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Some General Information on Lime and Its Uses and Functions in Soils

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Untreated Marl

Clover from equal areas of land.

AGRICULTURAL EXPERIMENT STATION

MICHIGAN STATE COLLEGE

Of Agriculture and Applied Science

SOILS SECTION

East Lansing, Michigan

Some General Information on Lime and Its Uses and Functions in Soils

A productive soil is fundamental to profitable farming. Crops produced on depleted or naturally infertile soil must compete on the open market with those grown on fertile soils. This places the operator located on the poorer soil at a great disadvantage, since the labor cost of producing a given crop unit may be much less on the more productive land. If the farm operator and his family are to enjoy high standards of living, such as modern conveniences in the home, a reasonable amount of recreation, and other desirable things of life, he must bring his soil to such a state of fertility that he can compete on more nearly even terms with those who are located on less depleted land.

The first step in a soil building program for depleted soils which are sour is an application of lime. The returns which are obtained from the use of lime are noted not only in the ability to produce alfalfa and the clovers but also in considerable increases in the yields of other crops. The production of leguminous hay greatly reduces the cost of keeping dairy cattle and other livestock and paves the way for a more prosperous farming system. The facts are that many farms in Michigan have been changed from unprofitable to profitable business enterprises through the use of lime. Alfalfa and clover hay have largely taken the place of commercial feeds and those of low feeding value which were formerly produced on the farm.

The use of lime to improve soils was followed in parts of Europe more than three thousand years ago. In some of the eastern states, liming has been practiced since the earlier stages of agricultural development, and its use has gradually spread until it is added to the soil to a greater or less extent as far westward as the regions of lighter precipitation. Its need, moreover, is quite generally recognized in several of the older settled regions west of the Cascade Mountains. All lands in the humid regions will sooner or later become deficient in lime, since it is constantly removed from the soil by water and by crops.

The amount of lime applied to the soil in Michigan is steadily increasing from year to year. According to our laboratory and field investigations, it can be stated that a large percentage of the soils of the state need lime, especially in the older fields. These studies also show that this condition is not confined to any particular class of soil, such as sands, loams, clays, or mucks, but is more or less common to all; yet the fact should not be overlooked that calcareous formations or those high in lime occur in all classes of soil.

The amount of lime which should be applied in order to obtain maximum returns on the investment varies greatly. Many fields require only small quantities in order to obtain satisfactory results from clover and alfalfa, while medium to very large amounts must be applied to others to establish these crops and produce suitable yields of many others.

FUNCTIONS OF LIME

The benefits derived from applications of lime are the results of induced soil changes which make the soil more suitable for plant growth. Some of the functions that lime performs are very general in their occurrence, while other more specific functions are confined to a limited number of soils. Inasmuch as several or all of the effects of liming may be operative at the same time, variable results from

Fig. I.—Sweet clover is solving the pasture problem on many Michigan farms. Two tons of limestone made this luxuriant growth possible.

the use of lime are to be expected. The various functions which lime may perform in the soil may be conveniently grouped as follows:

1. Modification of soil structure or tilth.
2. Neutralization of acids and other injurious substances.
3. Meeting the silicate requirements.
4. Effect upon the availability of minerals.
5. Increasing the rate of decay of vegetable matter.
6. Increasing the efficiency of fertilizers and manures.
7. Supplying needed lime to plants.

Improvement of the Physical Condition of the Soil. It was formerly assumed that the chief reason for adding lime to the soil was to improve its physical condition or tilth, due to the granulating effect of lime upon the fine particles. It is recognized that the tilth of heavy, compacted soils may be somewhat improved by liming, but this action is less general in occurrence and also less important than others.

Neutralization of Acids and Other Substances Injurious to Plants. Some poorly drained soils, as well as some that contain very large quantities of vegetable matter, such as peats and mucks, carry acids in their soil moisture. These may be injurious to plants and the extent of the inhibitive effect depends upon the amount present. Although adequate drainage may improve many such soils, liming is effective inasmuch as lime neutralizes these acids. Other injurious substances which occur in some soils may also be counteracted by adequate applications of lime. Refined methods that have been worked out indicate that many upland soils carry small amounts of acids in their moisture.

