Lime and Its Use
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LIME

and its use

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COOPERATIVE EXTENSION SERVICE
EAST LANSING

CONTENTS

Lime and Its Use

By J. A. PORTER, P. J. ROOD and E. D. LONGNECKER[1]

1. What is lime?

Agriculturally speaking, lime is any compound of calcium—or calcium and magnesium—capable of counteracting the harmful effects of an acid soil.

2. What conditions give rise to acid soils?

There is a natural tendency for soils to become increasingly acid in humid climates, and that trend is accelerated when soils are put under cultivation. The development of an acid soil situation is associated with the loss of lime. The two most important causes of loss of lime from soils are (a) leaching in drainage waters, and (b) crop removal. Some soils were developed from acid rocks and minerals. Those soils have always been acid, even in the virgin state. In Michigan, there are considerable areas of sandy soils which have been produced from acid rocks (See question 20).

3. What is the nature of the acids in an acid soil?

Soil acidity is primarily a function of the insoluble acid-clays and humic acids—although soluble acids such as nitric, carbonic, sulfuric, and phosphoric may contribute to the acid condition.

4. How are clay-acids developed?

In regions of high rainfall the carbonates are gradually carried away in the drainage water, and the calcium (lime) and other bases on the clay are replaced by acid hydrogen ions from the water. (*Bases* are substances chemically capable of neutralizing acids.) Calcium and other bases removed from clays by plants may be replaced by hydrogen. Both of these processes lead to soil acidity.

5. What are the different types of soil acidity?

The hydrogen ions in the solution surrounding the soil particles constitute the "active" acidity, whereas the hydrogen ions absorbed

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on the exchange complexes (clay and humus) constitute the "reserve" or "potential" soil acidity.

6. How is acidity of soils expressed?

The term "pH" is used to express the degree of acidity or alkalinity of the soil. At a pH value of 7.0 the soil is neutral. All pH values above 7.0 are *alkaline;* all values below 7.0 are *acid.* A soil of "pH 5.0" contains 10 times as many active hydrogen ions as a soil at "pH 6.0." Thus a change of 1 unit in pH value represents a tenfold change in concentration of hydrogen ions in the soil solution.

7. How is the pH of a soil determined?

Various dyes which give distinct color shades at different pH values are used extensively, in the laboratory and especially in field kits, for determining pH values with reasonable accuracy. The most accurate method is to use a *potentiometer* ("pH meter") to measure the pH of a soil-water mixture. (Fig. 1.)

8. What fraction of soil acidity is expressed by pH?

The pH values express the *active acidity* or intensity of acidity in a soil. They do not indicate the reserve acidity, nor are they measures of total acidity.

9. Is the pH value of a soil related to its lime requirement?

Due to the fact that pH values do not express *total acidity,* it is possible that two soils having the same pH value may require decidedly different quantities of lime to bring about a similar change in reaction. (See Table 7, page 33.) The *reserve acidity* is not measured in a pH determination, but still must be neutralized before the pH of the soil can be raised to a desired level.

Acid soils which have a high content of clay or organic matter usually contain large amounts of reserve acidity. Sandy soils low in organic matter have a small amount of reserve acidity—and thus require relatively small amounts of lime to change their pH. Thus, the content of clay and organic matter in the soil must be taken into consideration in making lime recommendations from pH values (See question 89).

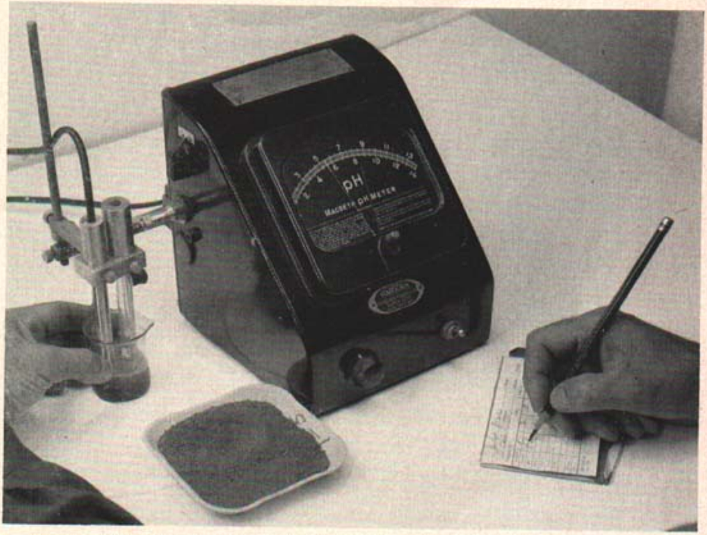


Fig. 1. A "pH meter" is employed in determining the soil reaction, or acidity, used as a basis for lime recommendations. An adaptation for soil-testing purposes of the standard "potentiometer"—long in use for the scientific measurement or comparison of electrical potentials—the meter is calibrated so that its dial reads directly in pH values. (Greatly simplified, the working principle is this: In each case, the degree to which a soil is acid or alkaline has a measurable effect upon certain basic relationships of electrical energy. Those relationships are established when the electrodes [at left] are thrust into a sample of soil mixed with water. The instrument then measures the effect with great accuracy, and indicates the result in terms of the pH scale.)

10. How can the lime requirement of a soil be determined?

The lime requirement can be determined by treating a series of soil samples with increasing amounts of lime and, after chemical equilibrium is reached, measuring the resulting pH values.

11. What is the range of pH in soils?

It is unusual to find mineral soils with a pH of less than 3.5, and in humid regions it is unusual to find a soil with a pH of more than 8.0 or 8.5. The usual pH of soils in humid regions ranges approximately from 5.0 to 7.2.

ACID SOILS IN RELATION TO THE GROWTH OF PLANTS

12. Does soil reaction affect plant growth?

The hydrogen ions as such, in concentrations normally found in soils, are not believed to be detrimental to plant growth. The chemical conditions which accompany the different degrees of soil acidity may be favorable to the growth of some crops; unfavorable to others; and in still other cases may affect plant growth very little. Even the same plant may not be similarly affected in all soils having the same pH.

For example, a mineral soil with a pH of 5.5 may need 2 tons or more of limestone per acre for the growing of acid-sensitive crops, while much less or possible no lime would be needed on a muck soil having the same pH.

13. Does acidity affect the solubility of iron and aluminum in soils?

The quantity of soluble iron and aluminum in many soils increases as soil acidity increases. Ferrous iron is rather toxic to many plants. It is also believed that soluble aluminum is one of the major factors contributing to poor plant-growth in strongly acid soils (See question 37).

(In reference to questions 13, 14 and 15, also see the chart in Fig. 2.)

