Lime for Michigan Soils

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By D. R. Christenson, D. D. Warncke and R. Leep
Department of Crop and Soil Sciences

LONG-TERM SOIL EXPERIMENTS in Michigan and other midwestern states indicate that every dollar spent on agricultural lime applied according to soil tests returns from $5 to $10. In these experiments, liming generally resulted in increased crop yields.

Lime applied to soil neutralizes (or corrects) acidity, a soil chemical condition that affects the growth of crops. Lime also supplies the soil with two essential plant nutrients, calcium and magnesium.

A recent soil test summary indicates that the average lime requirement to correct soil acidity in Michigan is one ton per acre per year. There are close to 6.3 million acres of crop land in Michigan. If we assume that lime should be applied once every three years, then Michigan farmers could profitably apply 2.1 million tons every year. Recent average annual use, however, has been about 550,000 tons. This amount is about enough to neutralize the acidity produced by annual applications of nitrogen in Michigan.

A soil test followed by adequate lime applications are the first two steps in a liming program. Retesting to follow the progress of the program is also essential.

This bulletin discusses: 1) the nature of soil acidity and the need and importance of liming the soil to neutralize acidity, 2) compares various liming materials and their neutralizing values, and 3) offers guidelines for liming soils for crops grown in Michigan.

WHAT IS SOIL ACIDITY?

Soils are acid because of positively charged hydrogen ions in the soil solution (water in the soil) and on the surface of clay and organic matter particles that make up the soil. Hydrogen ions in the soil solution are referred to as **active acidity**. The term, pH, measures this active acidity. A pH value below 7.0 is acid, 7.0 is neutral, and above 7.0 is alkaline, or nonacid.

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 these soil particle surfaces are known as **exchangeable** ions because they can be readily replaced by the positively charged ions, such as calcium, magnesium or potassium. These hydrogen ions are part of the **potential or reserve acidity** of the soil. The process of neutralization occurs because these ions are exchangeable.

Many acid Michigan soils also contain considerable amounts of positively charged aluminum ions. These ions react chemically with water present in the soil to produce hydrogen ions. Thus, aluminum is another source of potential acidity.

In a liming program, sufficient lime needs to be applied to neutralize both active and potential acidity. Actually, the active acidity in most Michigan soils could be neutralized by less than one pound of lime per acre. The remainder of the lime requirement is caused by potential acidity. At a given pH level, more lime is needed on fine-textured soils than on coarse-textured soils because the fine-textured soils have more exchangeable hydrogen and aluminum (potential acidity). Soils high in organic matter need more lime than those low in organic matter for the same reason.

WHAT IS LIME?

Chemically, lime is defined as calcium oxide (CaO). In this bulletin and agriculture in general, lime is a term used for a wide range of materials used to increase soil pH. Common lime materials available in Michigan include agricultural limestone, marl, refuse or by-product materials such as "sugarbeet" lime, "acetylene" lime, "water treatment" lime and other materials.

BENEFITS OF LIME

Some benefits of liming acid soils—**all of which have the general benefit of improving crop yields—are these:**

1. Liming reduces aluminum and manganese in the soil to levels that are not harmful to crops.
2. Liming increases the availability of nitrogen, phosphorus, potassium, magnesium, calcium, sulfur, boron and molybdenum.
3. All commonly used liming materials supply calcium, an essential plant nutrient, and dolomitic materials supply both calcium and another essential nutrient, magnesium.
4. Liming promotes favorable microbial activity (through more vigorous plant growth) which results in an increased availability of soil nitrogen and a 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 residues from higher crop yields and partly to chemical effects of decreasing hydrogen ion concentration and increasing calcium and magnesium ion concentrations.
6. Liming promotes longevity of legume stands, particularly alfalfa, due to the high calcium requirements of these plants. It also increases nitrogen fixation by these plants.

The influence of soil pH on availability of plant nutrients in mineral soils is shown in Figure 1. Note that the width of the bar is related to the availability of the nutrient. Crops vary in their tolerance of soil acidity. The soil pH ranges where crops grow best are given in Table 1. Some plants require strongly acid soils while others require a higher pH.

