LIME for Michigan Soils

COOPERATIVE EXTENSION SERVICE
MICHIGAN STATE UNIVERSITY
Extension Bulletin 471 ● Farm Science Series ● February 1979

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

Need for Lime in Michigan

Long term experiments conducted in Michigan and other midwestern states indicate that agricultural lime applied according to soil tests returns from \$5 to \$10 for every \$1 spent on lime.

A recent soil test summary indicates that the average lime requirement in Michigan is one ton per acre. There are approximately 5.7 million acres of cropland in Michigan. If we assume that lime should be applied once every 3 years, Michigan farmers could profitably apply 1.9 million tons of lime every year. In 1971, approximately 451,600 tons of lime were applied, which is sufficient to correct about two-thirds of the acidity produced by the nitrogen used.

A major hazard of uncorrected soil acidity is that if the plow layer becomes extremely acid, the subsoil also tends to increase in acidity. Subsoil acidity is not easily corrected as deep placement of lime is both difficult and expensive. Downward movement of lime from the topsoil is too slow to be of much help. If the subsoil becomes extremely acid, it will be difficult if not impossible to correct the acidity.

Benefits of Liming

Some of the benefits of liming acid soils:

1. Crop yields are improved.

2. Liming reduces harmful concentrations of aluminum and manganese.

3. Liming increases the availability of nitrogen, phosphorus, potassium, magnesium, calcium, sulfur, boron and molybdenum.

4. All commonly used liming materials supply calcium. Dolomitic materials supply both calcium and magnesium. Both are essential for plant growth.

5. Liming promotes favorable microbial activity which results in an increased availability of soil nitrogen and a decreased loss of gaseous nitrogen from the soil.

6. 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.

7. Liming promotes longevity of legume stands, particularly alfalfa, due to the high calcium requirements of these plants.

The effects of the degree of soil acidity on the availability of plant nutrients in mineral soils are shown in Figure 1. Note that the width of the bar is related to the availability of the nutrient. Crops vary in their tolerance levels for soil acidity and their requirement for high lime levels. The soil pH ranges where crops grow best are given in Table 1. Some plants require strongly acid soils, while others require high lime levels.

Table 1. Permissible soil pH ranges for various crops growing 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

**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.*

Table 2. Tons of limestone estimated from soil pH and texture to raise the pH of a 6⅔ 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.*

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 as positively charged particles or ions. This is called *active acidity*. The degree of soil acidity, known as pH, is a measure of the active hydrogen or acidity in the soil solution. A value below pH 7.0 is acid; pH 7 is neutral; and 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 positive charged ions such as calcium, magnesium, or potassium. These hydrogen ions are part of the *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 water present in the soil to produce hydrogen ions. This aluminum is another source of *potential acidity*.

In a liming program, sufficient lime needs to be applied to neutralize both the *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.

Measuring Lime Needs

Soil pH measures the active acidity of a soil. This measurement is useful for determining whether soils need lime and for making some micronutrient recommendations. Lime needs can be estimated from Table 2 and the soil texture. However, this method only gives an estimate and does not show variations in potential acidity, particularly exchangeable aluminum.

A lime requirement test in the central soil testing laboratory at Michigan State University uses a method called the SMP or Ohio lime requirement method in which both active and potential acidity are measured. This gives a more precise determination of lime requirement than an estimate from soil pH and soil texture. A comparison of this measurement (Lime Index) and Lime Requirement is given in Table 3. Where alfalfa is to be grown, use the recommendations for pH 6.8.

The maximum lime recommendation in any season is 5 tons per acre. The soil should be retested for additional lime needs in two years if the "Lime Index" is less than 6.5.

Methods and Time of Applying Lime

The equipment used for spreading lime should spread the material evenly. Lime will be distributed more evenly by discing 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 crops. 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 best time for this application is in late summer or early fall preceding plowing, rather than in the spring. This reduces the hazard of excess soil packing by spreading equipment.

For potatoes, the soil is generally limed to pH 6.0. If there is no history of scab and if scab-tolerant varieties are grown, consider liming to pH 6.5. The lime application should not exceed two tons per acre at one time, and should be applied immediately following potato harvest. 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.

On established sod (pastures, hayfields) which are not to be reseeded for several years, topdress with lime only if the soil pH is less than 5.8, using not more than 2 tons.