14. How does soil acidity affect the availability of phosphorus to plants?

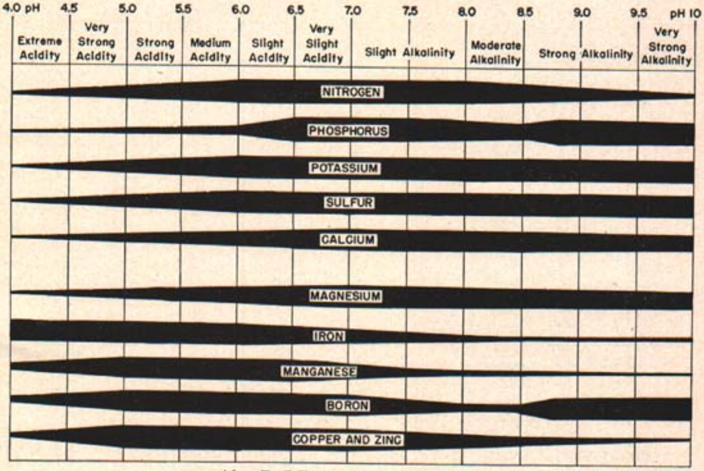
In soils below about pH 6.0, complex phosphates of iron and aluminum may be formed which have a very low solubility and frequently do not supply sufficient phosphorus for plants. Furthermore, under strongly acid soil-conditions the efficiency of applied phosphates is greatly reduced (See questions 33 and 34).

15. Do plants get sufficient calcium in soils of low pH?

Soils become strongly acid only when the supply of basic ions. chiefly calcium, has become depleted. This undoubtedly is responsible in part for the restricted growth of many plants on highly acid soils. There is considerable variation in the response of different plants to a calcium deficiency.

16. Does soil acidity influence the activity of micro-organisms?

Most, if not all, of the desirable microbial processes in the soil are adversely affected by a strongly acid condition. Fungi are more active than bacteria in acid soils. The nitrogen-fixing and nitrate-producing bacteria function best at or near the neutral point. However, the organisms responsible for potato scab also thrive best at the higher pH values; about 5.5 (See question 39).



—After *Emil Truog: U. S. D. A. Yearbook of Agriculture, 1943-1947*

Fig. 2. The general relation of soil reaction, and accompanying conditions, to the availability of plant-nutrient elements.

17. Why is it so important to have a liberal supply of calcium for alfalfa?

It can be noted from Table 1 that a 3-ton crop of alfalfa hay will remove the equivalent of over 200 pounds of calcium carbonate from the soil in the form of calcium and magnesium. Furthermore, an adequate supply of lime is necessary for the bacteria in the nodules of legumes to fix nitrogen. An acre of good alfalfa may fix as much as 150 pounds of nitrogen per acre, per year. This quantity of nitrogen is equivalent to that in 700 pounds of ammonium sulfate fertilizer, or 450 pounds of ammonium nitrate.

*TABLE 1—Quantities of lime contained in certain farm products**

FARM PRODUCT (on basis of amounts listed)		QUANTITY OF LIME (in pounds)		
Crop	Amount	Calcium Oxide	Magnesium Oxide	Total, calcium carbonate equivalent
Apples	300 bu.	1.2	1.7	6.4
Barley (grain-straw)	35 bu.	4.4	3.1	15.6
Beans (seed)	25 bu.	3.0	2.6	11.8
Corn (grain-straw-cobs)	50 bu.	14.7	5.6	40.1
Fat—				
steer	1000 lb.	12.8	0.4	23.8
pig	200 lb.	0.9	....	1.6
Grapes	6000 bu.	0.4	1.2	3.7
Hay—				
Alfalfa	3 ton	83.5	21.3	201.8
Bluegrass (Kentucky)	2 ton	16.7	....	29.8
Red clover	2 ton	45.7	10.8	108.4
Soybean	2 ton	49.2	15.5	126.2
Sweet Clover	2 ton	31.4	7.4	74.4
Timothy	2 ton	7.1	4.1	22.9
Leaves—				
Red Oak	2000 lb.	46.2	....	82.5
Sugar maple	2000 lb.	92.6	....	165.3
Milk	10000 lb.	17.0	11.0	57.6
Oats (grain-straw)	50 bu.	9.1	5.4	29.6
Onions	300 bu.	18.8	3.4	42.0
Potatoes (tubers)	150 bu.	1.8	2.7	9.9
Rye (grain-straw)	2000 bu.	4.5	2.7	15.5
Soybeans (grain)	20 bu.	9.9	12.6	48.9
Wheat (grain-straw)	25 bu.	5.8	3.5	97.2

*Based on data from Millar and Turk, *Fundamentals of Soil Science*, John Wiley & Sons.

18. May plants be classified on the basis of their tolerance of acidity?

No satisfactory explanation has been advanced for the variation in tolerance of acidity exhibited by different plants. In Table 2 several plants grown in Michigan are listed on the basis of their tolerance (or even need) of an acid growth-medium. The chart in Fig. 3 shows the same general relationship in another manner.

TABLE 2—Tolerances of plants for acidity

Slightly tolerant	Moderately tolerant	Highly tolerant	Very highly tolerant
Alfalfa	Lespedeza	Corn	Azalea
Ladino clover	Alsike clover	Oat	Rhododendron
Red clover	Vetch	Rye	Blueberry
Sweet clover	Barley	Buckwheat	Watermelon
Sugar beets	Soybean	Redtop	Cranberry
Beans	Wheat	Strawberry	
Table beets	Cantaloupe	Peach	
Asparagus			
Cabbage			
Cauliflower			
Spinach			

19. What substances are used to increase acidity?

Sulfur, aluminum sulfate, iron sulfate, or acid peat are materials used most commonly to increase soil acidity. The quantities required will depend on the pH of the soil, the clay and organic matter content of the soil, and the pH required. Rates of apply-

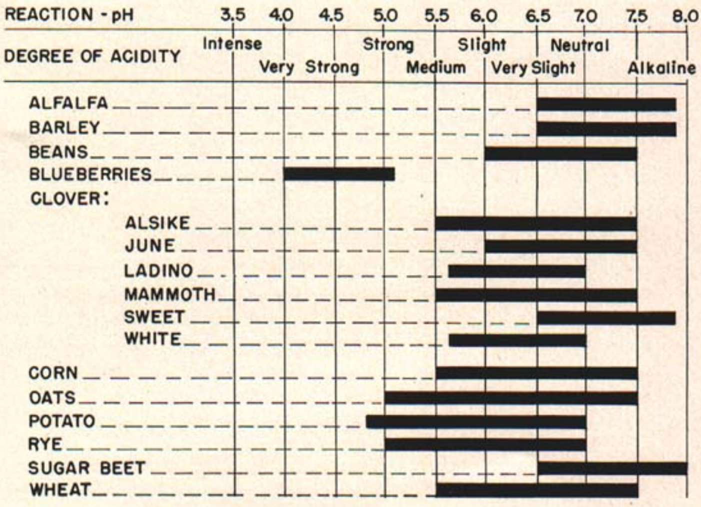


Fig. 3. Soil preferences of some important Michigan crops in relation to the soil reaction (pH) scale.

ing sulfur usually vary from 200 to 2000 pounds per acre—although for muck soils the quantities needed may be much greater. In greenhouses, phosphoric acid is sometimes applied in irrigation water, which aids in keeping the pH of the soil from becoming too high.

