LIME
FOR MICHIGAN SOILS

COOPERATIVE EXTENSION SERVICE
MICHIGAN STATE UNIVERSITY

Extension Bulletin 471, Minor Revision, July, 1966
Farm Science Series

By E. C. Doll*
Soil Science Department

Lime materials used in Michigan include agricultural limestone, marl, refuse or by-product limes such as "sugar beet" lime, "acetylene" lime and water treatment lime, and a few other materials.

Need for Lime in Michigan

About two-thirds of Michigan's cropland – 8 to 11 million acres – needs occasional liming. In general, Michigan farmers could profitably use 1⅓ million tons of agricultural limestone each year. The average annual use of limestone is now less than ⅓ million tons.

Long-time experiments conducted in Michigan indicate that agricultural lime applied according to soil test results will return at least $5 to $10 for every dollar spent for lime delivered and spread.

Benefits of Liming

Benefits of liming acid soils to modify their acidity can usually be attributed to some of the following factors:

1. Liming reduces harmful concentrations of aluminum, manganese and iron.
2. Liming increases the availability of phosphorus, molybdenum, and magnesium to cultivated crops.
3. All liming materials supply calcium. Dolomitic materials supply both calcium and magnesium. Both are essential elements for plant growth.
4. Liming promotes favorable microbial activity which results in increased release of organic nitrogen and decreased loss of gaseous nitrogen from the soil.
5. Liming promotes better soil structure and tilth – due partly to increased microbial action, partly to increased crop residue from higher crop yields, and partly to chemical effects of decreasing hydrogen ion concentration and increasing calcium and magnesium ion concentrations.

The effects of the degree of soil acidity (or pH, which is defined later) on the availability of plant nutrients in the soil are shown in Figure 1, page 2.

Most of the harmful effects reported from overliming mineral soils are due to decreased availability of certain nutrients – particularly manganese and zinc. As given in Table 1, crops vary in their needs for high lime levels or in their tolerance for soil acidity. Some plants require strongly acid soils for optimum growth.

What Is Soil Acidity?

Soils are acid because of hydrogen in the soil solution and on the surfaces of clay and organic matter particles that make up the soil. The soil solution is the soil water in which various chemical substances are dissolved. Hydrogen is present in it as *positively-charged* particles or ions. This is called *active hydrogen*. The degree of soil acidity, known as pH, is a measure of the *active hydrogen* in the soil solution. A value below pH 7.0 is acid; pH 7 is neutral; above 7.0 is alkaline.

The amount or concentration of *active hydrogen* in the soil solution is dependent on the amount of hydrogen held by the *negatively-charged* soil particles of clay and organic matter. Hydrogen ions on the surfaces of these particles are known as *exchangeable* ions because they can be readily replaced by other positively-charged ions such as calcium, magnesium or potassium. They represent *potential acidity*.

Many acid Michigan soils also contain considerable amounts of positively-charged aluminum ions. When the soil is limed, these ions react chemically with the soil water to produce hydrogen ions. This aluminum is another source of potential acidity.

Measurements of soil pH reflect only the *active*

**This bulletin is a revision of Extension Folder F-279, of the same title, by E. D. Longnecker, Extension Specialist in Soils, retired.*

