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Liming Ohio Soils

This good Summit County clover field is the result of liming, manuring, and fertilizing.

By

EARL JONES

Extension Agronomist, The Ohio State University

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Liming Ohio Soils

Why Lime the Land?

WHAT BENEFITS are to be expected from the use of liming materials? Under what conditions is their use necessary and profitable? The work of the Experiment Station and the experience of many farmers plainly indicate that the use of lime on acid soils is profitable. Lime prepares acid soils for satisfactory crops of clover, alfalfa, or sweet clover.

Growing these crops is profitable because: (1) livestock can be fed more economically when good quality legume hay is available than when other roughages only are fed; (2) the other crops of the rotation can be produced more economically, because liming acid soils increases the yields of all the rotation crops; and (3) when satisfactory legume crops are grown in a good rotation, the productivity of the soil can be maintained economically, although erosion control practices are also necessary on sloping land.

Liming a Profitable Practice

Livestock More Economically Fed.—If legume hay of high quality is available, more hay may be included in the ration of all farm animals and the amount of grain and high protein supplements, which are often the most expensive part of the ration, reduced. This results in more economical feeding of livestock and contributes to their health.

Increases Crop Yields.—The immediate economic benefits from the improvement in quality of forage and the increase in yield of all crops of the rotation due to liming are indicated by 8 years' results from the Legume-Reaction experiment at Wooster. In order to change the reaction from pH 5.0 to pH 6.8 and prepare the soil for alfalfa, an initial application of 3 tons of pulverized ground limestone per acre was made. Since then, 500 pounds per acre has been applied during each 3-year rotation (corn, small grain, and hay) to maintain the desired reaction. The initial cost was $11.25 per acre, and the cost of maintaining the desired reaction has been $0.94 per rotation. This has made it possible to grow good alfalfa instead of mediocre timothy for hay. As a result of the use of lime and the shift to

Table I.—Comparative Yields of Field Crops on Fertilized Unlimed and Adequately Limed Land

Ave. 8 crops hay, 5 crops corn, 2 crops small grain

Crop	Adequately limed land Per cent	Unlimed land Per cent
Alfalfa	100	9
Sweet clover	100	2
Red, alsike, and mammoth clover	100	21 to 29
Barley	100	23
Timothy	100	47
Corn	100	73
Soybeans for hay	100	79
Wheat	100	73
Oats	100	93

alfalfa, the total acre value of the crops per rotation was raised from $29.73 to $74.48 — or a net gain of $44.75 in crop values.

The prices used in the calculations of the value of crop increases due to the use of liming materials are as follows (stover and straw included with corn and grain): Corn 50¢ bushel, oats 30¢ bushel, wheat 90¢ bushel, barley 50¢ bushel, soybeans 90¢ bushel, potatoes 75¢ bushel, clover and timothy hay $8 per ton, alfalfa and soybean hay $10 per ton.

In the same experiment, the yields of all the common field crops at pH 5.0 (the usual reaction of the unlimed soils of eastern Ohio) were notably less than the yields on limed land at a reaction of pH 6.8 (see Table I).

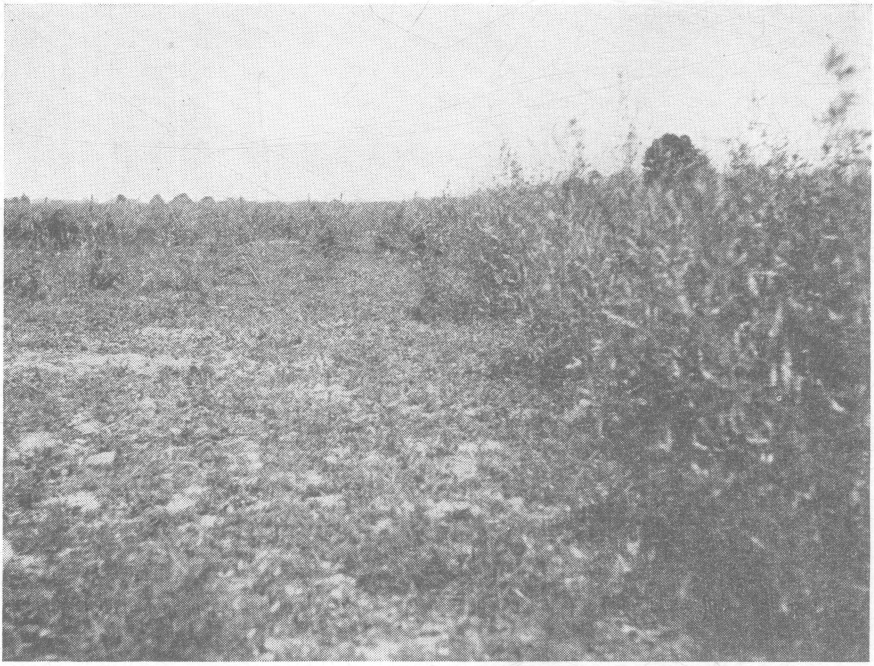


Fig. 1.—Light colored soil, Miami County. Left, no lime; right, limed. Sweet clover sown over entire field.

Use of Lime Pays Dividends.—The use of liming materials, where needed, is a highly profitable investment. The comparisons between the yields on limed and unlimed plots on experimental farms with acid soils in Ohio (all other conditions being the same) indicate that $1.00 invested in liming materials returns from $2.00 to $8.00 in the next two rotations after liming. All the crops in the rotation have helped pay for the lime, and in some experiments the increased yields of corn alone have almost paid for the lime.

The smaller returns have been obtained when the applications were larger than necessary or when the soil limed was above the average in productivity. The larger returns have been obtained where alfalfa has been grown after liming, where the soils were rather unproductive before liming, and where only the necessary applications were made.

In calculating these returns, the hay from the limed and unlimed plots was figured at the same value per ton. Since the hay on unlimed land was generally scattering clover, timothy, and weeds, and that on limed land was usually good clover or alfalfa, the market value per ton of the hay on limed land would be greater than that of the hay on unlimed land. There is an additional profit when the better hay is fed to livestock as compared with feeding the hay grown on unlimed land.

In the old 5-year rotation fertility experiment, begun at Wooster in 1894, the west end of all the plots has been limed regularly since 1903, while the east end has never been limed. The rotation is corn, oats, wheat, and two years of hay (clover and timothy seeded). The average yield of the fertilized plots is shown in Table II.