THE NEED OF SOILS FOR LIME

20. Were the parent materials of all soils well-supplied with lime?

Some soils have developed from materials which in themselves were naturally acid. Soils developed from acid rocks and minerals would be acid even though no loss of bases occurred during soil formation. Most acid soils, however, have developed as a result of leaching losses and crop removal of bases (See question 2).

21. Do most of the soils in Michigan need lime?

The majority of Michigan soils need to be limed for successful alfalfa and clover production, although a rather large acreage does not need lime.

To maintain the proper lime status in Michigan soils would require about 1,000,000 tons per year, after the initial lime needs have been met. The average annual use of lime (limestone, marl, etc.) in Michigan, from 1940 to 1950, was less than two-thirds this amount. Undoubtedly, that has meant reduced crop yields and profits on thousands of acres of Michigan farm lands.

22. Is lime readily lost from soils by leaching?

In humid regions, no single factor tends to remove lime from the soil to so great an extent as leaching. Since calcium and magnesium are readily lost from soils by leaching, the development of acid soils will occur eventually in humid regions—unless lime is applied.

23. Do cover crops decrease losses of lime through leaching?

Leaching losses are much greater from fallow soils than the losses from similar soils on which crops are growing. This difference is due to less water percolating through the cropped land. and to the uptake of lime by the plants.

24. Does cropping remove large quantities of lime from soils?

The removal of lime and other bases through cropping is greater than the like removal of acids, thus leaving the soil more acid. The legume crops, such as alfalfa and the clovers, are especially heavy users of calcium and magnesium.

Those crops make a heavier demand for such bases than other crops. An average crop of alfalfa may annually remove over 100 pounds of calcium per acre. The quantity of lime (calcium and magnesium) removed per acre by some of the commonly grown Michigan crops can be judged from Table 1. The quantities of lime contained in other farm products are also shown in that table (See question 17).

25. Do acid substances normally added to soils tend to increase the need of soils for lime?

Near industrial centers large quantities of sulfur may be carried into the soil with the precipitation. This sulfur is readily changed to an acid, which will lower the pH of the soil and at the same time encourage the loss of bases. Decaying organic matter produces various acids, such as carbonic acid and nitric acid. These acids also encourage the loss of bases.

It should be pointed out, however, that the humus produced from organic matter has a marked "buffering" effect, which helps prevent rapid and extreme fluctuations in soil pH. The effects of fertilizers on soil acidity are discussed in questions 26, 27, 28, and 29. (Note also Table 2.)

26. What effect do potassium fertilizers have on soil acidity?

The common potassium fertilizers, such as the muriate and sulfate of potash, have no permanent effect on soil acidity.

27. What is the effect of phosphates on soil acidity?

In general, superphosphates will have no permanent effect on soil reaction. Basic slag does have a tendency to correct soil acidity.

28. Do nitrogen fertilizers increase soil acidity?

Fertilizers containing nitrogen is the form of ammonia, or in a form subject to nitrification (being changed to nitrate), will produce acidity—unless sufficient liming material is present in the fertilizer to neutralize the acid formed. However, fertilizers containing nitrogen in the ammonium form should not be discriminated against, since the increased quantity of lime needed to neutralize such acidity produced under a normal system of soil management is of little practical significance.

Nitrogen in the form of nitrate—when combined with bases such as sodium or calcium—will result in *decreased* soil acidity as the plants utilize the nitrate. The acidity or basicity of several nitrogen fertilizers is given in Table 3.

TABLE 3—Effect of different fertilizer materials on the lime status of soils

FERTILIZER MATERIAL	Applications of 1 ton	
	Calcium Carbonate required to neutralize resulting acidity (in pounds)	Calcium Carbonate to which application is equivalent (in pounds)
Ammonium nitrate*	1170	....
Ammonium sulfate†	2249	....
Anhydrous ammonia*	2960	....
Bone ash†	....	1413
Bone meal, steamed†	....	1214
Calcium cyanamide†	....	1245
Calcium nitrate*	....	406
Dried blood†	451 (*variable*)	....
Milorganite†	238	....
Nitrate of soda†	....	583
Potash, muriate†	(*no effect*)	
Potash, sulfate†	(*no effect*)	
Potassium nitrate*	....	520
Rock phosphate, Tennessee brown†	....	1122
Superphosphate†	(*little effect*)	
Tankage, animal†	29 (*variable*)	....
Urea‡	1680	....

*Based on data by Pierre, *American Fertilizer 79*, 5-8 (Oct. 21, 1933).
†Based on data by Pierre, *Industrial and Engineering Chemistry 5*, 229 (July 15, 1933).
‡Also known under such trade names as NuGreen, Uramon, etc. (Figure based on data by Pierre, *Industrial and Engineering Chemistry 5*, etc.).

29. Do mixed fertilizers (those containing the three elements N, P, or K) have an appreciable effect on soil reaction?

Most of the mixed fertilizers used in Michigan are made up largely of superphosphate and muriate of potash, and it is obvious (See Table 3) that these would have little effect on the lime content of soil. Furthermore, dolomitic limestone is frequently used in mixed fertilizer as a filler and conditioner, and to neutralize any acid effects of the fertilizer ingredients. The quantity of lime added in this manner, however, is usually too small to affect greatly the lime status of the soil.

FUNCTIONS OF LIME IN THE SOIL

30. Are all forms of calcium effective in neutralizing soil acidity?

Not all forms of calcium are effective in correcting the harmful effects of an acid soil. Soil acidity is decreased by calcium compounds in the oxide, hydroxide, or carbonate form—but not by the sulfate (gypsum) or chloride form. When the latter two compounds are added to acid soils, strong, stable mineral acids are formed.

Lime in the form of either the oxide, hydroxide, or carbonate reacts rather rapidly with moist, acid soils—and, although the time required for these forms to neutralize the hydrogen in the soil varies somewhat, the final result is the same.

31. How does lime correct soil acidity?

When lime is added to the soil, the calcium of the lime dissolves in the soil water to liberate the calcium ions, which have the ability to replace hydrogen ions on the clay and humus compounds. The hydrogen ions are thus released to unite with hydroxyl (OH) ions, forming water (H_2O). When the soil particles become saturated with calcium, the soil is no longer acid; the acidity has been corrected. Neutralizing acid soils is the reverse of that process by which they become acid.

32. Is lime (calcium) essential for plant growth?

Calcium is an essential element for the growth of all plants. Many soils are too low in calcium content to supply the needs of crops, especially certain leguminous plants such as alfalfa and the clovers. When a deficiency of the element calcium occurs in the soil, lime might well be called a fertilizer. (See Table 1, for amounts of lime contained in certain farm products.)

33. Is the availability of phosphorus in soils influenced by the lime content?

As a general rule, a higher percentage of the phosphorus in soils well-supplied with lime is available for plant use than in soils low in lime content. Soil phosphorus is usually most readily available to plants in neutral or slightly acid soils. The availability of phosphorus decreases with increasing soil acidity (See question 14).