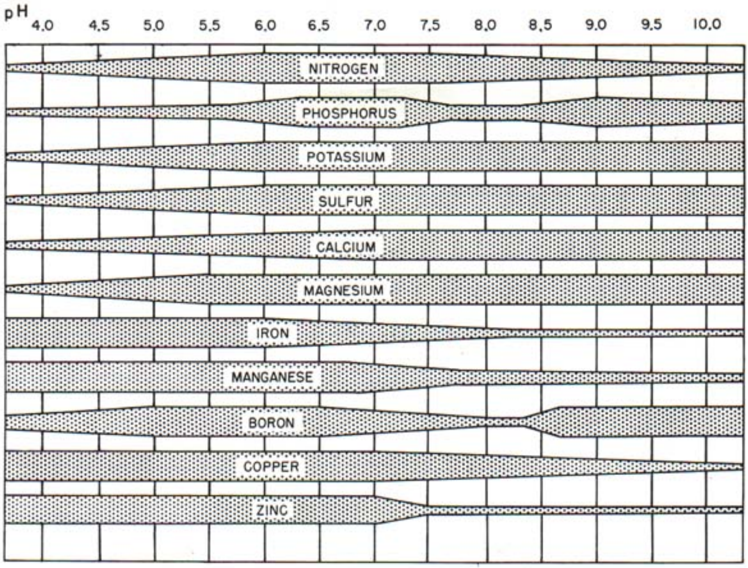

Fig. 1. — The general relation of pH to the availability of plant nutrients in the soil: the wider the bar, the more available is the nutrient. *(Adapted from Emil Truog, USDA Yearbook of Agriculture, 1943-47)*

Table 1. Permissible soil pH ranges for various crops growing on mineral soils.

On organic soils (peat and muck) a pH of 5.5 to 6.0 is most satisfactory. For the most efficient fertilizer utilization and the most effective microbial action on mineral soils, a pH from 6.5 to 7.0 is desirable.

LEAST ACID TOLERANT	
Alfalfa	6.3 to 7.8
Asparagus	6.0 to 8.0
Barley	6.5 to 7.8
Beans	6.0 to 7.5
Peas	6.0 to 7.5
Red Clover	6.0 to 7.5
Soy Beans	6.0 to 7.0
Sugar Beets	6.0 to 7.5
Sweet Clover	6.5 to 7.8

MEDIUM ACID TOLERANT	
Corn	5.5 to 7.5
Grasses	5.5 to 7.5
Trefoil	5.5 to 7.0
Wheat	5.5 to 7.0

MORE ACID TOLERANT	
Buckwheat	5.0 to 7.0
Oats	5.0 to 7.0
Potatoes	5.2 to 6.5
Raspberries	5.0 to 7.0
Rye	5.0 to 7.0
Strawberries	5.0 to 6.5
Vetch	5.0 to 7.0

STRONGLY ACID SOILS REQUIRED	
Blueberries	4.0 to 5.1
Cranberries	4.2 to 5.0

hydrogen; they do not measure the much greater amounts of exchangeable hydrogen and aluminum – *the potential* acidity – held on the soil particles. Nevertheless, enough liming material must be applied to neutralize both the active and the potential acidity.

The pH of most Michigan soils is between 4.8 and 7.8. Practically all field crops grown on mineral soils in Michigan yield best on slightly acid to neutral soils – pH 6.5 to 7.0. On organic soils, the optimum pH is usually 5.5 to 6.0.

More lime is needed on heavy-textured acid soils than on light-textured acid soils because the heavier soils contain more exchangeable hydrogen and aluminum. For the same reason, soils high in organic matter need more lime than those low in organic matter.

Effectiveness of Lime Materials

In comparing the ability of liming materials to neutralize soil acidity (assuming all of the lime to be immediately effective) it becomes necessary to establish a standard. Since calcium carbonate is the most common ingredient in limestone, it is used as the standard of comparison.

Pure calcium carbonate is given a "neutralizing value" of 100. A calcic limestone consisting of 98% calcium carbonate, 1% clay and 1% sand has a neutralizing value (N.V.) of 98.

The N.V. of liming materials varies above or below "100" as their ability to neutralize acidity varies from that of calcium carbonate.

The expression "calcium carbonate equivalent" means practically the same as "neutralizing value" except that it is an expression of weight. We say that a cubic yard of marl contains a certain weight of "calcium carbonate equivalent" such as 1,240 pounds. The neutralizing values of various liming materials used in Michigan are given in Table 2.

Table 2. Neutralizing value (per cent calcium carbonate equivalent) of various liming materials.