Table II.–Yields and Value of Crops Grown on Limed and Unlimed Soil 1917-1931

	Unlimed	Limed	Gain for liming
Corn	23.6 bu.	45.8 bu.	22.2 bu.
Oats	36.0 bu.	49.0 bu.	13.0 bu.
Wheat	17.7 bu.	27.9 bu.	10.2 bu.
First year hay	1288 lbs.	3405 lbs.	2117 lbs.
Second year hay	1496 lbs.	3684 lbs.	2188 lbs.
Total value of crops per rotation	$49.87	$91.79	
Gain for liming per rotation		41.92	
Cost of lime per rotation		7.50	
Balance per rotation		34.42	

Liming Insures Future Soil Productivity

In the development of new countries, little attention is given to the future productivity of the soil. This country is now definitely committed to the idea that we must maintain or increase the productivity of the soil for the benefit of future generations, and liming acid soils is an important part of this plan. Such a program promises to be highly profitable at the present time.

Growing Clovers and Alfalfa Fundamental.—There are a number of factors concerned in soil improvement and erosion control programs, but the following fundamental practices dominate all of them: (1) the growing of clover and alfalfa, alone or in mixtures, on the hay land; (2) good sods on the permanent pastures; and (3) growing sweet clover or other clovers for plowing under on rotation land where hay crops are not needed on the farm or cannot be profitably sold. A good soil cover when the land is in pasture or hay, and good sods to plow under preceding cultivated crops, are fundamental in any individual or public soil conservation program.

The common clovers, alfalfa, and sweet clover, alone or in mixtures with each other or with grasses, are the only real soil improving crops of the general farm rotation in Ohio. If we get good stands of these crops and plow under good sods we are well started on a real soil improvement program. If we cannot do this, we have accomplished little. The growing of good meadows or sweet clover is the best means known for improving the tilth of heavy soils.

Liming Necessary.—A number of factors contribute to the growing of good clover, alfalfa, or sweet clover. On acid soils the most important of these is the use of liming materials. If the soil is too acid for the satisfactory growth of these legumes, the other things done in preparing for them are largely wasted effort. On the other hand, where these crops can be grown satisfactorily without liming, the use of liming materials at the present time is not necessary, although their use may be necessary in the future.

Fig. 2.—Alfalfa-timothy mixtures on the Trumbull County Experiment Farm. This field was liberally limed, manured, and fertilized. *(Courtesy Carbon Limestone Co.)*

Other Essential Factors.—In addition to liming, the use of fertilizers is generally profitable and in many cases essential. Inoculation is necessary when a new legume is seeded on the field for the first time. Taking better care of the manure produced on Ohio farms and using it where it will be most beneficial to the new seedings are profitable practices. Even after the lime problem is cared for, attention needs to be given to varieties, sources of seed, and methods of seeding, if good seedings are to be secured year after year.

The Cause of Acid Soils

A brief consideration of the cause of soil acidity will help in understanding the problem and the remedy.

All Ohio soils, except the shale and sandstone soils in the unglaciated southeastern part of the state, originally contained some limestone. The soils of western Ohio contained the most limestone, because the bedrock in this area is limestone. Due to the mixing of rock fragments by the glaciers, some of the glaciated soils of northeastern Ohio originally contained a small amount of limestone.

In ordinary seasons Ohio's annual rainfall varies from 35 to 39 inches. Part of this water seeps through the soil into the lower subsoil and bedrock, forming the supply of water for wells and springs. Soil water absorbs considerable carbon dioxide, produced by the decay of soil organic matter and the respiration of plant roots, and is considerably more active in dissolving limestone than is pure water.

The limestone in the soil slowly dissolves in the soil water and is carried through the soil into the ground water. This dissolved limestone is responsible for the hard water in many wells and springs. Lime comes out of solution when hard water is boiled, and this accounts for the deposit in the teakettle on many kitchen stoves.

Extent of Lime Losses.—This loss of limestone by leaching is the main cause of soil acidity in Ohio. These losses are much larger than the removal of limestone in crops. Some of the limestone removed in crops is returned to the fields in the manure.

Table III.—Losses of Calcium and Magnesium, Cornell Lysimeter Tanks—15-Year Average (Cornell Memoir 134)

Cropping Practices	Average Annual Loss — Pounds per Acre					
	Calcium Carbonate			Magnesium Carbonate		
	By Leaching	Crop Removal	Total	By Leaching	Crop Removal	Total
Bare soil	921		921	205	..	205
Rotation without legumes..	551	28	579	150	19	169
Rotation with legumes ..	429	82	511	124	35	159
Continuous grass.......	581	25	606	142	16	158

It is difficult, in field experiments, to measure the losses by leaching. The Cornell Experiment Station has a number of tanks or lysimeters filled with soil to a depth of 4 feet, some of which are uncropped and the remainder cropped. The drainage water from these tanks is collected and analyzed and the crops have also been analyzed (see Table III). The losses of nutrient elements by leaching in lysimeters are larger than the losses from field soils.

Depth of Acid Soil Layer.—Limestone is first leached out of the surface soil, and, as time goes on, leaching continues from the upper subsoil. The depth of the acid soil layer varies throughout Ohio. In the old glacial soils of the Clermont area east of Cincinnati, the acid soil layer is 4 feet in depth, while in northeastern Ohio it is 2½ to 4 feet in depth. In western Ohio many light colored soils are acid in the plow layer, but a distinct lime layer is found at a depth of 1½ to 2½ feet.

The depth of the acid soil layer is important in determining the need for liming materials. Where the plow layer is acid and the subsoil layer containing limestone is 18 to 24 inches below the surface, alfalfa and sweet clover plants may live until their roots reach the subsoil layer containing lime and then make a normal growth. Where the subsoil lime layer is 30 to 40 inches below the surface, the young plants will ordinarily die unless the plow layer is liberally limed.

Some Fertilizers Tend to Increase Acidity.—The use of fertilizers containing ammonia nitrogen slightly increases soil acidity because the acid produced during the change from organic and ammonia nitrogen to nitrate nitrogen reacts with some of the lime in the soil. This is most important with sulfate of ammonia and ammonium phosphate but is of little importance in the fertilization of field crops in Ohio. If 200 pounds of 2-12-6 is used per acre and if sulfate of ammonia is the sole source of nitrogen in the fertilizer, not over 20 pounds of calcium carbonate would be involved in the reaction. When heavy applications of high nitrogen fertilizer are used year after year, the soil reaction may be slightly changed in either direction by the choice of nitrogen carriers (see also page 13).