It is also likely that liming acid soils results in a more rapid liberation of the organic phosphorus, through stimulation of decomposition processes. It is obvious, however, that lime alone will not solve the problem of phosphorus availability in soils which have been depleted of phosphorus.

34. Why is the availability of phosphorus low in strongly acid soils?

In the presence of soluble aluminum and iron compounds, the soluble phosphates in strongly acid soils combine with those compounds to form relatively insoluble phosphate compounds. The availability of the native phosphorus, as well as that added in fertilizers, is low in strongly acid soils (See question 14).

35. What effect does an excess of lime have on the availability of phosphorus?

In the presence of excess lime (free calcium carbonate), the availability of phosphorus in alkaline soils (above a pH of about 7.5) is lowered.

36. Does lime influence the availability of potassium?

Generally speaking, lime does not greatly influence the availability of potassium. Theoretically, lime (calcium) should liberate potassium. However, there is some evidence to indicate that overliming decreases the solubility of potassium in certain soils. Within certain limits, there is an inverse relationship between the intake of calcium by plants and the intake of potassium.

37. Is the solubility of aluminum, iron, and manganese influenced by soil acidity or the lime status of the soil?

When a soil is deficient in calcium and it becomes strongly acid, the solubility of aluminum, iron, and manganese increases.

The concentration of those elements may then become so high as to be toxic to crop plants.

Excess amounts of such substances can become available below pH 5.5 (See question 13)—but a normal application of lime, to bring the soils to a pH of 6.5 to 7.0, may eliminate the toxic concentrations. In some soils above pH 6.0 to 7.0, iron and manganese may become insoluble to such an extent that plants are unable to satisfy their needs. Too much lime may create an iron and manganese deficiency.

38. Is lime beneficial to the microbiological processes of the soil?

Calcium is closely associated with many important soil microbiological processes. Calcium promotes the decomposition of organic matter—which releases plant nutrients and improves soil structure; makes conditions favorable for the production of nitrates; and provides favorable conditions for the growth and function of nitrogen-fixing bacteria. The organisms responsible for such processes function most efficiently in soils well supplied with lime. In those processes, it is not necessarily a matter of changing the pH, but one of supplying soluble calcium (See question 16).

39. Are disease-producing organisms favored by the presence of lime?

It is generally thought (although it does not always occur) that the application of lime in amounts sufficient to make a soil neutral or alkaline favors the organisms which cause the potato-scab disease (See question 16).

40. What is the effect of lime on soil structure?

The effect of lime in improving soil structure—making it more granular—is mostly indirect. The favorable influence is brought about through the effect of lime on the production and decomposition of organic matter. Humus-formation aids in improving soil structure.

41. What is the influence of lime on the effectiveness of fertilizers and manure?

Lime is not in itself a substitute for fertilizers and manure—but, when lime is needed, its application will increase their effectiveness. The phosphorus in manure and fertilizers applied to soils deficient in lime may be changed into less-soluble forms. Although the nitrogen and potassium in fertilizers and manure may not be made insoluble as a result of a lime deficiency, plants can utilize those elements better when the growing conditions are made more favorable by the presence of lime. If nitrogen is applied to an acid soil in the form of ammonium, or other forms subject to nitrification, the presence of lime will hasten the production of nitrates.

FORMS OF LIME

42. What are the different chemical forms of lime?

Lime may be purchased in four chemical forms: the *oxide,* the *hydroxide,* the *carbonate* or the *silicate.* The latter form (silicate) is not commonly available in Michigan. None of these forms leaves a harmful residue in the soil.

43. Are the chlorides and sulfates of calcium and magnesium classed as "liming materials?"

Calcium and magnesium salts—such as the chlorides and sulfates—are not considered liming materials. This is explained in question 30.

44. What is carbonate of lime?

"Carbonate of lime" is commonly referred to as *calcium carbonate.* This is the form most widely used for liming purposes, and the one in which most of the natural occurring liming materials —such as limestone, marl, and shells—exist. By-product lime from various industries contains precipitated calcium carbonate. Such carbonates are usually produced either from calcium oxide or calcium hydroxide. Calcium carbonate may be produced by combining either form with carbon dioxide.

45. What are the oxide forms of lime?

Calcium oxide is known under several names—such as "burned lime," "quicklime," "caustic lime," "lump lime" and "unslaked lime." Commercial "oxide of lime" is usually sold in a pulverized form in paper bags, although some is sold in a granular or lump condition.

46. How are the oxide forms of lime made?

Commercial oxide of lime is prepared by heating any form of carbonate of lime (calcium and magnesium carbonate). In the burning process carbon dioxide is driven off, and the calcium and magnesium oxides remain as a solid residue. There is no loss of calcium in the burning.

47. What is meant by hydrated lime?

When the oxide forms of calcium and magnesium come in contact with water they undergo a process known as "slaking." The oxides form *hydroxides*—known commercially as "slaked lime," "caustic lime," "hydrated lime," "hydrate," or "water-slaked" lime. This product is marked as a white powder, and is usually handled in paper bags.

48. Is blast furnace (basic) slag a liming material?

"Slag" is a by-product of pig-iron manufacture from iron ore and limestone. In the smelting process *calcium silicate* is formed which, if finely ground, is an effective liming material. It is not commonly used as a liming material in Michigan (See question 73).

49. Do the different forms of lime have the same ability to correct soil acidity?

Pound-for-pound, they do not.

The ability of a liming material to correct acidity is usually referred to as its "neutralizing value." The neutralizing power of liming materials is usually calculated on the basis of pure calcium carbonate as 100 percent. If 100 pounds of calcium carbonate is burned, 44 pounds of carbon dioxide gas is driven off; leaving 56 pounds of calcium oxide. Thus 56 pounds of pure calcium oxide would correct as much acidity as 100 pounds of pure calcium carbonate.

When 56 pounds of calcium oxide is moistened, it reacts with 18 pounds of water to form 74 pounds of hydrated lime. The neutralizing value is lowered, but is still considerably higher than calcium carbonate.

It is obvious therefore, that 100 pounds of pure calcium carbonate, 74 pounds of pure calcium hydroxide, and 56 pounds of pure calcium oxide are equal in their ability to correct soil acidity.

50. How is the ability of lime to correct acidity usually expressed?

The relative ability of different liming materials to correct acidity is usually expressed on a percentage basis. Thus the neutralizing power of the different forms of lime in the pure state is determined by their molecular weights.

The molecular weight of calcium carbonate is 100; of calcium hydroxide, 74; and of calcium oxide, 56. By dividing 100 by 74, the figure 1.35 is obtained—which means that 1 pound of calcium hydroxide supplies the same amount of calcium as 1.35 pounds of calcium carbonate. If expressed on a percentage basis (1.35x100), pure calcium hydroxide has a neutralizing value of 135 percent relative to calcium carbonate.

The molecular weights, neutralizing values, and calcium carbonate equivalents for the common chemical forms of liming materials are given in Table 4.