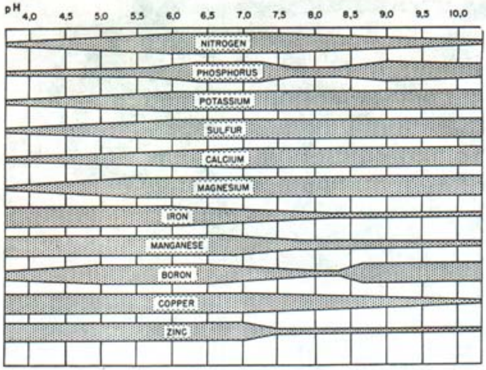

Fig. 1 — The general relation of pH to the availability of plant nutrients in the soil: the wider the bar, the more available is the nutrient. (Adapted from Emil Truog, USDA *Yearbook of Agriculture*, **1943-47.)**

MEASURING LIME NEEDS

The lime requirement test used by the Michigan State University soil testing laboratory involves a buffer method called the SMP or Ohio method. **This method measures both the reserve and active acidity.** A comparison of this measurement (lime index) and lime requirement is given in Table 2.

In the absence of a lime requirement test based on a buffer method, lime needs can be estimated from soil pH and texture as shown in Table 3. This method is not as satisfactory as the buffer-lime index system, because insufficient lime is usually recommended.

The SMP buffer method of determining lime requirement fails on soils with a low buffering capacity (low cation exchange capacity). This situation is easily recognized from soil test results. The conditions are as follows: 1) A sand or loamy sand soil texture (soil management groups 4 or 5), 2) lime index which indicates that less than 0.5 tons of lime is needed (lime index 69 or above) and 3) the soil pH suggests that lime should be applied. If all three conditions exist, refer to Table 3 for a suggested lime rate.

Table 1 — Desirable soil pH ranges for various crops grown on mineral soils.

Least Acid Tolerant		More Acid Tolerant		Medium Acid Tolerant	
Alfalfa	6.3 to 7.8	Buckwheat	5.0 to 7.0	Corn	5.5 to 7.5
Asparagus	6.0 to 8.0	Oats	5.0 to 7.0	Grasses	5.5 to 7.5
Barley	6.5 to 7.8	Potatoes	5.2 to 6.5	Trefoil	5.5 to 7.0
Beans	6.0 to 7.5	Raspberries	5.0 to 7.0	Wheat	5.5 to 7.0
Peas	6.0 to 7.5	Rye	5.0 to 7.0		
Red Clover	6.0 to 7.5	Strawberries	5.0 to 6.5	**Strongly Acid Soils Required**	
Soybeans	6.0 to 7.0	Vetch	5.0 to 7.0		
Sugar Beets	6.0 to 7.5			Blueberries	4.0 to 5.1
Sweet Clover	6.5 to 7.8			Cranberries	4.2 to 5.0

Table 2 — Tons of limestone needed on mineral soils to raise pH to 6.0 6.5, or 6.8 as determined by the "Lime Index" (SMP Buffer) method based on 90% neutralizing value.

Index	Desired soil pH 6.0	6.5	6.8
	—Tons lime per acre*—		
70	–	–	0.5
69	–	0.5	1.0
68	1.1	1.5	1.8
67	1.9	2.4	2.6
66	2.7	3.3	3.6
65	3.5	4.3	4.7
64	4.3	5.3	5.7
63	5.1	6.2	6.7
62	5.8	7.2	7.8
61	6.6	8.1	8.9
60	7.4	9.1	10.0

**To convert lime recommendations to depth of plowing other than 9 inches, divide rates by 9 and multiply by the depth of plowing.*

The maximum lime recommendation for one season is 6 tons. The maximum recommendation for one application is 4 tons. (See text.)

HOW AND WHEN TO LIME

The maximum lime recommendation in any season is 6 tons per acre on mineral soils. The soil should be retested for additional lime needs in 2 years if the lime index is less than 65. The maximum suggested rate in one application is 4 tons because it is difficult to mix larger amounts thoroughly with the soil. When larger amounts are needed, split applications are suggested. One half the requirement should be applied, incorporated and plowed under. Then the other half should be applied and worked into the soil.

The equipment used for spreading lime should spread the material evenly. Lime is mixed into the soil more evenly by disking or harrowing the soil thoroughly after spreading and before plowing. If possible, the lime should be applied and worked into the soil one year in advance of high lime requirement crops. Where alfalfa and other forage legumes are included in the crop sequence, an excellent time for lime application is on the old sod before plowing. The best time for this application is late summer or early fall preceding plowing rather than in the spring because there is less hazard of excess soil compaction by spreading equipment.