MATERIAL	Neutralizing Value
Calcium carbonate (pure)	100
Magnesium carbonate (pure)	119
Calcium hydrate (pure)	135
Magnesium hydrate (pure)	172
Calcic limestone	less than 100
Dolomitic limestone	less than 108
Calcic hydrated lime	less than 135
Dolomitic hydrated lime	less than 170

Measuring Lime Needs

Measurements of soil pH, as made in the county soil testing laboratories, are used to determine if a soil should be limed. Lime needs can then be estimated from Table 3 on the basis of soil pH and soil texture.

In the state soil-testing laboratory at Michigan State University, a lime-requirement test is made in which both active hydrogen, or pH, and exchangeable hydrogen and aluminum, or potential acidity, are measured. This gives a more precise determination of lime requirement than the estimates made from soil pH and soil texture. However, satisfactory results are usually obtained from Table 3; any errors in lime recommendations usually result in underliming rather than overliming, so that additional lime may be applied after the soil is retested.

Lime recommendations made in either the state or county laboratories are in terms of the amount of ground limestone, with a *neutralizing value of 90%*, required to raise the pH of a *6⅔-inch plow layer* to *pH 6.5*.

From fields on which alfalfa is to be grown, a pH value between 6.8 and 7.0 is desirable; consequently, the recommendation from Table 3 should be *increased approximately one ton per acre when alfalfa is to be grown.* For some crops where lower pH values may be desirable, the recommendations can be decreased accordingly.

Limestones sold in Michigan usually range from 80 to 103% calcium carbonate equivalent, so the lime recommendations given in Table 3 from the central soil-testing laboratory should be adjusted for liming materials with neutralizing values different from 90. Figure 2 can be used for this purpose.

Liming rates given in Table 3 refer to a plow layer of 6⅔ inches. With the advent of larger tractors and plows, many farmers regularly plow to a depth of 10 to 12 inches. Consequently, heavier lime applications will be necessary to reach the desired pH levels. Recommendations derived from Table 3 (and Figure 2) can readily be converted for deeper plowing depths by using Figure 3. Examples of liming recommendations developed by using Table 3 and Figures 2 and 3 are given in Table 4.

Magnesium Needs in Michigan

Magnesium deficiency may occur in acid soils that have a sandy loam, loamy sand, or sand plow layer with a subsoil as coarse or coarser in texture than the plow layer, and in similar soils limed with calcic limestone or marl. Responsive crops are cauliflower, muskmelons, potatoes, peas, oats, wheat and rye. Dolomitic limestone should be applied to acid sandy soils which have less than 75 pounds of exchangeable magnesium per acre, as measured in the state laboratory.

Table 3. Tons of limestone to raise the pH of a 6-2/3-inch plow layer of different soils to pH 6.5.

Texture of plow layer	Soil Management Group	pH Range			
		4.5 to 4.9	5.0 to 5.4	5.5 to 5.9	6.0 to 6.4
		Tons of lime recommended*			
Clay and silty clay	1	6	5	4	2½
Clay loams or loams	2	5	4	3	2
Sandy loams	3	4	3	2½	1½**
Loamy sands	4	3	2½	2	1**
Sands	5	2½	2	1½**	½**

*Lime recommendations based on a liming material having 25 per cent passing through a 100-mesh sieve and having a neutralizing value of 90 per cent.

**It is preferable to recommend 2 tons per acre so as to obtain uniform application and to justify the expense of application.

Table 4. — Examples of lime recommendations developed using Table 3 and Figures 2 and 3.

pH	Texture	Alfalfa to be grown*	Neutralizing Value of Lime	Plow Depth (inches)		
				6⅔	9	12
				Tons of Lime		
5.5	Sandy loam	Yes*	90	3½	4½	6
5.5	Sandy loam	No	90	2½	3½	4½
5.6	Loamy sand	Yes*	105	2½	3½	4½
6.2	Loam	No	70	2½	3½	4½
4.8	Sandy loam	Yes*	80	5½**	7½**	10**
5.7	Clay loam	Yes*	103	3½	4½	6**

*When alfalfa is to be grown, the rate of application should be increased approximately 1 ton.