TABLE 4—Relative neutralizing power of different forms of lime

FORMS OF LIME	Molecular Weight	Neutralizing Value (in percent)	Equivalent of 1 ton of pure calcium carbonate (in pounds)
Calcium Carbonate.......	100	100	2000
Magnesium Carbonate....	84	119	1680
Calcium Hydroxide.......	74	135	1480
Magnesium Hydroxide....	58	172	1160
Calcium Oxide...........	56	178	1120
Magnesium Oxide........	40	250	800

51. How is it possible for a limestone to have a neutralizing value greater than 100 percent?

A limestone containing *magnesium carbonate* (a "dolomitic" limestone) may have a neutralizing value of more than 100 percent. Pure magnesium carbonate with a molecular weight of 84 has a neutralizing value of 119 percent ($100 + 84 \times 100 = 119$). A limestone containing 80 percent calcium carbonate and 20 percent magnesium carbonate would have a neutralizing value of 103.8 percent [$80 + (20 \times 1.19) = 103.8$].

52. In considering the effectiveness of different forms of lime is the neutralizing power the only factor of importance?

The neutralizing power of a lime is not the only factor of importance. For example, the density, hardness, and fineness of grinding of limestone may greatly influence the speed of its action in the soil. Dolomitic stones are usually harder and dissolve more slowly than calcium stones, and for that reason it is not customary to consider the higher neutralizing value of magnesium stones in determining the amount of lime to apply.

53. Does burned lime (calcium oxide) or hydrate (calcium hydroxide react more quickly in the soil than finely ground limestone?

Theoretically, the hydrate and oxide forms of lime can be expected to react in the soil somewhat more rapidly than finely ground limestone—because they are finer (especially the hydrate), and can be more thoroughly distributed in the soil. Furthermore, they are somewhat more soluble in water, which can result in their being more thoroughly and uniformly distributed through the soil if rain follows soon after the lime is applied.

It should be emphasized, however, that the unreacted portions of the oxide and hydroxide forms of lime will sooner or later change into the carbonate form in the soil.

54. Is there a difference in the effectiveness of the various forms of lime?

Over a period of years, or even a crop rotation, there appears to be little difference in the effectiveness of the various chemical forms of lime *when applied in equivalent quantities.* Therefore, the effectiveness of a liming material in correcting an acid soil depends on its content of calcium and magnesium, its effectiveness is little influenced by the particular chemical form (carbonate, hydroxide, or oxide) in which it occurs. If the carbonate form is used it is assumed that it is ground to a satisfactory degree of fineness.

SOURCES OF LIME

55. What is limestone?

Limestone is a sedimentary ("deposited in water") rock, formed by the precipitation of calcium and magnesium in water in the form of carbonates. These deposits are subsequently consolidated.

56. Is there a sufficient quantity of limestone to meet the needs of the soil?

Limestone deposits are rather widely distributed and they constitute an important source of lime. There are many limestone quarries in operation. They are in a position to meet the demands of agriculture, and other industries, for lime.

Michigan counties in which limestone deposits have been developed commercially include Monroe, Jackson, Eaton, Huron, Alpena, Presque Isle, Charlevoix, Emmet, Cheboygan, Manistique, Chippewa. Thousands of marl deposits have supplied marl for acid soil improvement.

57. What is the most important single source of liming materials?

Limestone is the most important single source of commercial liming materials—not only in the United States as a whole, but also in Michigan. For the year 1950 there were the equivalent of 575,000 tons of lime used in Michigan, of which 280,000 tons were some form of ground limestone. The two most commonly used grades of limestone in Michigan are "limestone meal" and "pulverized limestone." It should be remembered that the calcium of commercial hydrate, commercial oxide, and calcium silicate of the blast furnaces essentially all comes from limestone.

58. What is limestone meal?

"Limestone meal" is limestone which has been ground to a medium fineness. Usually, 95 percent or more will pass an 8-mesh sieve, and 25 percent or more will pass a 100-mesh sieve. (The number of openings per linear inch determines the number of the mesh.)

This material is generally handled in bulk.

59. What is pulverized limestone?

"Pulverized limestone" has been ground enough finer than "limestone meal" so that all of it will pass a 10-mesh sieve, and 65 percent or more a 100-mesh sieve. This material is usually handled in bags.

60. What is marl?

From an agricultural point of view, *bog lime* is usually spoken of as "marl." Bog lime was formed by lime dissolved from the soil and carried in the drainage waters to swamps and lakes, where it was thrown out of solution. Sometimes this material accumulates on the bottom of a lake or a swamp as a soft, mush-like material. Marl beds are also found on dry land where an old lake has been drained by a change in the drainage level.

61. How extensive are marl deposits in Michigan?

Marl deposits are widely distributed in the state and fortunately many of these are located close to areas of agricultural land in great need of lime. These marl deposits may range in thickness from less than one inch to several feet, and the areas are quite variable in size. (Fig. 4.)

Fig. 4. Michigan has extensive deposits of marl, a good liming material if always tested first for "purity," so that its rate of application can be properly calculated. Many of the marl beds are of the size and quality to warrant commercial operation on the scale pictured here.

62. What is the principal form of lime in marl?

The lime in marl is chiefly in the form of calcium carbonate, with varying but small quantities of magnesium carbonate. The value of a marl to correct acidity is usually expressed as though all the carbonates were present as calcium carbonate. Thus a marl testing 95 percent (dry-weight basis) has the same ability to correct acidity as any other liming material testing 95 percent.

63. Do marl deposits vary in purity?

The purity of marl may vary considerably, even within the same deposit. It is always advisable to have a purity test made before using a marl, because it is impossible to determine the value of marl by its appearance.

64. What impurities are generally found in marl?

The common impurities found in marl are sand, silt, clay, and organic matter. Of these impurities, clay is perhaps the most objectionable. A marl containing clay may be very sticky when wet, and become very hard and lumpy when dry. In this condition it is difficult to handle and cannot be applied uniformly.

65. Why is marl usually spoken of and dealt with in terms of cubic yards?

Because of its variable moisture content, marl is spoken of and dealt with in terms of cubic yards. On the average a cubic yard of good marl (testing 95 percent or more) weighs about 2,300 pounds in the wet condition, and contains about 1,200 pounds of calcium carbonate.

Some marls which contain organic matter as an impurity will likely shrink a great deal on drying. The dry-weight test may be above 80 percent, but the content of calcium carbonate per cubic yard may be as low as 500 pounds, or even less.

66. Is it best to express the purity of a marl on a dry-weight or on a volume basis?

The volume test is best, because some marls shrink so much on drying. The importance of the volume test is shown by the data in Table 5.

*TABLE 5—The value of marl is expressed more accurately by tests based on volume than by tests based on dry weight**

NO. OF SAMPLES (tested both ways)	TEST OF SAMPLES BASED ON DRY WEIGHT — Test range of samples (indicates *percent* of calcium carbonate present)	TEST OF SAME SAMPLES BASED ON VOLUME (graded by *pounds* of calcium carbonate indicated per cubic yard) — Percentage of samples graded Low, Good or High: Low Grade (500-800 pounds)	Good Grade (800-1200 pounds)	High Grade (1200-1600 pounds)
10	Below 60	50	40	10
12	60-70	25	66	8
34	70-80	27	44	29
42	80-85	28	41	31
70	85-90	11	60	29
143	90 plus	4	36	60

*Summary of 311 consecutive marl samples submitted to Michigan State College for testing.