Properties of Acid Soils

A deficiency of lime produces many changes in the soil, all of them unfavorable to the common field crops and especially to the soil improving legumes. Soil acidity is less detrimental on productive soils, and on soils which have been fertilized and manured regularly during the rotation, than on other soils. It is less detrimental during favorable seasons than at other times.

In acid soils the acid itself may damage the roots of crops. On strongly acid soils, some of the aluminum in the soil becomes soluble and toxic to some crops. As acidity develops, the phosphorus in the soil becomes less available, while calcium and magnesium may become limiting nutrient elements in crop growth. Soil acidity interferes with desirable biological activities in the soil, especially the fixation of atmospheric nitrogen and the decay processes by which the nitrogen in organic matter is made available for crops.

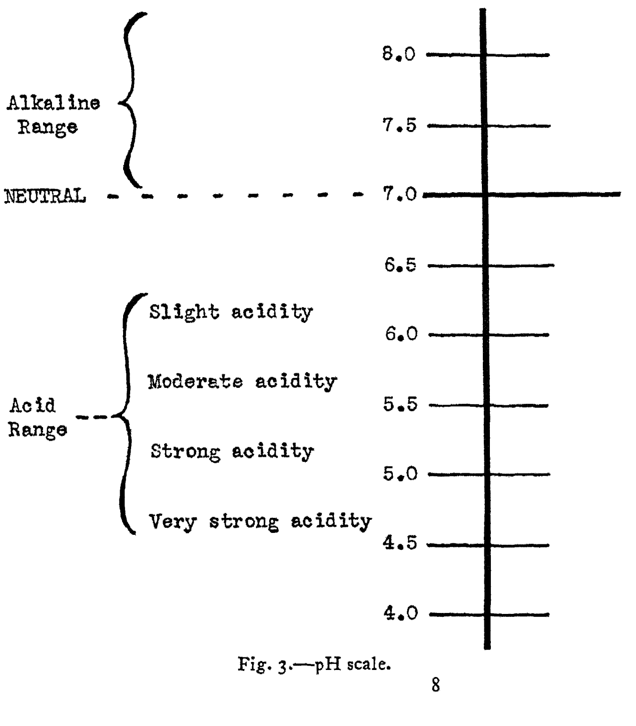


Fig. 3.—pH scale.

pH of Soils.—For our purpose soil acidity may be defined as a deficiency of important basic elements, calcium and magnesium. As these elements are leached out, hydrogen replaces them in the colloidal soil complexes. This tends to produce an acid reaction in the soil solution. The most common method of measuring soil reaction depends on the determination of its concentration of hydrogen ions. This is stated in terms of pH (Fig. 3).

Relation of Crops to Soil Acidity

Many agricultural experiment stations have studied the relation of field and vegetable crops to soil reaction, and the crops have been divided roughly into groups based on their tolerance of acidity (see Table IV).

Table IV.—Crops Grouped According to Their Tolerance of Acidity

Very sensitive to acidity	Will tolerate some acidity, but are usually helped by liming. These crops are not injured by liming unless excessive applications are made, although potato scab may develop when the pH is 5.4 or higher.		Strong acidity favorable
	Will tolerate Slight acidity	Will tolerate Moderate acidity	
Alfalfa	Red clover	Soybean	Blueberry
Sweet clover	Mammoth clover	Vetch	Cranberry
Barley	Alsike clover	Oats	Holly
Sugar beet	White clover	Rye	Rhododendron
Cabbage	Timothy	Buckwheat	Azalea
Cauliflower	Kentucky bluegrass	Millet	
Lettuce	Corn	Sudan grass	
Onion	Wheat	Redtop	
Spinach	Peas	Bent grasses	
Asparagus	Lima, pole and snap beans	Tobacco	
Beets	Carrot	Potato	
Parsnip	Cucumber	Field bean	
Celery	Brussel sprouts	Parsley	
Muskmelon	Kale	Sweet potato	
Rutabaga	Kohlrabi		
	Pumpkin		
	Radish		
	Squash		
	Sweet corn		
	Tomato		
	Turnip		

Potatoes.—If acid soils are limed so that the pH goes above 5.4, there is a possibility of scabby potatoes being produced, although this does not always happen. Commercial potato growers in acid soil areas are advised to keep the pH of their soils at pH 5.0 to 5.4, and the use of lime is not recommended at a higher pH. If potatoes are grown only on certain fields of the farm, the remainder of the fields may be limed so that alfalfa and sweet clover can be grown.

Fruit Crops.—For the most satisfactory growth of fruit crops the soil should have a pH of 5.5 or higher. A higher pH is essential for the satisfactory growth of soil improvement and cover crops, and does not injure the fruit crop.

Pastures.—Liming is fundamental in the improvement of the permanent pastures in eastern and southern Ohio, but fertilizers are also essential. The surface soil should have a pH of 5.8 or higher. The lime must necessarily be applied broadcast as a top dressing.

Liming Materials and Their Use

There are two main properties that determine the value of liming materials — total neutralizing power and fineness. The laws of Ohio require that they shall be guaranteed for all the commercial liming materials sold in the state. For bagged material these guarantees must be printed on the bag or on the tag attached to the bag. For bulk materials a printed statement must be furnished the purchaser.

The hardness of limestone, its weight, its porosity, or its color have apparently no relation to its value that cannot be expressed by neutralizing power and fineness.

Fig. 4.—Alfalfa mixtures, Ohio Experiment Station farm, Wooster. Foreground unlimed, background limed. Same fertilizer on entire area.

Total Neutralizing Power.—The total neutralizing power of a liming material is a measure of its total capacity to correct soil acidity, but gives no idea as to how quickly this action may take place. It is expressed in terms of calcium carbonate, and includes the neutralizing power of all the active acidity-correcting constituents (see Table V).

Chemically pure calcium carbonate has a neutralizing power of 100. A given weight of magnesium carbonate will correct 1.2 times as much soil acidity as the same weight of calcium carbonate. Dolomitic or magnesium limestones (containing up to 35 per cent magnesium carbonate in addition to calcium carbonate) will therefore have a higher neutralizing power than high calcium stones. The dolomitic limestones sold in Ohio have a neutralizing power between 100 and 108.