Meeting the Silicate Requirements. Probably one of the chief effects to be gained from liming the majority of mineral soils is to supply the silicates with lime. It is known that the loss of lime from the soil leaves the silicate compounds, which compose the major portion of the mineral constituents of the soil, deficient in lime. This condition is detrimental to plants and may be overcome by liming.

Effect Upon the Availability of Minerals. Lime may increase the availability of mineral plant food in some soils. This action of lime has long been held to be a very general and also a very important one, special emphasis having been placed upon the liberation of phosphorus and potash to the plants; but recent investigations indicate that undue emphasis has been placed upon the liberation of potash, as in many cases such liberation does not occur.

Increasing the Rate of Decay of Vegetable Matter. It is well known that the presence of sufficient amounts of lime in the soil results in a more rapid decay of vegetable matter as evidenced by the dark green color of various crops growing on limed land as well as the slightly delayed maturity in some cases. Moreover, the amount of nitrogen in the roots, tops, and seeds of crops may be increased by the addition of lime to the soil. Such changes in the composition of the crops, of course, show that the available nitrogen in the soil is increased by lime, which affects the soil bacteria. It is obvious that the free use of lime on the soil without suitable crop rotation and constant renewal of the vegetable matter content by means of stable manure, crop residues, and catch crops will result disastrously.

However, if these precautions are taken the lime will be instrumental in maintaining the vegetable content due to the increased crop production. In some soils, more frequently in muck than others, the root development of crops is retarded, being confined to the surface layers of soil until lime is added and worked deeply into the soil. Furthermore, the presence of lime in the soil is favorable for the development of bacteria which enter the roots of leguminous crops and result in the fixation in the plants of nitrogen from the soil atmosphere. Organisms that are able in the absence of legumes to remove nitrogen from the air and make it available to plants are likewise benefited by lime. It is probable that the amount of nitrogen made available by these bacteria is relatively small but it is worthy of consideration.

Increasing the Efficiency of Fertilizers and Manures. Experience teaches that maximum returns from commercial fertilizers and stable and green manures are not obtained in the presence of one or more adverse conditions such as poor drainage, deficiency of water in the soil, poor tilth, or lack of lime. It is unquestionably true that applications of lime to many of our soils long under cultivation as well as some of the newer ones should precede the use of fertilizers. If this were done, a more advantageous use of stable and green manures would result.

Some soils do not contain sufficient lime to meet the needs of the crops grown. There is an appreciable amount of evidence, contrary to past assumption, that the use of lime on some soils results beneficially because it is needed in plant nutrition; this is especially evident with such crops as clover or alfalfa or those which remove large quantities from the soil.

