradale silt loam, both from similar geologic formations of limestone and shale, react differently. Mercer requires 4.4 tons and Loradale 5.4 tons of ground limestone per acre to produce neutral conditions in these soils. In the same comparison, Culleoka silt loam, developed from calcareous siltstones and sandstones, requires 2.5 tons per acre. Thus, it is apparent that the type of soil determines, to a large extent, the amount of lime needed to correct the acidity.

The organic matter in a soil has a high buffering capacity or resistance to a pH change, but the organic matter content in most of Kentucky soils would not differ enough to be of great importance.

Many farmers are now plowing deeper than 6 inches because they have more powerful tractors than in the past. This means that more limestone is needed to correct acidity of the plowed soil. If 4 tons of lime was needed when a field was plowed 6 inches deep, 6 tons would be needed when it is plowed 9 inches deep because the lime is being mixed, by repeated plowing, with 3 million instead of 2 million pounds of soil, assuming uniformity of the soil properties with depth.

The soil pH range most suitable for the common crops is shown in Fig. 6. Many of these crops will grow outside these ranges, but will produce best within the ranges shown. Corn, for example, will grow over a wide range of soil pH, but pH 6.0 to 6.5 is most desirable, especially if the corn is grown in a rotation with clovers or other legumes. The Irish potato will grow at a much higher soil pH than indicated, but a scab disease is favored by less acid conditions, which in turn lowers yield and quality of the crop. Tobacco is a similar example; soil borne diseases may often be favored and nutritional balances upset at near neutral soil pH.

In summary, the amount of lime to apply depends upon a number of factors including cropping sequences. All of these factors must be considered along with results of the pH determination by the soil test, in order to reliably estimate the amount of the liming material necessary to raise the pH to a desired level.

WHEN AND HOW SHOULD LIME BE APPLIED?

Most forms of lime may be applied at any time of the year or of the crop rotation. It is best, however, to apply the material well in advance of planting the crop in the rotation that has the highest lime requirement, usually it will be a legume, such as alfalfa. It is im-

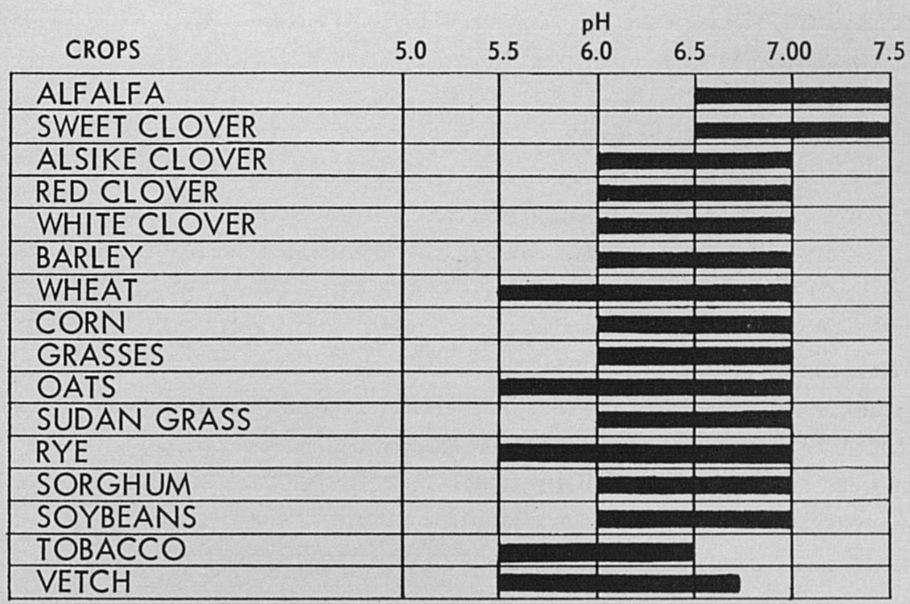

Fig. 6.— The best pH range for some common crops.

portant to get the needed lime on the land at the most convenient time, but as far as possible in advance of the desired crop.

Strongly acid soils should be limed 6 to 12 months in advance of seeding alfalfa, sweet clover and other legumes because the full effect of moderate to heavy applications of limestone will not be rapidly reached. Consequently, do not expect a rapid change in soil pH as measured by soil tests. Three to four years will frequently be required for a heavy application of ground limestone to raise the pH to the level which many have thought to be the optimum for most crops. Table 3 illustrates the seemingly small changes in acidity, as reflected by pH from various rates of limestone applied to 3 silt loam

Table 3.— Effect of finely ground limestone on the pH of three silt loam soils

Soil Type	*Lime T/A*	*Original pH*	*pH After Liming-Year* 1st	2nd	3rd
Pembroke sil	1.5	5.4	—	5.5	6.3
	3.0		—	5.8	6.5
	6.0		—	6.3	6.8
	12.0		—	6.6	7.0
Grenada sil	1.5	5.2	5.8	5.7	5.8
	3.0		6.1	6.0	6.3
	6.0		6.3	6.5	6.8
	12.0		6.5	6.7	7.1
Dickson sil	1.5	5.7	—	6.0	6.0
	3.0		—	6.0	6.2
	6.0		—	6.4	6.5
	12.0		—	6.5	6.7

soils. Although the change in pH was slow, the lime was very beneficial to crop growth.