CROP GUIDELINES

For alfalfa seeding, lime to pH 6.8.

For Potatoes, adjust pH to 6.0. If there is no history of scab, and if scab-tolerant varieties are grown, consider liming to pH 6.5. Do not apply more than 2 tons per acre at one time in order to reduce the possibility of scab. Also, apply lime well ahead of growing potatoes; for example: apply lime immediately after harvest to allow time for the lime to react before the next crop of potatoes is grown.

If potatoes are not the primary crop in the rotation, it may be best to lime for optimum production of the primary crop or crops.

No-till corn presents some unique pH problems. Soils in no-till corn production develop an acid layer in the surface 2 inches because in many cases the nitrogen is applied on the surface. This condition reduces the effectiveness of some herbicides. Annual or every-other-year application of 0.5 to 1 ton per acre is often necessary to maintain a favorable surface soil pH. Check the pH of the top 2 inches annually.

On established sod (pastures, hay fields) which is not to be reseeded for several years, top-dress with lime only if the pH is less than 5.8, using not more than 2 tons per acre.

For lawns, check the pH of the 0 to 3-inch soil depth, and if it is below 5.5, topdress at a rate of 25 to 50 pounds of finely ground lime per 1,000 square feet. When establishing a lawn, test the soil and apply lime at the recommended rate, mixing it with the soil prior to seeding.

Under extensive agriculture, the question arises as to whether to apply the full lime requirement on a few acres or less lime on additional acres. If legumes are to be established, lime should be applied at recommended rates so as to increase soil pH sufficiently to establish and maintain the legume stand. When grasses are to be seeded, liming to pH 6.0 will usually be satisfactory.

Crops grown on organic soils do not benefit from liming above a soil pH of 5.2 except for celery, which requires a soil pH above 5.5. Blueberries benefit from lime only when the

Table 3 — Tons of limestone required, as estimated from soil pH and texture, to raise the pH of a 9-inch plow layer to pH 6.5. Add ¾ ton to raise soil pH to 6.8.

Texture of Plow Layer	Soil Management Group	Soil 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	8	6¾	5½	3½
Clay loams or loams	2	6¾	5½	4	2¾
Sandy loams	3	5½	4	3½	2
Loamy sands	4	4	3½	2¾	1½**
Sands	5	3½	2¾	2	¾**

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

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

pH falls below 4.0; then apply 4 tons per acre. Recommended lime rates given in Table 4 are intended to raise organic soil pH to near 5.5. Some organic soils have acid subsoils, while others have alkaline subsoils. Since some of this material may be brought to the surface during plowing, take soil samples to the planned plow depth for determining lime needs.

LIME MATERIALS COMPARED

A standard is needed when comparing the effectiveness of lime materials because a pound of one kind of lime does not necessarily equal a pound of a different kind of lime. Since calcium carbonate is the most common ingredient in limestone, it is used as a standard of comparison.

Pure calcium carbonate is given a neutralizing value of 100. A calcitic limestone with 98 percent calcium carbonate, one percent clay and one percent sand has a neutralizing value of 98. The neutralizing value of liming materials varies above and below 100 as the capacity to neutralize acidity varies from that of calcium carbonate.

The lime recommendations given in Table 3 are for a neutralizing value of 90. If the material used has a neutralizing value greatly different from 90, the amount should be adjusted. Table 5 can be used for this purpose. For example, if the recommended rate were 4 tons and the neutralizing value of the available liming material was 120, the amount of that material to apply would be 3

Table 4 — Lime requirements of organic soils to raise the soil pH to 5.5.

Soil pH	Lime requirement
	Tons/acre
4.9 to 5.0	3
4.6 to 4.8	5
4.2 to 4.5	8*
3.8 to 4.1	10*

**Plow down half and disk in other half after plowing.*

Table 5 — Correction factor for neutralizing values other than 90. Multiply the factor times the recommended rate to determine the amount of material of a different neutralizing value to apply.