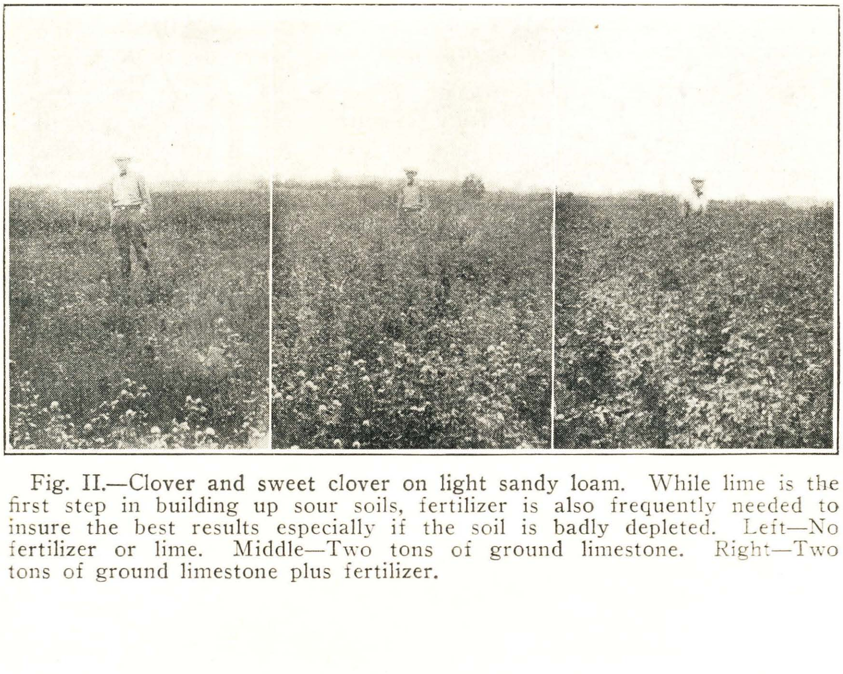

Fig. II.—Clover and sweet clover on light sandy loam. While lime is the first step in building up sour soils, fertilizer is also frequently needed to insure the best results especially if the soil is badly depleted. Left—No fertilizer or lime. Middle—Two tons of ground limestone. Right—Two tons of ground limestone plus fertilizer.

FORMS OF LIME

Lime is placed on the market in three forms, namely, oxide, hydrate, and carbonate. These different forms are often given a variety of names. The oxide is known as quick lime, burnt lime, stone lime, caustic lime, lump lime, unslaked lime, and building lime. The hydrated lime is called slaked lime. The carbonate is the form of lime found in ground limestone and marl and it also occurs in air-slaked lime.

The term "Agricultural lime" may be applied to any of the three forms and refers to lime sold for agricultural purposes but unfortunately does not necessarily refer to a product especially well adapted for application to the soil.

When high grade limestone is burned in a kiln, 100 pounds of the dry stone gives off approximately 44 pounds of carbon dioxide gas, leaving about 56 pounds of lime oxide or quick lime. When 56 pounds of quick lime is moistened it takes up 18 pounds of water and forms 74 pounds of slaked lime or hydrated lime. It is evident then that 56 pounds of quick lime, 74 pounds of hydrated lime and 100 pounds of limestone or lime carbonate have the same power to satisfy the needs of the soil.

Neutralizing Power of Different Kinds of Lime. Some limestone deposits are made up almost entirely of calcium or lime carbonate while others contain more or less magnesium carbonate and, consequently, a lower percentage of calcium carbonate. If the amount of magnesium carbonate is rather high, the product is called magnesium or dolomitic limestone.

Since 84 pounds of pure magnesium carbonate will correct as much acidity as 100 pounds of pure calcium carbonate we can see that the dolomitic or magnesium limestone will have a higher neutralizing power, pound for pound, than will the pure calcium store. The neutralizing power of liming materials is always calculated on the basis of pure calcium limestone as 100. In consequence magnesium limestones may have an acid correcting power of over 100, in fact such stones are sometimes advertised as having a neutralizing power of 108. Likewise, on the basis of pure calcium carbonate as 100, hydrated lime may have a neutralizing power of 135 if made from pure calcium carbonate and of 151 if prepared from magnesium limestone.

In considering limestone, however, it must be remembered that total neuralizing power is not the only factor of importance. The density and hardness of the stone may influence considerably the rate at which it neutralizes the acid condition of the soil. For this reason, it is not customary to give a great deal of weight to the high neutralizing power of magnesium stones.

SOURCES OF LIME

Michigan is fortunate in possessing two inexhaustible sources of lime, her limestone deposits and marl beds.

Limestone. At present there are in the State about 13 operating limestone quarries. The majority of these are located in the Upper Peninsula and northern part of the lower peninsula. There is a group of quarries in the extreme southeastern part of the State and an occasional quarry is found along the eastern coast and at other points throughout the commonwealth.