67. How should a marl sample be taken for a test based on volume?

The marl should be sampled as it will be hauled or purchased by the farmer. If the marl is loaded directly from the deposit, the sample may be taken from either the marl bed or the truck. If the marl is stock-piled before hauling, take the sample from either the stock pile or loaded truck.

Take several sub-samples of about a handful each, mix together, and take a one-pint sample of the mixture. Place the sample immediately in a moisture-proof container. (A pint fruit jar with rubber and tightened lid is very satisfactory.) Forward this sample to the Soil Testing Service, Michigan State College—or to your county agricultural agent.

68. What is sugar-factory lime?

This is lime which has been used in purifying the juice from sugar beets. The lime is precipitated as calcium carbonate (which is filtered out and discarded), the same chemical form of lime found in limestone and marl. Generally, this lime is washed out to the waste pile with water used in washing the beets, and may contain considerable dirt. Sugar-factory lime contains insignificant quantities of organic matter and plant nutrients other than calcium. Because of its variable moisture content it is usually handled on the cubic-yard basis.

69. What is the neutralizing value of sugar-factory lime?

On a dry basis, this type of lime will usually test about 80 percent calcium carbonate. Because of variable quantities of impurities, the test of different samples may vary considerably. On the average, sugar-factory lime can be expected to contain about 1200 pounds of calcium carbonate per cubic yard. This lime should be sampled and tested as described for marl (See question 67).

70. Are wood ashes of value as a liming material?

Ordinarily wood ashes may be expected to contain from 20 to 40 percent of lime expressed as calcium carbonate. They may also contain from 1 to 5 percent potash and very small amounts of phosphorus—but they are much more important as a liming material than as a source of potash. The composition of ashes depends on the composition of the original wood, completeness of burning, amount of leaching that has occurred, and the impurities with which it may have become mixed.

71. Are coal ashes of value as a source of lime?

Coal ashes are very low in content of lime, and are not considered a satisfactory source. When applied in large quantities, coal ashes may improve the tilth of heavy soils.

72. Is lime from Acetone plants, Gasworks, Acetylene plants, paper mills, and city water softeners suitable for soil-improving purposes?

These limes are all valuable for soil application, but should be used on the basis of test. The principal disadvantage of this type of lime is that it usually contains a high content of water and is difficult to spread. Since these materials are regarded as waste products generally they can be obtained at little or no cost.

73. Will blast-furnace slag correct soil acidity?

This is an important source of lime in some of the southeastern states, but it has not been used extensively in Michigan. Slag is considered a liming material—inasmuch as it supplies calcium, leaves no harmful residue, and reduces soil acidity (See question 48).

74. Do oyster or egg shells contain lime?

Such shells contain about 90 to 95 percent of calcium carbonate. When finely ground they are a very satisfactory liming material.

THE USE OF LIME

75. How can the need of soils for lime be determined?

The need for lime can be determined accurately only by soil tests. The amount of lime needed cannot be determined from observations, although some indications for the need of lime may be evident.

76. What are some common indications of an acid soil?

Within certain limits, the general need of a soil for lime may be made by observation, although the amounts to apply cannot be so indicated.

Some of the common indications of an acid soil are: (1) the repeated failure of alfalfa and clover; (2) the prevalence of red sorrel; (3) thin or patchy stands of alfalfa or clover; or (4) clover or alfalfa may turn yellow in early spring. These conditions frequently are associated with a deficiency of calcium, but the amount of lime needed can be determined only by soil tests or field trials.

77. Why is it so important to test a soil for its need for lime?

Lime applied where it isn't needed does no good; too much may be harmful. Lime and legume seed are expensive and soil testing costs relatively little. Two good rules to follow are (1) never use lime except as indicated by soil test, and (2) never make a legume seeding without first testing the soil if its lime status is not known.

78. Are the simple colorimetric tests for determining lime needs sufficiently accurate?

For all practical purposes, the simple colorimetric tests are sufficiently accurate.

79. How should a field be sampled for determining its lime needs?

Each field may vary in acidity from place to place. It is advisable that several tests be made of the surface soil (plow depth), and at least one or two tests of the subsoil (at a depth of 2 to 3 feet) of each soil-type in each field. It is necessary that several tests be made of each soil-type to avoid such irregularities as droppings of manure, ashes from the burning of brush, weeds, or crop residues, and straw or hay stack residues.

80. Is it possible for farmers to determine the lime requirement of their soils?

"Soiltex," a mixture of dyes giving distinct color shades at different pH values, can be used—either in the field or laboratory—to determine the lime needs of a soil. This simple testing kit can be obtained through your county agricultural agent.

In case the farmer does not wish to make the test himself, the samples can be submitted to a local soil-testing laboratory, or to the Soil Testing Service at Michigan State College.

81. What crops are especially responsive to lime?

In general, the legume crops respond more to lime than do the non-legumes. Of the legumes commonly grown, alfalfa, sweet clover, red clover and ladino respond most markedly to liming (Fig. 5). All other legumes commonly grown respond to lime, but less than do those mentioned.

Of the non-leguminous crops, sugar beets, table beets, cabbage, asparagus, and cauliflower are particularly responsive to lime. Practically all crops are benefited either directly or indirectly by adding lime to acid soils. The indirect effect is produced through the greater growth of legumes—which leaves more organic matter and large quantities of active nitrogen in the soil.

Crops like potatoes, redtop, strawberries, buckwheat, bent grass, fescue, and millet appear to be little influenced directly by the addition of lime. As pointed out elsewhere (See question 18) certain non-leguminous plants are very highly tolerant of strongly acid soils.

Fig. 5. Good legumes are important for hay or pasture, and to soil improvement; and lime is important to good legumes. Since all the legume crops have high lime requirements, sound liming practices have become essential. A 3-ton crop of alfalfa alone can remove the equivalent of 200 pounds of lime per acre.

82. Why is it usually not necessary to apply lime to the home garden and lawn soils?

These soils are usually not in need of lime, because most sprinkling is done with water carrying considerable quantities of lime. Furthermore, many home gardens have received heavy applications of wood ashes. For some idea of the lime-content in Michigan water supplies, see questions 101, 102 and 103. Certainly no lime should be applied, except as indicated by a soil test.

83. What kind of lime should be used?

The form or grade of lime that should be used will depend upon several factors, chief of which are: (1) relative cost; (2) fineness; (3) rapidity of action; and (4) convenience in handling.

Equivalent quantities of the different chemical forms of lime (of similar fineness) are, essentially, equally effective in correcting soil acidity and in increasing crop growth. Obviously, therefore, *cost* is one of the most important factors to consider in choosing a liming material. If the material must be transported a considerable distance, it may be cheaper to purchase the more concentrated materials. If the liming material is close at hand, those forms containing less calcium may be the least expensive.