When limestone is burned, carbon dioxide is lost to the air, and the resulting burned lime contains a higher per cent of calcium and magnesium than did the limestone, and therefore has a higher neutralizing power per pound of material. Upon exposure to the air it absorbs carbon dioxide and water, and slowly changes to the carbonate form with a decrease in neutralizing power. Home burned lime generally has a lower neutralizing power than commercial burned lime. It contains some ashes and soil.

Burned lime is usually hydrated before it is sold to farmers, because hydrated lime is less disagreeable to apply than burned lime and burned lime must be pulverized in some way. Water is sprayed on burned lime during this process. Hydrated lime contains less calcium and magnesium than burned lime and therefore has a lower neutralizing power. The hydrated limes on the market in Ohio have a neutralizing power between 120 and 170. Hydrated limes and all materials claimed to be hydrated lime should be purchased on the basis of their neutralizing power.

Table V.—Neutralizing Power of Chemically Pure Liming Materials

Calcium carbonate or calcium limestone	100
Calcium oxide or burned lime (Quicklime)	179
Calcium hydroxide or hydrated lime	135
Calcium-magnesium carbonate or dolomitic limestone	108
Calcium-magnesium oxide or burned dolomitic lime	207
Calcium hydroxide-magnesium oxide, or hydrated dolomitic lime	176

Many commercial liming materials contain small amounts of impurities and therefore have a slightly lower neutralizing power than is given in Table V.

Fineness.—The fineness of a liming material is important because it influences the rate at which that material will correct acidity. For ground limestone materials this rate depends upon the extent of surface in contact with the soil acids. The finer the limestone, the larger is the surface exposed by a given weight of limestone. Variation in fineness is the main distinguishing feature between the commercial grades of limestone (see Table VI).

The fineness of liming materials is determined by screening them through sieves of various mesh sizes, such as 200-, 100-, 50-, and 10-mesh sieves (a 100-mesh sieve has 100 meshes per linear inch in both directions, or 10,000 openings per square inch).

Amount of Lime Required Depends on Fineness.—Limestone particles of any size will begin to correct acidity as soon as they are incorporated in an acid soil. However, the rate at which this action takes place and the time required to produce the maximum effect depends upon the size of the individual particles.

One-hundred-mesh material is dust-like in character and will exert its maximum effect soon after incorporation with the soil. Particles of 50-mesh size look like the finest grains of sand. They are less rapid in their action and 1 to 1½ years may be necessary for them to exert their maximum effect. Particles of 10-mesh size are about the size of large grains of sand. They are still slower in their action and several years may be required for complete dissolution.

With hydrated lime there is no fineness problem, since all of this material generally passes through a 100-mesh sieve.

Table VI.—Fineness of Ground Limestone Materials

Material	Per cent passing through 100-mesh-sieve
Screenings*	Less than 20
Limestone meal — Coarse	20 to 25
Limestone meal — Fine	30 to 40
Agr'l ground limestone (sometimes kiln dried)	45 to 60
Pulverized limestone (kiln dried)	65 to 80
Superfine limestone (kiln dried)	85 to 95

* Not sold commercially, but available at some limestone quarries.

Limestone Products Graded on Fineness.—The producers of liming materials in Ohio have agreed upon a classification of the ground limestone materials sold in the state, based upon their fineness (see Table VI).

The kiln dried materials are available in bags at an additional cost of about $1.00 per ton.

Fine grinding increases the cost of production and therefore the price to the farmer. Experimental evidence indicates that the use of materials finer than agricultural ground limestone is seldom justified at present prices.

Minor Liming Materials

Marl.—Marl is pure or impure calcium carbonate found in deposits in swamps. It is in most cases a soft material and usually of satisfactory fineness. Some deposits are pure, while others contain considerable amounts of clay which was washed into the deposit during its formation. The total neutralizing power of a marl should be known before it is applied to the land.

Marl is usually allowed to dry for some time before it is used. Thorough drying is impossible some seasons, and because of this, its extensive use is more or less restricted to farms near the deposit and it is best applied with a manure spreader or by hand.

Slag.—Blast furnace or agricultural slag is a by-product of the smelting of iron ore in blast furnaces. The impurities in the iron ore combine with the limestone used as a flux. The resulting slag is calcium silicate rather than calcium carbonate. Its neutralizing power varies, depending upon the materials used in the furnace, but most lots have a neutralizing power around 85.

The water-cooled or granulated slag is a soft porous material, but since only a small part will pass a 100-mesh screen it is rather slow in its action on soil acids. Tests indicate that 3 to 4 tons of slag must be used in place of 1 ton of agricultural ground limestone, if immediate results are desired. Two to 2½ tons of slag are equivalent to 1 ton of agricultural ground limestone if immediate results are not desired.

Except for the differences in neutralizing power, slag is apparently equal to ground limestone, if it is ground as fine as the limestone.

By-Products.—Fine calcium carbonate is a by-product of many city water softening plants. Its neutralizing power, when dry, is approximately the same as that of ground limestone and its fineness is like that of superfine limestone. Its water content is variable, and it cannot be thoroughly air dried because it holds water tenaciously, due to its fineness. Its use will probably be restricted to neighboring farms since it must be spread by hand or with a manure spreader.

A similar material of variable moisture content is produced as a by-product in the manufacture of sugar from sugar beets. It has a neutralizing power of 80 to 95 on the dry basis.

Fig. 5.—Field of alsike and red clover on the H. M. Call farm, Summit County.

Precipitated calcium carbonate is also a by-product of the soda ash and certain other chemical industries. It is as fine as pulverized limestone, has a neutralizing power of about 95, and looks like hydrated lime when dry.

The fresh residue from the manufacture of acetylene gas is hydrated lime. Under exposure to air the lime changes to the carbonate form rather rapidly.

Fertilizer Materials that Correct Soil Acidity.—These fertilizers cannot be economically substituted for the common liming materials on acid soils, because of their cost.

Basic slag has a neutralizing power around 85 and contains 8 to 18 per cent phosphoric acid. It is used primarily as a phosphatic fertilizer. Calcium cyanamid, a nitrogenous fertilizer, has a neutralizing power similar to that of ground limestone, or 100 (see Table V). Bone meal has a neutralizing power of about 40.