These quarries produce stone for a great variety of purposes, only a small portion of their output being used in agriculture. Some of the quarries turn out only a coarsely ground rock containing small amounts of fine material, but others furnish a very finely ground high grade rock. The limestone from the Michigan quarries are quite variable in composition some containing 96 to 97 per cent of calcium carbonate with only a trace of magnesium carbonate, while others carry as much as 44 or 45 per cent of magnesium carbonate.

Marl. There occur throughout the State many beds of marl varying from low to very high grade. The lime is present in the marl as carbonate and hence supplies calcium to the soil in the same form as ground limestone. In addition to lime carbonate, some marls contain varying amounts of magnesium carbonate, which also aids in meeting the "lime requirement" of the soil. The value of marl then, depends on the amount of calcium and magnesium carbonates it contains. A marl carrying 90 per cent or more of these carbonates is considered to be of very high grade.

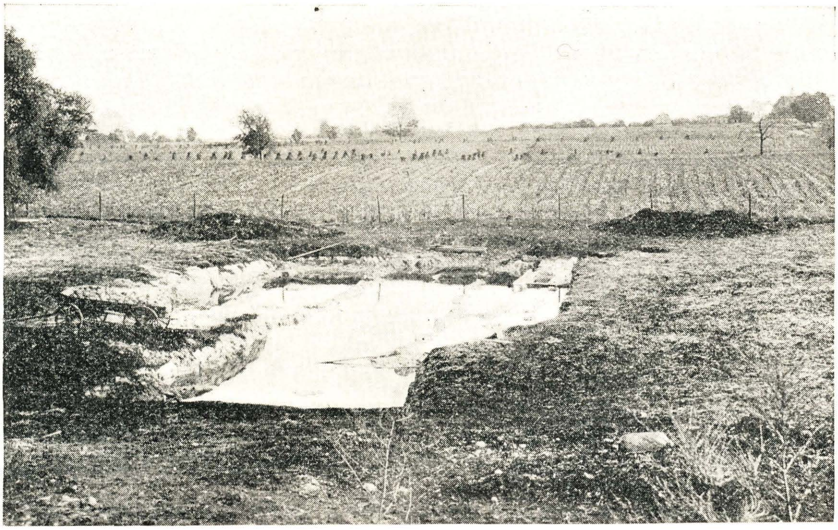

Fig. III.—An easily accessible marl bed. A more general utilization of Michigan's marl deposits for agricultural purposes is desirable.

Occurrence of Marl. Marl is frequently found underlying areas of muck and peat and also along the shores and in the beds of lakes. In some instances, the marl is covered by a few inches of muck while in others it lies beneath several feet of it. The thickness of the beds or deposits is also quite variable. The marl owes its existence to lime that was washed out of the surrounding soil and deposited in lakes and to the accumulation of shells of lower animals such as the mollusca.

As it occurs in the beds, marl is generally a pasty mass varying in color from light to dark gray, depending upon the impurities present. Upon drying it becomes lighter in color and is easily crumbled or broken up. If a small amount is placed in half a tumbler of strong vinegar or weakened muriatic acid, it will give off bubbles of gas and go into solution. This is one method of identifying marl as well as roughly estimating its purity. Some deposits are filled with small shells which aid in its identification.

Water Content and Weight of Marl. When marl is thrown out of the bed and allowed to drain, the amount of moisture retained is quite variable and depends somewhat on the amount of impurities. In general, the purer the marl the less water it will hold but sandy marls contain less water than clay marls. The following table shows the water content, the weight of a cubic yard, and the weight of lime carbonate contained in a cubic yard of several Michigan marls.