Experimental data and the fact that successful farming is not a "one shot" business dictate that a farm liming program must be a continuing thing. Cropland should never be neglected to the point that it becomes strongly acid. Lime requirements should be checked every 3 or 4 years to determine the necessary maintenance applications.

For such special crops as tobacco and potatoes in continuous culture, it is considered most desirable to apply any needed lime in the fall after the crops are harvested, in order that the major lime-soil reaction will occur before the next crop is planted.

Most of our soils are likely to need some maintenance lime every 4 to 6 years, when used in row crop rotations with high rates of fertilizers containing such materials as ammonium sulfate. For every pound of sulfur applied, in fertilizers or fungicides, theoretically about 3 pounds of limestone will be required to neutralize the acid formed. Ammonium nitrate and urea also tend to increase soil acidity slightly because hydrogen ions are released when ammonium and amine forms of nitrogen are converted to nitrate by nitrifying bacteria in soils.

Grassland type of farming may require an approach somewhat different from annual row crops. It may be advisable to use high rates of lime that will be effective for a period of 8 to 10 years, or until renovation and reseeding are anticipated. A permanent pasture or hay crop will benefit to some extent from surface applications, but many years are required for surface-applied limestone to penetrate to plowing depth without cultivation. In West Virginia, a top dressing of 1.5 T/A of hydrated lime (equal to 2.3 T/A limestone) on a permanent sod raised the pH of the top 1.5 inches from 5.2 to 7.0 after 13 years, while the pH of the 5- to 7-inch layer was increased only from 5.0 to 5.6. This observation and other data show that liming materials applied on the surface move very slowly to lower depths, especially on the heavy textured soils. On such soils, if the subsoil is acid, and high-lime-requiring crops are to be grown, plowing under half the lime and harrowing in the remainder will help neutralize the entire plow layer. For maintenance purposes, on soils used in rotations and already having a somewhat favorable pH, all the lime may be plowed under with a sod or cover crop. This method will save labor and spreading costs, and it may speed up decomposition of the organic matter.

There are many ways to apply limestone, but it should be applied in a manner that will keep the finer dust particles, which are most effective, confined to the field being limed. If the very fine particles are carried away by wind and only the larger particles are left, the correction of the acid condition of the soil will be much slower and, consequently, crop response will be disappointing at first.

Much of the limestone spreading done by commercial spreaders is by trucks equipped with hopper-shaped bodies and endless, or screw-type conveyers which continuously move the material to the spreading mechanism mounted on the backs. The two types of spreading mechanisms are the fan, or spinner type, and the transverse conveyer type. Of the two spreading mechanisms, the transverse conveyer is preferable from the standpoint of getting a uniform spread and preventing loss of the dust due to wind. The fan or spinner type spreader depends on the force with which the lime is thrown

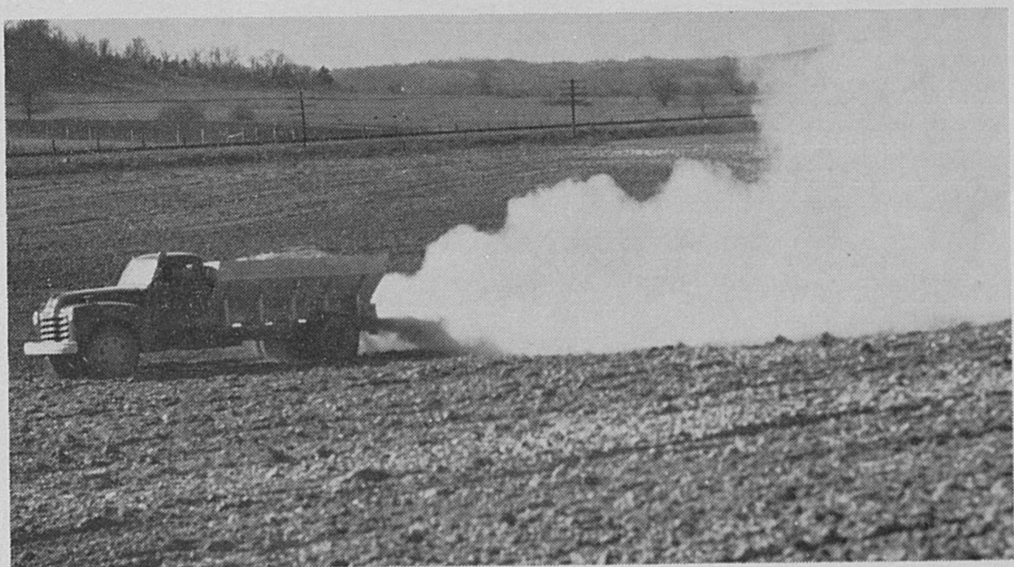

Fig. 7.— Finely ground lime particles may be carried away by the wind and a poor job of spreading may result.