**One-half of lime should be disked in prior to plowing and one-half after plowing.

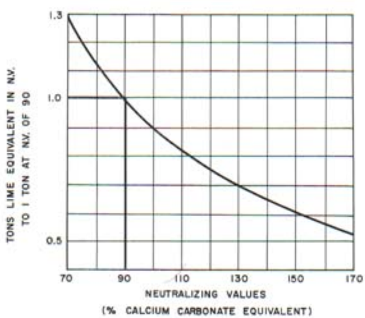

Fig. 2. — Conversion chart to determine amounts of limestone of various neutralizing value (N.V.) that are equivalent to 1 ton lime with N.V. of 90.

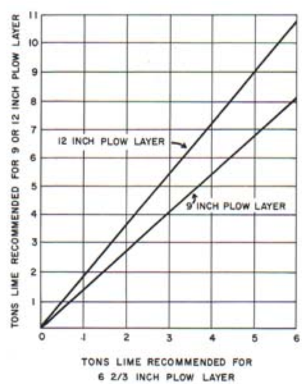

Fig. 3. — Diagram to convert recommendations made for a 6⅔-inch plow layer to recommendations for a 9- or 12-inch plow layer.

Kinds of Lime

In chemical terms, agricultural lime includes the oxide, the hydrate, and the carbonate of calcium or calcium and magnesium. Practically no oxide or burnt lime is used in Michigan. Hydrated lime makes up about 1%, calcic limestone 28%, dolomitic limestone 38%, marl and calcareous tufa 31%, and lime refuse from various local industries approximately 2% of the agricultural lime now used in Michigan.

Calcic Limestone

Calcic limestone, sometimes called high-calcium limestone or calcitic limestone, is limestone containing less than 5% magnesium carbonate. With the exception of the limestone quarried in Monroe County, most of the agricultural limestone produced in the lower peninsula of Michigan is calcic limestone.

Dolomitic Limestone

In soil test reports and in making recommendations, magnesium is expressed as the element. To convert from the carbonate ($MgCO_3$) to the element (Mg) form, the factor is 0.29. As an example, a dolomitic limestone having 30% magnesium carbonate carries 30% of 2,000 or 600 pounds magnesium carbonate per ton. Applying the factor of 0.29, the magnesium value would be $600 \times 0.29 = 174$ lbs. elemental magnesium per ton.

Dolomitic limestone contains appreciable quantities of magnesium carbonate. That being marketed in Michigan contains from 15% to 45% magnesium carbonate, the remaining 85% to 55% being largely calcium carbonate. Practically all of the agricultural hydrate being used in Michigan is made from dolomitic limestone and is called dolomitic hydrate.

Neutralizing Effect of Magnesium

Magnesium in lime raises its neutralizing value because an ion of magnesium is lighter than an ion of calcium, but can replace the same amount of hydrogen from the soil.

Marl

Marl and refuse limes are satisfactory liming materials if applied in conformity with their lime contents and if spread evenly. Many of these materials have settled out of water charged with lime and are very fine in texture.

Under the Michigan lime law, marl and refuse limes are sold and guaranteed on the basis of the number of pounds of "calcium carbonate equivalent" per cubic yard. (This term is explained in detail in the section on "effectiveness.") Michigan marls average about 3.5% magnesium carbonate.

Because of their variability, marl and refuse lime are generally applied on the basis of two cubic yards per ton of limestone. More than two-thirds of the marl now being applied tests between 1,200 and 1,800 pounds calcium carbonate equivalent per cubic yard. This means that the actual liming rate is higher than recommended when marl is applied on the basis of two cubic yards per ton of limestone.

Rate of Reaction of Lime in the Soil

Limestones from various sources react at different rates; almost all dolomitic limestones are harder than calcic limestones and consequently react more slowly in the soil. In general, differences between sources of limestone are not great enough to warrant the preferential use of one source of limestone rather than some other source, except when dolomite is used to supply magnesium as well as raise the soil pH.