Sample number	Per cent of carbonates	Per cent of water on dry basis	Per cent of water on wet basis	Weight of cubic yard dry, in lbs.	Weight of cubic yard of wet marl in lbs.	Weight of lime carbonate in 1 cubic yd. dry marl	Weight of lime carbonate in 1 cubic yd. wet marl
1	75	46.7	32	1652	2430	1239	1239
2	85	45.5	31.3	1665	2424	1415	1415
3	88	38.9	28	1670	2319	1470	1470
4	95	35.1	26	1731	2339	1644	1644

Sugar Factory Lime. Lime is used by sugar factories to clarify and purify the juice, and, since impurities cause trouble later in the process of refining, a very high grade of lime is used. Milk of lime is added to the vats of juice and then carbon dioxide is run in to precipitate the lime as lime carbonate. This is later filtered out and discarded. This material contains a small amount of organic matter and slight quantities of plant food elements from the beet juice, but, otherwise is a very pure carbonate of lime and is admirable material to apply to the soil. It can generally be obtained at little or no cost, since it is simply a waste product. It very often contains water and hence it should be bought by the yard rather than by the ton because a cubic yard will contain about the same amount of lime carbonate whether the material is wet or dry.

There is another form of lime which may occasionally be obtained from sugar factories. This is the cleanings from the kiln. Many of the factories prefer to burn their own lime and when the kilns are cleaned a quantity of impure burnt lime or stone lime is obtained. This material is variable in composition but is mostly quick lime when fresh; after standing a short time, it contains a large amount of hydrated lime.

Wood Ashes. In some localities, wood ashes may be obtained in sufficient quantities to apply to the soil. Ordinarily, wood ashes contain from 20 to 50 per cent of lime, expressed as quick lime, in addition to small amounts of potash.

Lime from Acetone and Alkali Works. There are in the State various acetone and alkali works which turn out lime as a by-product. This material is usually of high grade, its chief drawback being a high water content if exposed to the weather. When such products can be obtained near at hand and at a low price, it is sometimes more advisable to use them than to buy the more expensive forms of lime. The cost of transportation and difficulty in distribution must be taken into consideration when figuring the cost.

CHANGES LIME UNDERGOES WHEN ADDED TO THE SOIL

When the various forms of lime are added to the soil, their composition is altered. The change that is now considered to be most desirable is the union of the lime and silicates to form calcium silicates or the correction of soil acidity. When hydrated lime is added to the soil, some of it goes to form the carbonate and some the calcium silicate. The lime or magnesium carbonate thus formed and that added to the soil as marl or ground limestone likewise gradually passes to the silicate form.

It is now understood that the immediate efficiency of the various forms of lime is dependent upon the rate at which they pass over to the silicate and other forms. The hydrate is quite rapid and the carbonates are governed mainly by their mechanical state or the size of their particles as well as the thoroughness of mixing with the soil mass. Particles of limestone which will pass an 80 mesh screen are about as rapid in correcting soil acidity as the hydrate or 2,000 pounds of it approximates 1,500 pounds of the hydrate in this respect.