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, less lime per acre, covering more acres, will usually be satisfactory. As a guide, apply one-half the amount suggested in Table 3. For example, for a "Lime Index" of 6.5, apply 2.25 tons of lime; for a "Lime Index" of 6.1, apply 4.0 tons of lime per acre (adjust for plow depth as shown in the footnote of Table 3).

Effectiveness of Lime Materials

A standard is needed when comparing the effectiveness of liming 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 (N.V.) of 98.

The N.V. of liming materials varies above or below "100" as the capacity 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. For example,

Table 3. Tons of limestone needed to raise soil pH of mineral soils to pH 6.5 or 6.8 as determined by the "Lime Index" method.

Lime Index	Tons Lime Per Acre (9" Plow Depth)*	
	to pH 6.5	to pH 6.8
7.0	0.5	1.0
6.9	1.0	1.5
6.8	1.5	2.0
6.7	2.5	3.0
6.6	3.5	4.0
6.5	4.5	5.0**
6.4	5.5	6.0
6.3	6.0	7.0
6.2	7.0	8.0
6.1	8.0	9.0
6.0	9.0	10.0
5.9	10.0	11.0
Below 5.9	11.0	12.0

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

***The maximum lime recommendation for one season is 5 tons. Retest soil in 2 years for additional lime needs if the lime index is less than 6.5.*

Table 4. 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

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.

The lime recommendations given in Table 3 are for a neutralizing value of 90. If the material used has a neutralizing value different from 90, the amount should be adjusted. Figure 2 can be used for this purpose. For example, a material with a neutralizing value of 100 would require 0.9 tons to equal 1 ton of the 90% material. Ground limestone materials sold in Michigan usually range from 80 to 103% calcium carbonate equivalent. Hydrated limestone materials may range as high as 130.

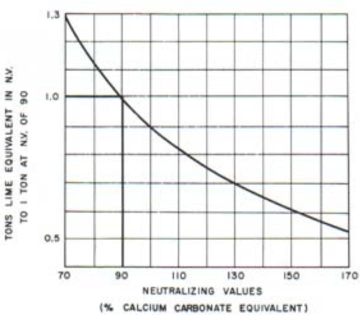

Fig. 2. — Conversion chart to determine amounts of limestone of various neutralizing value (N.V.) that are equivalent to 1 ton lime with N.V. of 90.

Rate of Reaction of Limestone in Soil

Liming materials react at different rates because of their chemical composition, hardness, and fineness to which the materials are ground. The finer a limestone is ground, the more quickly it will react if it is thoroughly mixed with the soil. This is due to the increased surface area with the finer material. Since the fineness of grind can be controlled more easily than chemical composition or hardness, this property usually affects the reaction rate more than the other two. However, Michigan State University research indicates that some softer, more porous calcitic materials will react more quickly than harder, more finely ground dolomitic materials. Figure 3 shows the avail-

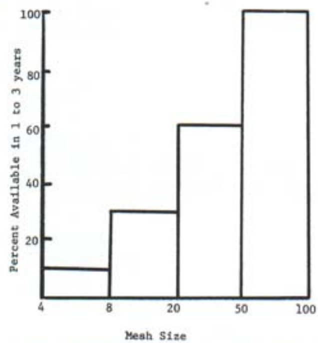

Fig. 3. — The relative availability of ground limestone as influenced by mesh size.

ability of limestone as affected by mesh size (8 mesh is approximately ⅛ inch). It should be emphasized that mesh size comparisons must be made between similar materials.

Limestone should be ground so that practically all the material passes an eight mesh sieve. All the fine material from the grinding should be saved.