84. Is there any advantage in buying finely ground lime?

Where immediate or first-year effects are desired, particular attention should be given to the degree of fineness. Allowance should be made for this factor in comparing costs of ground limestone. In general, the finer a limestone is ground the more expensive it is—and the more rapidly it reacts with the soil.

85. Why are the carbonate forms of lime generally used?

The carbonate forms of lime (such as ground limestone) are usually cheaper—and more convenient to handle and less disagreeable than the caustic forms. Although marl (a carbonate form of lime) is difficult to handle, it is a common source of lime in Michigan—because it is often found locally and can usually be obtained at a low cost.

86. What changes does lime undergo when applied to the soil?

Lime applied to soils in the form of oxide or hydroxide, which does not react with the soil, is sooner or later changed to the carbonate form. Under field conditions, over a period of years, differences in the effectiveness of the various forms of lime generally have not been observed. Practically they are of little significance. Thus lime (in its various forms) may be considered to act principally in the carbonate form in the soil.

Lime which has been added to soils exists largely in two forms: as carbonates, and as exchangeable ions in association with the organic and inorganic colloids.

87. What factors should be considered in determining the quantity of lime to use?

The amount of lime that should be used will depend primarily on: (1) the acidity of the soil; (2) the buffer capacity of the soil;

(3) the crops to be grown; (4) the form or grade of lime to be used; and (5) the frequency of applying lime.

88. What is the most desirable pH-range for general farming?

Under most general farming conditions, it is advisable to maintain the soil reaction at a pH of about 6.5.

89. Do all soils having the same pH require the same amount of lime?

Sandy soils usually require less lime to bring them to any desired pH than do finer-textured soils having the same degree of acidity. Furthermore, the amount of lime necessary to change the pH of a strongly acid muck is much greater than for mineral soils. These differences are due largely to the much greater buffer capacities as determined by the colloidal material, both organic and inorganic. (See question 9; also Table 7.)

90. What is the rate of applying lime most generally recommended?

On mineral soils, the equivalent of 2 to 3 tons of finely ground limestone per acre (or 3 to 4 tons of a coarser grade) is most generally recommended. However, 5 to 10 tons of lime per acre are sometimes recommended for certain acid organic soils.

91. Is it possible to apply too much lime?

It is generally believed that if the pH of the soil is raised above 7.0 or 7.5 the availability of phosphorus, potassium, iron, manganese, copper, boron, and zinc is decreased. Over-liming injury is most likely to occur on strongly acid sandy soils low in organic matter. Although the question of over-liming has in some instances been over-emphasized, it is well to keep in mind some of the possible dangers resulting from such a practice.

92. How long will an application of lime last?

A specific answer cannot be given to this question. The frequency of liming will depend, among other things, on the amount of lime applied, the fineness of lime, the kind of soil, and the cropping system. When soil is limed for the first time, it may need an additional application for the next legume seeding. Once the lime needs have been fully met, an application may last for 10 or more years. This can be determined by a soil test. It is advisable to re-test the soil 2 years after the initial lime application.

93. What time of the year should lime be applied?

Lime may be applied any time during the year when it is most convenient. Late summer or fall application is usually most convenient. At this time of the year, the roads and fields are generally in a good condition for hauling and spreading.

94. When should lime be applied in the crop rotation?

It is advisable to apply lime where it can be used to the best advantage in the rotation of crops, as for example, preceding the legume crop or for a legume used for green-manuring purposes. For best results, lime should be applied and worked into the soil at least six months prior to seeding legumes—although good legume seedings sometimes are obtained by applying lime immediately preceding or with the legume seeding.

If a legume seeding is to be made with a nurse crop, such as wheat, it is a good practice to apply lime before the wheat is seeded in the fall. If a sod crop is to be turned under for a cultivated crop —to be followed by one or two grain crops in either of which a legume is to be seeded—lime can usually be conveniently applied to the sod before plowing.

95. When potatoes are grown in the crop rotation, why is it best to apply lime immediately following them?

It is generally believed that lime makes conditions more favorable for the development of the organisms which produce potato scab. Many growers have found that potatoes give greater yields when they follow a leguminous sod. Yield increases are usually sufficient to justify the use of enough lime on sour soils so as to make the growth of leguminous crops possible. In this situation it is recommended that a minimum amount of lime be applied directly after the potato crop is harvested. Pulverized lime at the rate of 1000 pounds per acre with the legume seeding may be sufficient.

96. Should soil of orchards and vineyards be limed?

Such crops thrive on soils having a wide variation in pH. Apparently those plants are able to get sufficient quantities of lime from the lower depths of soils which may be quite acid on the surface. Unless clovers, or other legumes which require a liberal supply of lime, are to be grown as cover crops, it is usually not necessary to add lime unless the pH of the soil is below 5.5. Heavy applications of lime should be avoided on sandy soils low in organic matter.

97. What is the principal requirement in any method of applying lime?

Lime should be distributed evenly and, except when applied to pastures, it should be thoroughly mixed with the soil. Lime moves in the soil only to a very limited extent, and it is essential that it come in contact with all the soil particles so far as possible. The only satisfactory way of mixing lime with the soil is by tillage operations.

98. What types of spreaders are commonly used for spreading ground limestone?

The three common types of spreaders are: (1) trucks with specially designed hoppers and distributors (See Cover); (2) the two-wheeled box-type of spreader; and (3) the end-gate spreader.

99. Can grain drills be used for applying lime?

Yes, that is an excellent method for applying small amounts of finely ground limestone. The lime is placed in the fertilizer compartment, and may be applied at seeding time or as a separate operation.

100. How are marl and similar types of liming materials generally applied?

Materials usually wet and difficult to handle are generally applied by means of a manure spreader, or by a truck equipped with a spreading device. If a manure spreader is used, it will work better if a layer of straw or manure is first placed in the bottom of the spreader.

LIME IN IRRIGATION WATER

101. What is the lime content of well water in Michigan?

A 1948 report made by the Michigan Department of Health[2] on the analysis of a large number of water samples showed the following:

Of 254 samples from drift wells in Michigan, 184 contained the equivalent of between 200 and 400 parts per million of calcium carbonate. Fifty samples contained less, and 20 samples contained more than that amount of lime. Furthermore, the analyses of 82 samples of water from rock wells showed that 50 contained the equivalent of between 200 and 400 parts per million of calcium carbonate. Twenty samples contained less and 12 samples contained more. (See Table 6 for converting parts per million to pounds of calcium carbonate).

TABLE 6—The calcium content of water (in terms of calcium carbonate) expressed in different ways

Parts per million	Pounds per acre inch	Pounds per 1000 gallons
100	22.5	.83
200	45.0	1.67
300	67.5	2.50
400	90.0	3.33

102. What is the lime content of water from the Great Lakes?

Water from Lakes Erie, Huron, Michigan, and Superior contains the equivalent of 158, 105, 132, and 50 parts per million of calcium carbonate respectively[2]. (See Table 6 for converting parts per million to pounds of calcium carbonate.)