Equivalent Applications of Different Liming Materials

It is difficult to make a definite statement about the equivalent applications of the liming materials on the market in Ohio. Fine materials work faster than coarser materials, but their effects are less permanent. The comparative value of different liming materials varies, depending upon the time over which the returns are measured (see Table VII).

Coarse dolomitic limestones dissolve more slowly than coarse calcium limestones. Heavier applications of dolomitic limestone meal and agricultural ground limestone are therefore necessary than of calcium stone of the same fineness. For equal efficiency dolomitic stone of the above grades should have about 10 per cent more 100-mesh material than calcium stone of the same grades.

Table VII.—Equivalent Applications of Liming Materials on Basis of Agricultural Ground Limestone

Material	Per cent through 100-mesh sieve	Applied several months preceding seeding of legume or earlier		Applied at time of planting legume	
		Calcium stone lbs	Dolomitic stone lbs	Calcium stone lbs.	Dolomitic stone lbs.
Coarse limestone meal	20-30	2850	3600	4100	5500
Fine limestone meal	30-40	2400	2900	3300	4300
Agricultural ground limestone	45-60	2000	2300	2500	3150
Pulverized limestone	65-80	1800	1900	1950	2250
Superfine limestone	85-95	1800	1700	1800	1850
Hydrated lime (NP 135)	100	1350	1350	1350	1350
Hydrated lime (NP 170)	100	1070	1070	1070	1070

Use of Lime

How Much?—The amount of any particular liming material which must be used to attain the desired results varies, depending upon the following factors: (1) crops to be grown, (2) reaction of soil, (3) soil type, and (4) depth to subsoil layer containing lime.

The reaction of sandy soils can be changed with the smallest applications of liming materials. Heavier applications are necessary to make the same change in silt loam soils, and still heavier applications in silty clay loam and clay soils.

Heavy applications are necessary to change the reaction of soils with a high content of organic matter like peats, mucks, and other dark colored soils. This is not as serious a problem as it might seem, since it is not necessary to have as high a pH with these soils as with light colored soils having a lower organic matter content.

When the reaction and soil type are known, other factors must be considered before accurate recommendations for the use of liming materials can be made. Less liming material is required on a productive soil than on an unproductive soil of the same texture. Clover will do better on manured acid soils than on unmanured soils of the same reaction.

Information is available regarding the amount of liming material needed to make a definite change in the reaction of soils of different textures. Gradations between different soil types are often found in one field (see Table VIII).

Table VIII.—Lime Requirement of Different Soil Types of Same Reaction

Present pH of soil	Tons of agricultural ground limestone needed per acre to raise					
	Sandy loam soils		Silt loam soils		Silty-clay loam soils	
	to pH 6.0	to pH 6.5	to pH 6.0	to pH 6.5	to pH 6.0	to pH 6.5
6.0	none	0.5	none	0.9	none	1.25
5.5	0.5	1.0	0.9	1.8	1.2	2.50
5.0	1.0	1.5	1.8	2.7	2.5	3.75
4.8	1.2	1.7	2.1	3.0	3.0	4.25

Unlimed sandy and silt loam soils in eastern Ohio generally have a pH around 5.0, while silty clay loams have a pH around 4.8. Unproductive areas are generally more acid than the remainder of the field, and should have heavier applications of liming materials.

Experimental results indicate that an application of approximately 1 ton of agricultural ground limestone will raise the reaction of sandy loam soils 1 pH towards neutrality, while about 1.8 tons is required to make the same change in silt loam soils, and about 2.5 tons in silty clay loam soils.

In using Table VIII the farmer should modify the recommendations if his soil is intermediate in type or of mixed types.

Reasonably good clover and alfalfa-clover-grass mixtures can be grown at pH 6.0. On light colored soils, alfalfa-clover-grass mixtures should be used the first time alfalfa is sown on a field, and in many cases they, or alfalfa-grass mixtures, are more satisfactory than straight alfalfa.

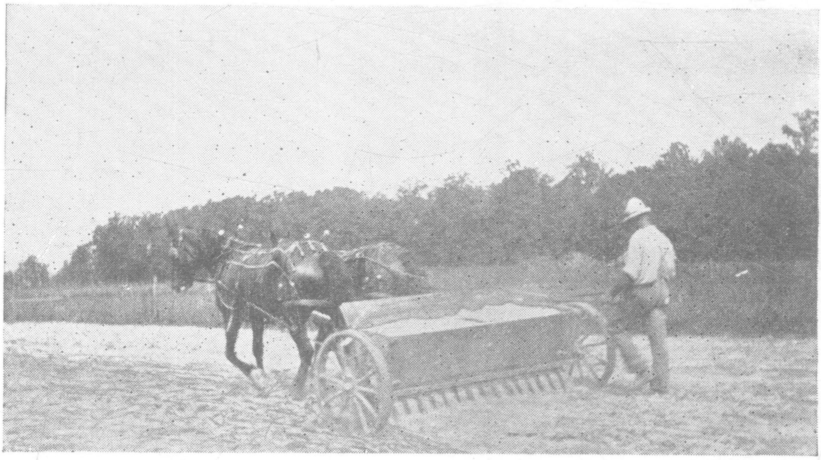


Fig. 6.—Hopper type of lime spreader.

A Liming Program for Eastern and Southern Ohio

(Areas 1 to 6 on map)

What is the best procedure for the eastern and southern Ohio farmer who is farming acid soils and does not have much money to spend for liming materials? The first step in improving such a soil is to make a liberal broadcast application of the liming material that can be gotten on the land with the smallest cash expenditure, even if the handling and spreading of these materials means extra labor and possibly some inconvenience.

Limestone meal or agricultural ground limestone sold in bulk are, usually, the liming materials that may be used to change the soil reaction with the smallest cash expenditure. The first application should be sufficient to raise the pH of the soil to 6.0 or 6.5, and the entire rotated area should be covered as soon as possible. This will provide a good foundation on which soil improvement programs can be built and it will soon pay for itself.

If this application cannot be made on the entire area, as much of the farm as possible should be covered the first rotation, and the increased returns from this will make it easier to complete the work the next rotation.

Lighter applications of liming materials (1500 to 2000 pounds or more of agricultural ground limestone per acre or equivalent) are the next best solution of the problem when the desired application cannot possibly be made. Followed consistently for several rotations, these smaller applications will gradually produce the desired soil reaction.