Neutralizing value	Correction Factor*
170	0.53
160	0.56
150	0.60
140	0.64
130	0.69
120	0.75
110	0.80
100	0.90
90	1.00
80	1.12
70	1.28

**Ninety divided by the neutralizing value will give the correction factor.*

tons (0.75 times 4 tons). Ground limestone materials sold in Michigan usually range in neutralizing value from 80 to 103 percent. High grade limestone materials may run as high as 130. Table 6 gives neutralizing values for some lime materials.

The expression "calcium carbonate equivalent" means practically the same as neutralizing value except that it expresses weight of lime per cubic yard. For example, if a cubic yard of marl has a "calcium carbonate equivalent" of 1,240 pounds, this means that a cubic yard of marl will neutralize the same amount of acidity as 1,240 pounds of calcium carbonate.

Table 6 — Neutralizing value (percent 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	*<100
Dolomitic limestone	<108
Calcic hydrated lime	<135
Dolomitic hydrated lime	<172

**< = less than*

RATE OF REACTION

Liming materials react at different rates because of their chemical composition, hardness and fineness to which the materials are ground. The finer the material, the more quickly it will react if it is thoroughly mixed with the soil. This is due to the increased surface area of the finer material. Since fineness of grind can be controlled more easily than chemical composition or hardness, this property usually affects the rate of reaction more than the other two. Figure 2 shows the availability of limestone as affected by mesh size (8 mesh is approximately 1/8 inch). Limestone should be ground so that practically all the material passes through an 8-mesh sieve. All fine material should be saved.

A method exists which allows us to compare materials of different fineness of grind and neutralizing value. A new number is calculated which is called **effective calcium carbonate** (ECC). First, a fineness factor is calculated. Next this value is multiplied times the neutralizing value to give the ECC. Multiply the percent material coarser than 8-mesh times 0 (0% effective), the percent material between 8- and 60-mesh times 0.50 and the percent material finer than 60-mesh times 1.0. Add these values to obtain the fineness factor.

In the example in Table 7, the two samples have the same ECC, but different neutralizing values and sieve analysis. The calculated ECC value can be substituted for neutralizing value in Table 5 to adjust lime rates.

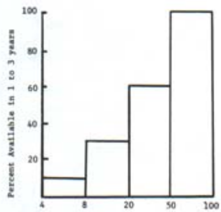

Fig. 2 — The relative availability of ground limestone as influenced by mesh size.

LIME SUSPENSION

Lime suspensions, liquid lime and fluid lime are all names for a system of suspending lime in a fluid (liquid fertilizer or water) for delivery to the field. **There is nothing magical about lime suspensions.** The concepts about neutralization of soil acidity are the same for lime suspensions as they are for dry liming materials.

The limestone used in suspensions is usually finer than 60 mesh. It is suspended in water or liquid fertilizers with a dispersing agent and clay as the suspending agent. Typically, suspensions contain 50 to 75% liming material, 0.5 to 5.0% clay and a small amount of dispersing agent; the remainder is liquid fertilizer or water. Nitrogen fertilizer solutions are used as well as nitrogen-potassium and sulfur-containing solutions. Fertilizers containing phosphorus should not be used. Lime containing appreciable amounts of calcium oxide (CaO) should not be used with nitrogen solutions due to nitrogen loss.

Lime suspensions have the following advantages:

1. React faster than coarser materials
2. Can combine with N, K, and S fertilizer solutions
3. No dust problem during application
4. Easy uniform application
5. Favored by renters for fast reaction

Disadvantages:

1. May have to apply every year
2. Cost may be greater in the long term
3. Cannot be used with phosphorus fertilizer
4. Large pH changes not possible with small quantities
5. Application in combination with herbicides not recommended

Table 7 — Example calculation of the effective calcium carbonate (ECC) for two lime sources with different analyses.*

Component or factor	Sample A	Sample B
Neutralizing value	90	100
Sieve analysis		
Coarser than 8-mesh (%)	2	10
8-60 mesh (%)	18	20
Finer than 60 mesh (%)	80	70
Calculated fineness factor		
% Coarser than 8 mesh × 0% effectiveness	0	0
% 8-60 mesh × 50% effectiveness	9	10
% Finer than 60 mesh × 100% effectiveness	80	70
Fineness factor	89	80
ECC = Fineness factor × neutralizing value	80	80

*The ECC can be substituted for neutralizing value in Table 5.