103. What is the lime content of the water of Michigan's inland lakes?

Waters from Michigan's inland lakes usually contain from 10 to 50 parts per million of calcium (Ca), and from 2.5 to 20 parts per million of magnesium (Mg).[2]

LIME REQUIREMENTS OF MICHIGAN SOILS

All soils should be tested for soil reaction (pH), unless they are known to contain an adequate supply of lime. Knowing the

[2]"Chemical Analyses and Their Interpretations", Public Water Supplies in Michigan, Engineering Bulletin No. 4, Michigan Department of Health, 1948.

soil-type will aid in interpreting the pH tests. In some cases it will be unnecessary to test the soil if the soil-type is known. For example, the soils in Group 1, page 34, are naturally neutral to alkaline and do not need lime.

The pH's of light- and dark-colored soils of different surface textures in Table 7 apply particularly to the soils of Group 3, page 35, and should be adequate for the growth of deep-rooted legumes for about 10 years. Soils of Group 2, page 34, may require smaller and less frequent applications than listed in the table. Soils of Group 4, page 36, may require larger and more frequent applications of lime than indicated in the table for the satisfactory growth of deep-rooted legumes.

(In considering Table 7 below it should be clearly understood that these recommendations are estimates for what might be considered average conditions. The actual quantities of lime needed may vary somewhat from the figure shown, for any particular textural group, because of variations in content of clay or organic matter within the group.)

TABLE 7—Tons of limestone required to raise the plowed layers to a pH of 6.5, for light- or dark-colored soils of different textures and pH values. (Group 3 soils, page 35)*

Soil Texture	TONS OF LIMESTONE					
	Light-colored soils			Dark-colored soils		
	pH 4.0	pH 4.5	pH 5.5	pH 4.0	pH 4.5	pH 5.5
Sands and loamy sand.........	1 ½	1	½	3	2	1
Sandy loams.................	...	2	1	..	3	2
Loams and silt loams..........	...	3 ½	2	..	4 ½	3
Clay loams....................	...	5	3	..	6	3 ½
Organic soils.................	...	...	..	10 (5 ½)†	8 (3 ½)†	4 ½ (0)†

*A pH of 6.5 is desirable for deep-rooted legumes and most field crops. Blueberries do best at a pH of 4.2 to 4.8, and scab-susceptible potato varieties do best at a pH of 5.0 to 5.8. (The lime requirements for those crops can be found by subtracting the figures in the column for the pH most desirable for them, from those in the column for the pH of the soil. For example: If you desire to grow a scab-susceptible variety of potatoes on a light-colored sandy-loam soil, a pH of 5.5 would be satisfactory. If that soil now has a pH of 4.5, you should add only about 1 ton of lime per acre.) (2.0—1.0 = 1.0 ton.)

†Figures in parentheses are amounts of lime recommended for the crops most commonly grown on organic soils of these reactions.

SOIL CLASSIFICATION

The trend in soil classification over the years has been from a small number of general units with a wide range in properties, to a larger number of soils with more narrowly defined ranges in properties. Consequently, soil names used in areas surveyed earlier in Michigan may include several soils now recognized as separate types, and the earlier name has frequently been much restricted in current usage.

The soil names in this report are used as they are defined at the present time. Consequently there is need to re-examine and re-interpret many of the older soil-survey maps in terms of the current usage of soil names.

MICHIGAN SOILS: GROUPS 1 AND 2

(Names in Italic are the most common soils in each group)

GROUP 1. Soil series naturally neutral to alkaline in reaction. Containing adequate to excessive amounts of lime. *DO NOT NEED LIME.*

Alpena
Carlisle†
Detour
Edwards†
Essexville*
Johnswood
Maumee*
Moran
Rodman*
Ruse*
Satago*
St. Ignace
*Thomas**
Warners*
*Wisner**

GROUP 2. Soil series naturally slightly acid to neutral in reaction. May need lime for satisfactory growth of alfalfa or sweet clover. Have about two-thirds of the lime requirements of Group 3 soils.

Angelica*
Antrim
Bark River*
*Bergland**
Bono*
Bowers*
Brevort*
*Brookston**
Bruce*
Butternut*
Chatham
Colwood*
Eastport
Eel
Emmet (high lime phase)
Ensley*
Epoufette
Ewen
Genessee
*Gilford**
*Granby**
Griffin
Hessel*
Jeddo*
Kawkawlin
Kerston†
Kiva
Kokomo*
Lacota*
Longrie
*Munuscong**
Pickford*
Posen
Poygan*
Shoals
Summerville
Thomastown*
Toledo*
Trout Lake
Waiska*
Wallkill
Washtenaw
*Wauseon**

*Dark-colored soils. Other soils in this group are light-colored.
†Organic soil.

MICHIGAN SOILS: GROUP 3

GROUP 3. Soils naturally moderately acid. Usually need lime for satisfactory growth of legume crops.

Adolph*
Ahmeek
Alger
Allendale
Barker
Bellefontaine
Berrien
Bohemian
Brady*
Bridgman
Brimley
Bronson
Brule
Burt*
Cadmus
Carbondale†
Celina
Channing
Cheneaux
Coldwater
Conover
Coral
Crosby
Deer Park
Diana*
Duel
East Lake
Echo
Edmore*
Emmert
Emmet
Fox
Freesoil
Freer*
Fulton
Gagetown
Gilchrist
Hibbing
Homer
Houghton†
Ingalls
Iosco
Isabella
Kendalville
Kennan
Kent
Kibbie
Locke
Macomb
Mackinac
Mancelona
Manistee
Menominee
Metea
Miami
Moye
Nappanee
Nester
*Newton**
Nunica
Ogemaw
Onaway
Ontonagon
Parma
Pelkie
Rifle†
Rimer
Roscommon
St. Clair
Selkirk
Tahquamenon (non-agricultural)
Traverse
Trenary
Tuscola
Warsaw* (Some Warsaw is actually strongly acid. See Group 4)

*Dark colored soils.
†Organic soils.
Other soils of this group are light-colored.

MICHIGAN SOILS: GROUP 4

GROUP 4. Soils naturally very strongly acid. Need lime for satisfactory growth of legume crops. May need lime for satisfactory yields of scab-susceptible varieties of potatoes. Have about double the lime requirements of Group 3 soils.

Alcona
Allouez
Amasa
Arenac
Au Train
Baraga
Blue Lake
Boyer
Champion
Coloma
Coventry
Crystal Falls
Dawson†
Froberg
Gaastra
Gogebic
Grayling
Greenwood†
Hartwick
Hiawatha
Hillsdale
Iron River
Kalkaska
Karlin
Lake Linden
McBride
Montcalm
Munising
Negaunee
Omega
Onamia
Onota
Oscoda
Oshtemo
Ottawa
Otto
Plainfield
Randville
Roselawn
Rubicon
Sauble
Saugatuck
Shelldrake
Skanee
Spalding†
Sparta*
Spinks
Stambaugh
Strongs
Traunik
Vilas
Wallace
*Warsaw**
(Some Warsaw is moderately acid. See Group 3)
Watton
Weare
Wexford

*Dark-colored mineral soils.
†Organic soils.
Other soils in this group are light-colored.

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