Methods and Time of Applying Lime

The equipment used in spreading is not important as long as it spreads the lime uniformly and covers every square foot of the field area evenly. Lime will be distributed more evenly by disking and harrowing the soil thoroughly after spreading and before plowing.

If possible, lime should be applied and worked into the plow layer one year in advance of high lime requirement crop. Where alfalfa or other forage legumes are included in the crop sequence, an excellent time for lime application is on the old sod before plowing. The better time for this old-sod application is in late summer or fall preceding plowing, rather than in the spring. This reduces the hazard of excessive soil packing by spreading equipment.

Fineness of Grinding

The finer limestone is ground, the more quickly it will react in the soil.

Research data indicates that particles larger than 8-mesh (about ⅛ inch in size) have very little effect on the soil. However, particles in the 50- to 60-mesh range are about as effective after 6 to 9 months as finer materials.

Limestone should be ground so that practically all of the material passes an 8-mesh sieve and about 25% passes a 100-mesh sieve. All the fines from grinding should be retained. Finer grinding is not generally necessary; although lime ground more finely would react somewhat more quickly, the coarser material would have a longer lasting effect on the soil.

Lime Losses from the Soil

It is impossible to state definitely how long the benefits from a given application of lime will last. It is advisable to retest soil from the limed field after two to four years to measure the change in pH.

Lime is lost from the soil by cropping and pasturing, by leaching (drainage through the subsoil), and by wind and water erosion. Keeping a growing crop on land as much as possible will retard leaching losses and erosion. Legumes remove more calcium and magnesium than other crops.

Possibly 200 to 300 pounds of lime are lost per acre of top soil in Michigan each year. How frequently you should lime your soil can only be learned by testing representative samples of soil.

Effect of Fertilizers on Soil Acidity

Present fertilizer practices increase crop yields, and thus increase the removal of calcium and magnesium from the soil. In addition, many fertilizers, particularly the nitrogen carriers, leave an acidic residue in the soil. Table 5 gives the amount of lime (as pounds of calcium carbonate) required to neutralize the acids formed from one pound of nitrogen from each of the various nitrogen fertilizers. Over a period of years, these fertilizers can markedly decrease the soil pH.

While the differences between these sources of nitrogen are not great enough to justify selection of any particular source (lime is much cheaper than nitrogen) these effects should be recognized so that lime can be applied when needed.

Table 5. Pounds of lime (calcium carbonate) required to neutralize the acidity produced per pound of nitrogen (N).

Nitrogen Carrier	Pounds Calcium Carbonate
Ammonium nitrate	1.8
Ammonium sulfate	5.5
Anhydrous ammonia	1.8
Urea	1.9

The Michigan Lime Law

The Michigan Lime Law is simply a labelling act. It requires that all agricultural liming materials offered for sale within Michigan be licensed with the Michigan Department of Agriculture each year.

With each sale of lime the purchaser is to be provided with a written statement giving the name of producer, his address, the name of the material, the net weight of the lime, the neutralizing value, and the percentage of the lime passing an 8-, 60- and 100-mesh screen.

For marl and refuse limes, the volume (cubic yards) and test expressed as pounds of calcium carbonate equivalent per cubic yard are to be stated in place of neutralizing value and screen test.

Extension Bulletins such as this one are part of the educational services provided by the Cooperative Extension Service of Michigan State University. These services to the people of Michigan are financed jointly by your county, state, and federal governments. At the County Extension offices, agents can provide information and help on many farm, home, and community problems. They work in agriculture, home economics — family living, 4-H, marketing, and community and resource development. Publications on more than 500 subjects are available at the County Extension Offices usually located at the County Seat — or from MSU Bulletin Office, P. O. Box 231, East Lansing, Michigan.

Cooperative extension work in agriculture and home economics. Michigan State University and the U. S. Department of Agriculture cooperating. N. P. Ralston Director, Cooperative Extension Service, Michigan State University, East Lansing. Printed and distributed under Acts of Congress, May 8 and June 30, 1914.
2P-8:66-15M-HK