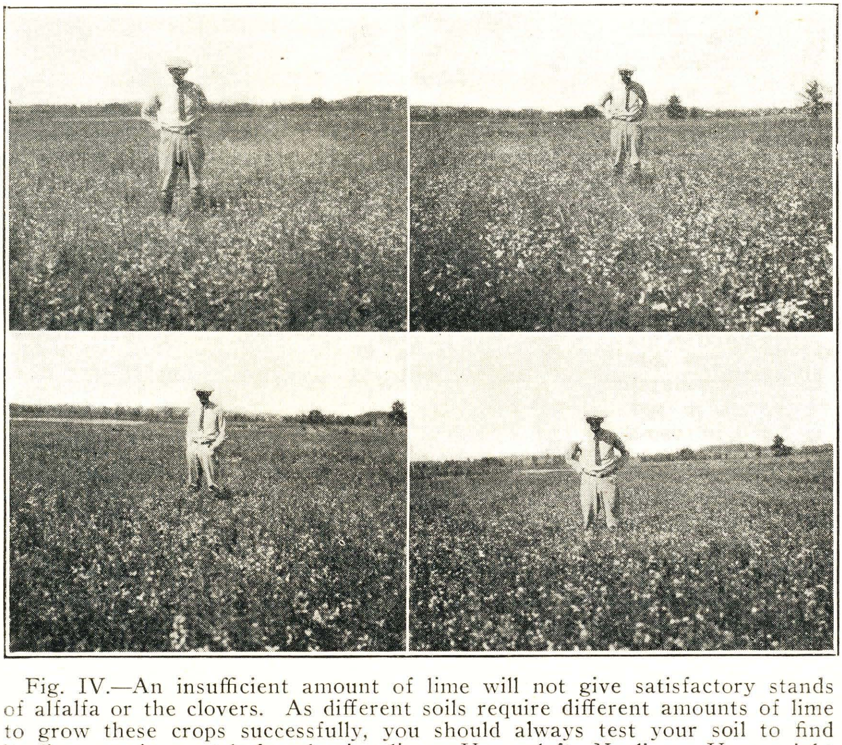

Fig. IV.—An insufficient amount of lime will not give satisfactory stands of alfalfa or the clovers. As different soils require different amounts of lime to grow these crops successfully, you should always test your soil to find its lime requirement before buying lime. Upper left—No lime. Upper right One ton of limestone. Lower left—Two tons of limestone. Lower right—Four tons of limestone.

The comparative values of limestone ground to different degrees of fineness and also of hydrated lime and marl are shown in Table II. The soil upon which this lime was used was a sandy loam with a high degree of acidity and in a low state of fertility. The finely ground stone was applied at the rate of two tons per acre and the other limes were applied in sufficient amounts to give the same total neutralizing power, disregarding the rate of availability. In the eleven years that this experiment has run the land has received five applications of available phosphoric acid, seven applications of available nitrogen, and two applications of potash.

Table II. Comparative value of hydrated lime, marl, and limestone ground to different degrees of fineness.

Value of increase in crops due to lime less cost of the lime	Hydrated lime	Marl	Limestone ground to pass through		
			80 mesh screen	40 mesh screen but catch on a 60 mesh screen	10 mesh screen but catch on a 20 mesh screen
For first 4 crops	$19 96	$21 77	$21 87	$13 10	$9 60
For 11 years	58 03	50 52	65 49	52 56	67 35

If the lime is not mixed with the soil mass, its efficiency is somewhat impaired. As the individual particles of marl are very minute, its immediate effectiveness is governed largely by the condition in which it goes into the soil. If the marl is lumpy, larger quantities are required to bring about a given result than if it is more or less disintegrated. The condition of the marl as it usually goes on the land makes it necessary to apply two or more cubic yards to give the same immediate results as 1,500 pounds of hydrated lime or 2,000 pounds of finely ground limestone.

CROPS BENEFITED BY LIME

The response of cultivated plants to lime is variable, some are more tolerant to a deficiency in the soil than others. Reports which are on record show that some crops will thrive on a given soil without application of lime and others will not, and some soils are so low in lime that they are practically barren of plant growth. Thus, in discussing the response of different crops to lime, it is essential that the condition of the soil with respect to this substance be considered. Some of the field crops which are known to respond to lime are:

LEGUMES	NON-LEGUMES	
Alfalfa	Corn	Potatoes
Sweet clover	Oats	Carrots
Crimson clover	Wheat	Turnips
Mammoth clover	Barley	Cucumbers
June clover	Rye	Cantaloupes
Alsike clover	Timothy	Pumpkin
Soy beans	Buckwheat	Tobacco
Cow peas	Sorghum	Cabbage
Beans	Beets	
Vetch		

Fig. V.—Wheat on a depleted and sour soil (compare with Fig. below.)

Fig. VI.—Wheat on the same soil shown above after liming. The lime made possible the growing of a sweet clover crop which was plowed under for the wheat.

Where soils are low in lime the following vegetables are known to respond to its use: pepper, parsnips, salsify, squash, spinach, red beet, celery, cauliflower, lettuce, and onion. Many plants grown for their blossoms also respond to lime.