MAGNESIUM NEEDS

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 calcitic limestone or marl. Responsive crops are cauliflower, muskmelons, celery, tomatoes, potatoes, peas, oats, wheat and rye.

Present criteria for recommending magnesium in Michigan are: (1) if the exchangeable magnesium level is less than 75 pounds per acre, or (2) if as a percent of the total exchangeable bases (calcium plus magnesium plus potassium expressed as milliequivalents per 100 grams of soil), potassium exceeds magnesium, or (3) if the soil magnesium (as a percent of total bases) is less than 3%.

At least 1,000 pounds of dolomitic limestone should be applied on acid soils where magnesium is needed. For further information on magnesium fertilization, see Extension Bulletins E-486, E-550 and the following section on dolomitic limestone.

Dolomitic Limestone

Dolomitic limestone contains appreciable amounts of magnesium carbonate. That being marketed in Michigan contains 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. There is no evidence to suggest that dolomitic limestone has any detrimental effect if used where magnesium is not limiting.

Magnesium (Mg) concentration is expressed as percent magnesium carbonate ($MgCO_3$) in the analysis report on limestone materials, but is expressed as the element in fertilizer recommendations and soil test reports. To convert from $MgCO_3$ to Mg form, multiply the $MgCO_3$ percent by 0.29. For example, a dolomitic limestone having 30% $MgCO_3$ contains 174 pounds elemental Mg per ton (0.30 times 0.29 times 2,000).

Calcitic Limestone

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

Marl and Refuse Lime

Marl and refuse lime are satisfactory liming materials if applied in conformity with the lime contents and if spread evenly. Many of these materials have settled out of water charged with lime and are very fine in texture and may present some problems in spreading.

Under the Michigan Lime Law, marl and refuse lime materials are sold and guaranteed on the basis of the number of pounds of calcium carbonate equivalent per cubic yard. (This term is explained in the section on effectiveness of lime materials.) Michigan marl averages about 3.5% magnesium carbonate.

Marl and refuse liming materials are sometimes applied on the basis of 2 cubic yards per ton of limestone. However, more than two thirds of the marl now being applied tests between 1,200 and 1,800 pounds calcium carbonate equivalent per yard. This suggests that using a general guide is not the best practice.

LIME LOSS FROM SOIL

Because of lime losses through leaching, crop removal and effects from applied fertilizer, it is impossible to state how long lime will last in the soil. Losses of 400 to 600 pounds of lime per acre per year can be expected under many cash crop systems. When intensive fertilization is practiced, losses may be higher, and soil pH levels may drop rapidly. Limed fields should be retested for soil pH within 3 to 4 years after application.

EFFECT OF FERTILIZERS

Present fertilizer practices increase crop yields and thereby increase the removal of calcium and magnesium. In addition, many fertilizers leave an acidic residue in the soil. Table 8 gives the amount of lime (as pounds of calcium carbonate) required to neutralize the acid formed from one pound of nitrogen for each of the various nitrogen fertilizers.

Table 8 — Amount of lime ($CaCO_3$) required to neutralize the acidity produced by one pound of nitrogen from various sources.

Nitrogen carrier	Amount of lime
	lb Lime/lb N
Ammonium nitrate	1.8
Anhydrous ammonia	1.8
Urea	1.9
Nitrogen solutions	1.8
Ammoniated phosphates	1.9
Ammonium sulfate	5.5

The differences between these sources of nitrogen are not great enough to justify selection of any particular nitrogen source, since the cost of lime is less than the differences in cost of nitrogen sources. However, these effects should be recognized so that lime can be applied when needed.

MICHIGAN LIME LAW

The Michigan Lime Law is a labeling act designed to protect both the user and producer of lime. It requires that all agricultural materials offered for sale within Michigan be licensed with the Michigan Department of Agriculture each year.

With each sale of lime, the purchaser is provided a written statement with the name and address of the person responsible for placing the commodity on the market, the name of the material, the net weight of the lime, the neutralizing value and the percentage of lime passing an 8-, 60- and 100-mesh screen.

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

For participants in agricultural conservation programs, the state ASCS requires ground limestone to have a neutralizing value of at least 80% with 85% passing through an 8-mesh sieve and 25% passing through a 100-mesh sieve. The minimum ASCS requirement for marl is a calcium carbonate equivalent of 800 pounds per cubic yard.

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