Still lighter applications and the use of manure to help clover is the next best procedure,

Fig. 7.—Lime need of unlimed soils. Areas 1 to 5 inclusive parent material sandstone and shale. Unlimed soils acid.

Area 1—Mostly silt loams, heavier in the northern part of the area. Scattered deposits of limestone in part of area.

Area 2—Unlimed soils, strongly acid and mostly silty clay loams.

Area 3—Soils vary from sandy loams to silty clay loams.

Area 4—Intermediate in texture between silt loam and silty clay loams.

Area 5—Unlimed light colored soils acid in surface, but lime in some of the subsoils. Silt loams and silty clay loams.

Area 6—Parent material limestone, but deeply leached so that surface and subsoil are acid. Silt loams predominate.

Areas 7—Parent material limestone and lime in subsoil. Light colored surface soils, generally moderately acid.

Area 8—Parent material limestone. Dark colored soils which have no lime requirement predominate. Light colored soils, slightly acid in surface.

but the benefit is temporary. In experimental work at Wooster, an application of 500 pounds of pulverized limestone per acre at wheat seeding time has been more effective than the same application in the spring when seeding clover.

A light application of manure or straw on the wheat during the fall or early winter helps clover get started on slopes and light colored soils average or below in productivity. The same applications may be made in the case of summer seedings, just before or just after the seeding is made. Applications of manure or straw are of little value in preparing acid soils for alfalfa or sweet clover.

A Liming Program for Western Ohio
(Areas 7 and 8 on map)

The dark colored soils will generally grow alfalfa and sweet clover without liming.

The acid light colored soils differ from those of eastern Ohio in that the acid soil layer is shallow and the active calcium content likely to be higher. Many of these light colored soils still grow alfalfa and sweet clover satisfactorily without liming, but others will not. Even though these soils will grow alfalfa without liming, an application of liming materials often means a better stand and larger yields. Soils which have a grayish appearance when dry are generally more acid than yellowish or brown colored soils.

Where the use of liming materials is necessary for the successful growth of alfalfa and sweet clover, an application of 1 ton of agricultural ground limestone per acre (or equivalent application of another liming material) is usually satisfactory and will have considerable residual benefit. On some soils a light application of liming material with the seed will be sufficient. The county agricultural agents generally have information concerning the lime needs of the soil types of their counties.

Light Applications of Liming Materials with Alfalfa and Clover Seed

Light applications of fine dry liming materials, applied when the legume crop is seeded, have been successfully used on some soils. These applications have a place, but they fall far short of solving the problem over much of Ohio. They must be repeated each rotation, since they change the soil reaction only slightly and have little residual effect. One explanation of their benefit is that the seed germinates in limed soil and establishes itself where it might otherwise fail. The idea is to lime a small area of soil in which the seed is sown rather than all the surface soil.

Where Are Light Applications Valuable?—Complete experimental results concerning the value of light applications are not available, but they have considerable short-time value under the following conditions, and a trial is suggested.

1. In western Ohio for all legumes where the subsoil layer containing lime is near the surface. Often an application of 1 to 1½ tons per acre of limestone meal, or equivalent in agricultural ground limestone, can be made with only a little more expense than is required for an application of 500 pounds of kiln-dried pulverized limestone. The use of these bulk

materials does not interfere with the fertilizer applications on the grain crop.

2. In eastern Ohio for all legumes on slightly acid soils or soils which have been liberally limed in the past. Potato growers who wish to avoid heavy applications of liming materials may find these light applications useful even on acid soils.
3. For clover and clover mixtures in eastern Ohio where satisfactory broadcast applications cannot be made. Such applications are better than no lime at all, but they are not entirely satisfactory on strongly acid soils.
4. As a supplement to moderate broadcast applications in eastern Ohio. This is probably the most important use for them at the present time.

Materials and Rate of Application.—Four hundred to 700 pounds per acre of dry, fine liming material is distributed from the fertilizer box of a grain drill. As much as the grain drill will sow may be used. Agricultural ground limestone, pulverized limestone, superfine limestone, or hydrated lime may be used, although hydrated lime does not drill as uniformly as the others. Additional tillage operations to cover the seed may or may not be necessary, depending upon conditions.

Seeding in Winter Wheat and Light Liming.—The seed is sown as soon as possible after a team can be taken on the field in the spring. It is run down the same spout as the liming material. It may be necessary to attach rubber or tin tubes to the ends of the spouts from the clover seed box so that this can be done.

Seeding in Spring Sown Grains and Light Liming.—A firm seedbed is essential and a roller or cultipacker should be used on newly plowed fields. The suggestions given below may not fit all conditions, but the legume seed should be covered shallowly and as far as possible dropped in soil that has just been limed.

Seed grain and fertilizer in the usual way. On the second trip over the field, set disks or hoes of the drill so that they barely penetrate the soil and run liming material and legume seed down the same spout.

Maintaining the Desired Soil Reaction

Table IX.—Liming Applications Necessary to Maintain Present Reaction

Desired pH	Pounds per acre needed every four years in terms of agricultural ground limestone
5.5	375
6.0	600
6.5	860
7.0	1200

Losses of lime by leaching and crop removal continue after the desired soil reaction is reached. Experimental work at Wooster indicates that the liming applications shown in Table IX are necessary to maintain any desired reaction. The time of application and the material used are not important.

Hauling and Spreading Problems

Hauling.—The problem of getting liming materials to the farm has changed over large sections of Ohio in recent years with the development of the trucking industry. Liming materials are now trucked directly to the field over considerable areas, and at less cost than is charged for delivery to the railroad station. In some cases the liming material is spread from the truck. Limestone meal or agricultural ground limestone in bulk are generally handled in this way.

Delivery by truck simplifies the problem, regardless of whether or not the liming material is spread at once. The farmer who can use a truck load need not depend upon his neighbor's orders, has no storage charges or demurrage to pay, and no hauling problem.

Elsewhere in Ohio, much liming material is trucked from the railroad station to the farm, and this relieves the farmer of part of the problem.