HOW TO DETERMINE IF A SOIL NEEDS LIME

A farm operator can tell by observation and tests quite accurately if his soil is in need of lime. Some common indications of soil acidity or lime deficiency are:

1. A prevalence of red or horse sorrel.
2. Repeated failure of clover or alfalfa seedings.
3. Serious winter killing of new seedings which appear thrifty in the fall.
4. Thin or patchy stands of alfalfa or the clovers on soils which produce good yields of other crops.
5. Medium to good stands of clover on the edge of fields bordering a gravel or stone road with poor stands on the rest of the field.

The lime needs of a soil may be determined, also, very quickly by means of one of several simple tests. The Soiltex method developed by C. H. Spurway of the Soils Department of the Michigan State College is satisfactory. This method is rapid, simple of operations, requires a minimum of equipment, and indicates whether the soil is acid, neutral, or contains an excess of lime.

In making tests for the lime requirement of soils, samples should be taken two or three inches below the surface rather than at the surface. Each soil type in the field should be tested as some of them may be strongly acid while others will require little or no lime. In many cases, it is possible to make a considerable saving by taking into consideration the needs of the different soil types. Several tests should be made of each type as one test may be faulty, due to droppings of manure, ashes from stump or brush fires, residues from straw stacks, or similar causes. At least one test on each soil type should be made of the subsoil at a depth of about two and one-half feet because a lime-rich subsoil will influence the lime needs of the soil to a considerable extent.

HOW TO APPLY LIME

The first requirement in applying lime is that it shall become thoroughly mixed through the soil before alfalfa or any of the clovers are seeded. Lime does not move horizontally, or sideways, in the soil after going into solution. The soluble lime does move upward and downward in the soil water to some extent but this does not distribute the lime over the field. The only way of distributing the lime through the soil is by tillage operations and this is a slow and expensive method, therefore it is essential that the lime be applied evenly over the soil.

As soil acidity is more largely due to a lack of bases existing on the surface of the soil particles than to the presence of soluble acids in the soil solution, it is essential that the lime come in contact with the soil particles. This requires a thorough and even mixing of the lime through the soil.

Lime may be applied by means of a shovel from the wagon box. Sometimes the lime is placed in piles over the field and later spread with a shovel. These methods are more expensive, since they require much labor, than applying lime with a machine but may be employed if a mechanical spreader cannot be obtained.

Two types of spreaders are in common use. The two-wheeled box spreader, which can be drawn by one team and operated by one man,

Fig. VII.—The two most commonly used methods of applying lime. Each has its advantage. Left—The endgate spreader. Right—The two-wheeled or box spreader.

can be filled from piles of lime at the ends of the field or, more frequently in the case of long fields, from piles within the field. The end gate style of spreader fits on the end of the wagon box and the agitator is operated by a chain running on gears bolted to the wagon wheel. This spreader is easily shifted from one wagon to another and covers a much broader strip at each trip across the field. Four horses are required to pull the loaded wagon and spreader over a plowed field and rapid work is needed to feed the spreader. Two men also are required, one to drive and one to scoop the lime into the spreader.

A modified type of the two wheeled spreader can be made at home for a comparatively small cost. Full directions for the construction of this machine have been prepared by the Agricultural Engineering Department of the college and are presented in Circular Bulletin No. 62.

Marl is usually applied by means of a manure spreader. Some manure is usually put in the bottom of the spreader and the load completed with marl. With the endless apron type of spreader, this is not necessary but with the drag bottom type it should be done. Sludge lime from the sugar factories should also be applied in the same manner.

WHEN TO APPLY LIME

Since legumes such as clover and alfalfa are more sensitive to a lack of lime in the soil than other crops, it is best to apply lime a considerable time prior to seeding these crops. This procedure is best in order that the lime may have time to correct the acid condition of the soil. Occasionally, a successful seeding is obtained by applying lime very shortly before seeding. This is the result of very favorable climatic conditions or may occur on soils which are not strongly acid. Usually, the lime should be in the soil from six months to a year or so before seeding in order to be sure of best results.