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

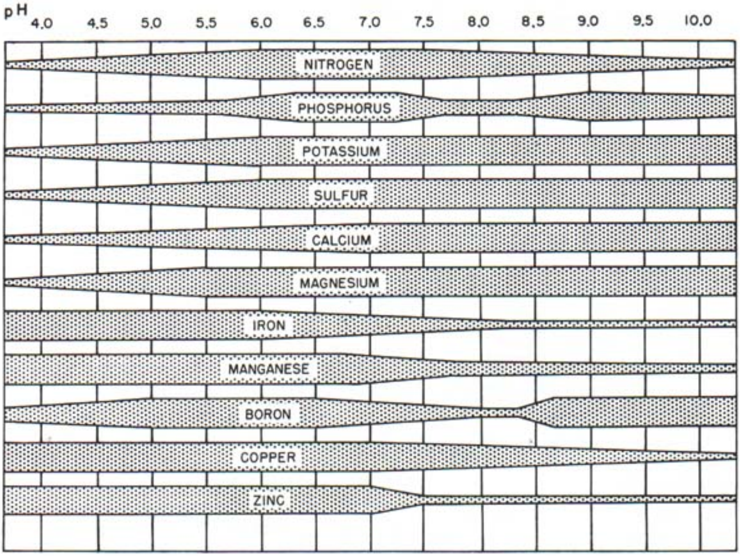

Fig. 1. — The general relation of pH to the availability of plant nutrients in the soil: the wider the bar, the more available is the nutrient. *(Adapted from Emil Truog, USDA Yearbook of Agriculture, 1943-47)*

Present soil 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 bases (calcium + magnesium + potassium expressed as milli-equivalents per 100 grams of soil), potassium exceeds magnesium, or (3) if the soil magnesium (as a percent of total bases) is less than three percent.

On acid soils where magnesium is needed, at least 1,000 pounds of dolomitic limestone should be applied. For further information on magnesium fertilization, see Extension Bulletin 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 percent magnesium carbonate, the remaining 85 to 55 percent being largely calcium carbonate. Practically all of the agricultural hydrate being used in Michigan is made from dolomitic limestone and is called dolomitic hydrate.

In soil test reports and in making recommendations, magnesium is expressed as the element. To convert from the carbonate ($MgCO_3$) to the elemental (Mg) form, the factor is 0.29. For example, a dolomitic

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limestone having 30 percent magnesium carbonate carries 30 percent of 2,000, or 600 pounds magnesium carbonate per ton. Applying the factor of 0.29, there would be 600 × 0.29, or 174 pounds of elemental magnesium per ton. Pure dolomitic limestone would supply 240 pounds of magnesium per ton.

Calcitic Limestone

Calcitic limestone, sometimes called high calcium limestone or calcic limestone, is limestone containing less than five percent 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

Marl and refuse lime 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 and may present some problems in spreading.

Under the Michigan lime law, marl and refuse liming 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 detail in the section on "Effectiveness of Lime Materials"). Michigan marl averages about 3.5 percent magnesium carbonate.

Because of their variability, marl and refuse liming materials 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 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.

Lime Losses from the Soil

Because of lime losses through leaching, crop removal and neutralization of acidity from applied fertilizers, the acidity of the soil is increased and soil pH decreases. It is impossible to state how long lime will last in a soil. Limed fields should be retested in two to four years to check on the change in pH. With the high rates of fertilizer used today, soil pH levels may drop rather rapidly. This suggests the necessity of checking on lime needs frequently.

Under typical cropping, we can expect to lose 400 to 600 pounds of lime per year. Under intensive fertilization, particularly with nitrogen, losses may be even higher.

Table 5. Amount of lime ($CaCO_3$) required to neutralize the acidity produced by one pound of nitrogen from various sources.

Nitrogen Carrier	Soil pH Range*	
	Above 5.5	Below 5.5
	pounds of lime	
Ammonium nitrate	1.8	4– 6
Anhydrous ammonia	1.8	4– 6
Urea	1.9	4– 6
Nitrogen solutions	1.8	4– 6
Ammoniated phosphates	1.9	4– 6
Ammonium sulfate	5.5	11–13

**Note the increased lime requirement when the soil pH drops below 5.5.*

Effect of Fertilizers on Soil Acidity

Present fertilizer practices increase crop yields which increases the removal of calcium and magnesium. In addition, many fertilizers leave an acidic residue in the soil. Table 5 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. Note that when the soil pH falls below 5.5 the amount of lime needed for each pound of nitrogen doubles. Under present fertilization practices, soil pH can be decreased in a very short period of time.

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

The Michigan Lime Law

The Michigan lime law is simply a labeling act. 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 to provide a written statement giving the name of the producer, his address, 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 expressed as pounds of "calcium carbonate equivalent" per cubic yard are to be stated in place of the neutralizing value and screen test.