Spreaders.—Spreading liming material is always a problem where lime spreaders are not available. Using the manure spreader is probably the most

Fig. 8.—Trailer spreader. Liming corn field just after planting.

satisfactory method when a lime spreader is not available. The bottom of the manure spreader may be covered lightly with soil, manure, straw, or chaff, and the liming material spread evenly over it. Hydrated lime and manure should not be mixed. Wet materials may be spread in this way, but on windy days fine, dry materials blow away to some extent. The number of trips that must be made to cover an acre is known, and the amount of liming materials to be spread on one trip can be calculated. They may be weighed for the first trip and estimated later.

Ordinary lime spreaders of the hopper type (see Fig. 6) are used in communities where the use of liming materials is a regular practice. The cost is greater than that of endgate spreaders but the distribution is more uniform. The new models have a double agitator which permits the spreading of damp, but not sopping-wet, materials. They are operated by the driver alone and will spread dry materials more satisfactorily on windy days than endgate spreaders.

Endgate lime spreaders have a low initial cost and spread damp materials satisfactorily. One type of endgate spreader is attached to the back of the wagon box, and power is furnished to the spreader by a chain which operates on a sprocket wheel attached to one wagon wheel (see Fig. 9). The liming material is shoveled into the spreader as the wagon moves across the field, and it is spread by two whirling fans under the spreader box. Endgate spreaders which may be attached to some manure spreaders are on the market.

A trailer endgate spreader (see Fig. 8) which is operated by power from its own wheels, is now on the market. This operates like the other endgate spreaders except that no chains or sprocket wheels on the wagon wheels are necessary. The spreader is pulled by the wagon or truck.

Some producers of liming materials rent spreaders to purchasers of their materials, and many local dealers have spreaders for rent.

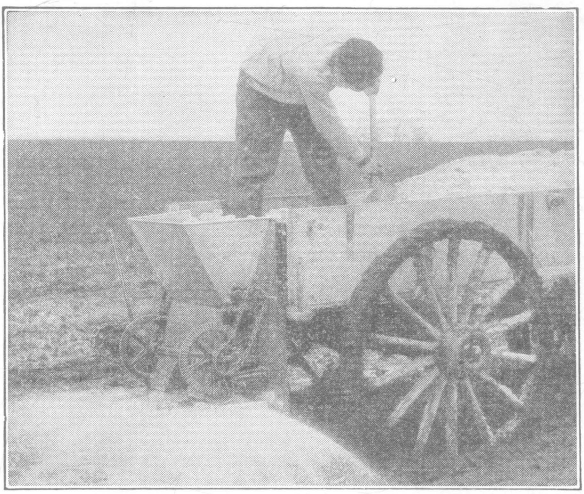
When to Apply Liming Materials

The time of application is important, since it influences the immediate results that are obtained. It is also desirable that, as far as possible, the applications be made when other work is not pressing.

Light Applications with the Seed.—These applications are always made when the clover, alfalfa, or sweet clover is seeded.

Broadcast Applications.—On acid soils, broadcast applications are preferably made several months before the clover or alfalfa is seeded. This permits incorporation with the soil and reduces soil acidity. The quickest returns from the application are secured when the field that is next to be seeded down is limed each year.

When the application is not large enough to bring the entire plow layer to the proper reaction for clover or alfalfa, best results are obtained if the liming material is concentrated in the upper 3 to 4 inches where the clover and alfalfa seed start to grow. The smaller the application, the shallower should be the incorporation.



(Courtesy The Holden Co., Inc.)

Fig. 9.—Endgate lime spreader in action.

The application is preferably made

before seeding the grain crop with which clover and alfalfa are seeded, but it should be made after the grain crop is sown if it has not been made before.

Applications on Sod Before Plowing for Corn.—Liming materials can often be more conveniently applied on sod land before plowing for corn than at any other time, and there is more time in the fall than in the spring. This method of application is entirely satisfactory when the application is large enough to prepare the soil to full plow depth for alfalfa or alfalfa mixtures, but it is somewhat less satisfactory with smaller applications. This is often the most convenient method of applying liming materials and a truck can be taken on the sod fields in the fall.

We cannot afford to quibble about the best time in the rotation to apply liming materials. The above suggestions should be followed as far as possible, but the important factor is to get the land limed before the clover and alfalfa are seeded.

Lime or Fertilizers — Which?

Farmers who realize the value of both liming materials and fertilizers often ask how the money spent for soil improvement should be divided between them when they cannot use both.

The experimental work in Ohio indicates that on acid soils the money available for soil improvement should be spent for liming materials. The use of fertilizers can be omitted for one rotation, if this will permit the liming of the farm. Wheat is the only crop of the rotation that will suffer noticeably because of this program for one season, and wherever possible an application of 200 pounds of fertilizer per acre should be made on wheat when carrying out this program. Yet even this fertilizer application may be omitted if the farm cannot be limed in any other way.

In making these statements we have in mind the future productivity of the farm rather than immediate profits for a year or two.

Soil Tests to Determine Need for Liming Materials

The Department of Agronomy of the Ohio State University tests soils for lime requirement. Many county agricultural agents and Smith-Hughes high school teachers also do this work, and there is no charge for it in either case. The county agricultural agents will send samples of soil to the Agronomy Department, Ohio State University, for anyone, without charge.

If the tests are to be of value, the samples must be taken so that they are representative of the area, and the person who makes the recommendations for their treatment must have certain information about them.

Directions for Taking Soil Samples.—Separate soil samples should be taken (1) from different soil types in the same field, indicated by color, texture, elevation, etc., (2) from the parts of the field that have had different liming treatments in the past, and (3) from the parts of the field on which the past growth of legumes and other crops has been noticeably different.

The sample may be taken with a spade, trowel, or auger. Six to eight samples to plow depth from a representative place ($\frac{1}{2}$ to 1 acre) in each soil type of the area are necessary for accuracy. A hole is dug with the spade or trowel, and a thin slice taken from the side of the hole to plow depth.

The entire sample should be dried at air temperature, pulverized, mixed thoroughly, and one pint taken for the analysis. (It may be dried near the stove, if necessary, but not in the oven.) Each sample should be named or numbered, and labeled. A record should be kept so that the farmer will know where each sample was taken.

Information That Should Accompany the Sample.—The information concerning each sample should give the crops grown for the past few years, with their fertilizer and manure treatments, and all past liming treatments. The future rotation and manure available should be given. The labels should indicate whether the samples represent good, average, or unproductive parts of the field.