from the spinner to spread the lime over a wide area. Consequently, a hood mounted over the spreader is necessary to prevent a major loss of the most valuable part of the lime—the dust. Few, if any, of the custom operators in the state have either the transverse conveyer or the hood for the spinner-type spreader.

An uneven coverage with the lime that does remain on the field, as in Fig. 8, is a result of spinner-type spreader operating without a hood and negligence on the part of the operator.

Farmers who prefer to do their own spreading would do well to choose a tractor-drawn spreader such as the hopper spreader shown in Fig. 9. Such spreaders serve the purpose well when the soil is too wet or soft to support heavy trucks, when crop requirements

Fig. 8.— Ground limestone should be applied uniformly. Parts of this field were heavily limed, while other areas received little.

make uniform spreading a must, when the fields are small and difficult to cover with a heavy truck, and when light maintenance applications are made.

CAN SOILS BE OVERLIMED?

The philosophy, "if a little is good, more is better," is not always true where lime and crop growth are concerned. The most profitable procedure is to add enough lime to an acid soil to raise the pH to the most desirable level, and then maintain that level. Below that level,

Fig. 9.— Use of a hopper spreader drawn by a fractor is a good way to spread limestone evenly.

the greater solubility of some substances (manganese and aluminum, for instance), may be sufficient to result in a toxic effect on the growing plant. As the pH value of a soil is raised above neutrality, phosphorus, boron, zinc, manganese, and copper, all of which are essential for plant growth, become less soluble, and therefore, less available to plants. In addition to paying for extra lime, the farmer who actually overlimes may also have the expense of corrective treatments, necessitated by the high pH attained.

An example of the effects of too much lime and the resulting fixation of zinc on corn yield is presented in Table 4. Zinc deficiency symptoms appeared in the third-crop year after the limestone was applied, but they were not identified and diagnosed for several years. The rate of zinc sulfate used in this trial has since been found to be much more than actually needed. Rates of 12 to 15 pounds per acre placed with the seed at planting time now appear to be sufficient.

Table 4.— The effect of zinc sulfate on the yield of corn grown on overlimed soil

Treatment in addition to N, P and K		*pH*	*Yield, bu/A*
No lime	No $ZnSO_4$	5.8	39.5
70 T/A lime	No $ZnSO_4$	7.8	4.9
70 T/A lime	259 lb/A $ZnSO_4$	7.8	46.5

High pH values are especially troublesome on sandy soils. Such soils are likely to contain only small amounts of essential minor elements, and the availability of these small amounts is greatly reduced as the pH value goes up.

Two methods may be followed to overcome these shortages of the essential elements which are induced by overliming. The first and most common way is to apply the elements which are deficient because of their low solubility at the high pH. These must be applied in a manner that will supply the elements to each crop, such as sweet clover, alfalfa and corn, until the slow processes of nature lower the pH of the soil to the level at which the elements in the soil again become soluble and available to the plants. The difficulty with this method is the lack of easy methods to diagnose what is needed, how much should be used, and how to apply it before crop yields have been drastically reduced. The procedures required for the determination of the quantity of the minor elements in the soil or in the plant are not so short and simple as the determination of phosphorus or potassium; special laboratory equipment is required.

The second way to overcome shortages is to make a soil more acid, particularly when growing blueberries and certain ornamental plants. Sulfuric acid, iron and aluminum sulfates, and powdered sulfur can be used. Sulfuric acid reacts quickly and is often cheap enough for field application, but is hazardous to handle. Iron and aluminum sulfates are usually too costly, but are often used in nurseries. Because of its relatively low cost, sulfur is the logical choice for use. Sulfur is relatively slow in reacting because it must first be oxidized by soil organisms to form sulfuric acid before it is available for reaction with the soil. Rates of 800 to 1500 pounds per acre of elemental sulfur are likely to be required on most silt loams to lower the pH ½ to 1 unit. Sulfur should be broadcast and mixed thoroughly into the soil by disking. Two to three warm months will be required for the sulfur application to react.

Although the high buffering capacity of our soils helps prevent overliming, farmers should not depend upon this. A good soil test is the best guide to follow when determining the quantity of lime needed.

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