In case the legume is to be seeded in wheat or rye, the lime may be applied when the seed bed is being prepared. An application on the growing grain during the winter or spring cannot be relied upon.

If a sod is to be plowed under for corn, beans, or beets to be followed by one or two crops of small grain, in either of which the legume is to be seeded, the lime can be very conveniently applied before plowing.

In rotations which include potatoes, consideration must be given to the well established fact that lime makes conditions more favorable for the development of the scab fungus, but the increased yields of potatoes when grown on a leguminous sod warrant the use of lime on sour soils in order to make the growing of alfalfa, clover, or sweet clover possible. It is advisable to apply the lime as many years previous to the planting of potatoes as is possible in the crop rotation. This usually necessitates the use of lime directly after one crop of potatoes is harvested. When potatoes are to be grown in the rotation, the minimum amount of lime which will insure a satisfactory growth of the legume should be used. By observing these precautions, lime may be used with little danger of increasing the amount of scab on the potatoes if clean seed is used and if potatoes are not planted on the same land oftener than once in five years.

Weather conditions and lack of time sometimes hinder success with applications of lime in the spring while fitting the soil for oats or barley, in which a seeding is to be made. If properly worked into the soil, however, lime will usually give satisfactory results when applied at this time.

On soils with low water retaining power where it seems advisable to seed alfalfa or sweet clover alone, the lime may be applied early in the spring of the season the seeding is to be made. It may be more convenient to lime the land the preceding year or even two or three years in advance, and this may be done with full assurance of good results.

RESULTS FROM APPLYING LIME

That an application of lime on strongly acid soils gives very profitable increases in crop yields has been established beyond question, both by State Experiment Stations and by the experience of numberless farmers. The idea has sometimes been expressed that the clovers and alfalfa are the only crops benefited by liming a sour soil. Lime undoubtedly benefits these crops to a greater extent than it does non-legumes but the yields of the common cereals, as well as of sugar beets, beans, soybeans, and root crops, are also increased. Some results from the use of lime on Michigan farms are given below.

On the farm of Mr. Armstrong of Hillsdale county lime increased the yield of wheat from 25.6 bushels to 29.9 bushels. The soil was of the Hillsdale loam type which makes up about 325,000 acres in south central Michigan.

On the Isabella sandy loam type, which is of wide extent in west central Michigan, lime increased the yield of clover hay from 3158 pounds to 6854 pounds on the Cary Brothers farm. The following year corn on the limed soil yielded 63.0 bushels while on the unlimed land only 54.6 bushels of shelled corn were obtained.

In St. Joseph county on the farm of Mr. E. D. Fairchild, the following yields of crops were obtained in succeeding years on limed and unlimed Fox sandy loam.

	Corn, bushels	Rye, bushels	Corn, bushels	Soybeans, bushels
Limed land	42.1	17.8	26.8	7.81
Unlimed land	38.0	14.1	23.1	5.70

In cooperative tests on the farm of Mr. B. L. Green of Ingham county, very satisfactory increases in yield resulted from the use of lime on Miami loam soil. Oats on the limed land yielded 46.0 bushels per acre, while the following clover gave 3264 pounds of hay. Where no lime was used the oats yielded 43.6 bushels, and only 1680 pounds of clover were harvested the following year.

That fertilizers will not replace lime on acid soils and that maximum returns from fertilizer applied to very sour soils cannot be expected unless lime is used is shown by the results of experiments on the County Farm of Cass county. The following yields were obtained following one application of limestone. The fertilizer was applied as seemed best, both the limed and unlimed land receiving equal applications.

Soil treatment	Soybeans, bushels	Rye, bushels	Wheat, bushels	Sweet clover, lbs.	Rye, bushels	Corn bushels	Wheat, bushels
Complete fertilizer	4.8	12.4	9.6	Failed	17.5	20.9	9.3
Complete fertilizer and limestone	6.8	21.3	15.0	4,280	24.3	29.3	16.8