Tests of Liming Materials.—The Agronomy Department also tests samples of liming materials for neutralizing power and fineness. Most Smith-Hughes teachers and county agricultural agents are not equipped to do this. Representative quart samples of pulverized materials and six to eight pieces the size of a walnut from deposits should be sent in. The limestone deposits in eastern Ohio sometimes vary in neutralizing power at different levels. In order to get the correct neutralizing power, samples should be taken at 1-foot intervals in a vertical section of the deposit and kept separate.

Why Hasn't More Lime Been Used in Ohio?

Present soil conservation and erosion control programs are based to a large extent on the growing of clover, alfalfa, or alfalfa mixtures in rotation, or long time meadows and good pasture sods on the land which is to be improved. Unless this land can be adequately limed, these programs can be only slightly effective. In other words, the future of agriculture in most of Ohio depends upon our being able to lime the land that needs lime. If the use of liming materials is so profitable and so fundamental to a successful future, why haven't farmers already limed the land that needs lime?

There are a number of reasons why this has not been done. They may be summed up as follows:

1. Farmers undoubtedly have not realized the profit to be gained from liming. Where their value is thoroughly appreciated there is less trouble in finding money for their purchase.

2. Compared with fertilizers and feeds, liming materials are relatively cheap, and the local agents' commission for selling these materials is small. He cannot ordinarily extend credit, nor visit every farmer in the community. He visits only the farmers who are likely to give him a good order. Since higher commissions would add to the cost, it is necessary that the farmer order what he needs, without waiting for a visit from the dealer, if the land is to be limed at the least possible cost.

3. In some communities, only the most expensive forms of liming materials are being handled by local dealers. Small applications have often been made because of the cost of the material, and the desired results have not been secured. Both of these conditions have held back the use of liming materials in these communities.

4. The returns from the use of liming materials do not come as quickly as do the returns from fertilizers and feeds. Because of this, liming seems like an expense rather than an investment to many farmers. A special type of credit is needed to finance the purchase of liming materials.

5. Many farmers have not appreciated the necessity of keeping the soil productive for the benefit of themselves and of future generations.

6. When the clover crop begins to fail, failures have been attributed to causes other than soil acidity. Several failures or partial failures must occur before soil acidity is generally accepted as the cause. Many farmers then try substitute crops, or trust that their troubles may be solved without using liming materials.

There are clover and alfalfa failures due to causes other than soil acidity, but the number of failures due to unfavorable seasons, etc., diminishes rapidly after the land is adequately limed.

Sometimes a farmer waits until he can lime a whole field or until he gets the field thoroughly tile drained before he starts liming. The farmer who is farming acid soils should start liming even if he can get only 1 or 2 acres limed the first time. Only the fields that are to be seeded down next need be limed in any one year.

7. There are many difficulties in ordering, hauling, and spreading liming materials. In communities where liming materials are not widely used and where shipments must be made by railroad, a carload must be ordered, and it is often difficult to get the orders together for shipment on a definite date. Storage of liming materials in the local dealer's warehouse means additional expense.

Hauling liming materials from the railroad siding to the farm seems like a tremendous task until the benefits are fully appreciated. Yet many farmers did this with horses and wagons before the day of trucks.

Spreading is a difficult proposition when liming is a new practice in the community, and when special machinery is not available.

Summary.—The use of liming materials is so profitable, and the losses from delay in their use are so great, that every farmer on acid soils should overcome these difficulties and start liming this year.

Help Lime Ohio's Acid Soils

The best estimates available indicate that a yearly application of approximately 2,000,000 tons of agricultural ground limestone (or equivalent) would be necessary during a 25-year period to prepare the rotated farm land of Ohio for good clover or alfalfa, and to replace the lime losses during that period. Pastures will require a large additional tonnage. In 1937, Ohio farmers purchased 353,409 tons of liming materials, and this is the highest yearly tonnage so far. We should be using 6 to 8 times this amount each year.

Approximately two-thirds of our cropped land is now too acid for the satisfactory growth of clover or pasture mixtures, and about three-fourths of it is too acid for the satisfactory growth of alfalfa and sweet clover.

The use of liming materials over large areas in Ohio is necessary if the present operators are to realize any profit, and if the soil is to be kept productive for the future. This problem can be solved only by the combined activities of every individual farmer and every organization interested in agriculture and the future of the country.

Farm Credit Agencies.—Bankers and farm credit organizations can help by encouraging the use of liming materials, and by extending to farmers long time credit at low interest rates. Profits from the use of liming materials are often not secured until the third to fifth year after application. These agencies may well provide for the liming of a farm BEFORE they loan money for its purchase, and include the cost of this in the mortgage. This will many times insure the payment of the mortgage, because a farmer heavily in debt and farming acid soils can make his payments only with the greatest difficulty and by making many sacrifices.

Producers of Liming Materials.—The producers of liming materials should reduce the number of products on the market to the lowest possible minimum, and all materials of the same grade should have the same trade designations, such as "limestone meal," "agricultural ground limestone," etc. Assistance should be given the farmer in his hauling and spreading problems by the local agents, and every effort should be made to make it easy for every farmer to get the liming materials he can use, even if he must start with 2 to 3 tons per year.

Educational Agencies.—The educational institutions, the Agricultural Extension Service, and the Smith-Hughes high school teachers should consider the liming of acid soils as one of their major projects. Assistance in testing soils and liming materials, comparing costs of different materials, problems of hauling, spreading, etc., will be given upon request. The value of liming and the cost of failure to lime should be constantly brought to the attention of farmers.

Local Deposits.—In southeastern Ohio the use of local deposits should be encouraged. Assistance in working out plans for developing these deposits and help with burning and crushing problems will be furnished by the county agricultural agents. The problem of the home burning of lime is not covered in this bulletin, but the Agronomy Department of the Ohio State University will be glad to send information about this practice upon request.

Others.—All citizens who are conservation minded, both urban and rural, should lend a hand, whenever possible. Only by the work of all these agencies can the problem be solved.

Publications Dealing With Related Subjects

Other available Extension Bulletins dealing with related problems and available at the offices of the county agricultural agents are: Fertilizing Field Crops in Ohio; Management of Manure in Barn and Field; Alfalfa in Ohio Farming; Better Pastures for Ohio Livestock; When and How in Haymaking; Our Heritage — The Soil; Soil Testing; Erosion Control in Ohio Farming.