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LIMING IOWA SOILS
Liming Iowa Soils

By B. J. Firkins

The use of liming materials on acid soils to supply available calcium and correct soil acidity long has been regarded as a basic principle in the Iowa system of soil management. The beneficial effects are associated primarily with the efficient production of legumes in various cropping systems, thereby contributing to the maintenance of soil fertility and conservation of the soil resources. Many of the important agricultural soils in Iowa were originally well supplied with lime, but through leaching, erosion, decomposition processes, removal by crops and the sale of livestock products there has been a gradual tendency for them to become acid.

MOST IOWA SOILS ARE ACID

It has been conservatively estimated that over 75 percent of the soils of the state require liming for the efficient production of alfalfa, sweet clover, red clover and other legumes. The lime requirement is greatest in the eastern and southern sections of the state, including the Carrington-Clyde, Fayette, Clinton-Lindley, Tama-Muscatine and the Grundy-Shelby soils associations. A map indicating the occurrence of these associations is shown on page 472. Frequently found within these sections are areas of level upland, low-lying terrace or bottomland soils which show no immediate need for lime because of the lime which they receive from drainage waters from the surrounding watersheds or underground strata. In general, however, most soils show a need for 2 to 4 tons per acre. In contrast, the need for lime in the areas of the Clarion-Webster and Marshall-Knox associations in north-central and western Iowa, as well as the alluvial bottomlands adjacent to the Missouri River, is not so large. This is due primarily to the presence of much larger supplies of lime in the lower horizons of the soils in these sections. However, an increasing number of tests on samples of upland soils submitted from these areas indicate a need for 1 to 2 tons per acre.
CONSUMPTION IS FAR SHORT OF NEEDS

A recent National Resources Board survey indicates that it would require 3 million tons of limestone annually over a 10-year period to meet the needs on approximately 15 million acres of cropland and pasture land in the state. Table 1 shows the average and yearly consumption of liming materials for the period 1930-1939, indicating that approximately 10 percent of the requirement is being met. The conservation materials program of the AAA, in cooperation with Soil Conservation Service or soil conservation districts, and the educational program of the Extension Service resulted in the use of over 1 million tons for the years 1940 and 1941. This amount is still insufficient to meet the needs and should be increased materially in the future.

**TABLE 1. CONSUMPTION OF LIMING MATERIALS IN IOWA***

<table>
<thead>
<tr>
<th>Year</th>
<th>1930</th>
<th>1931</th>
<th>1932</th>
<th>1933</th>
<th>1934</th>
<th>1935</th>
<th>1936</th>
<th>1937</th>
<th>1938</th>
<th>1939</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>350</td>
<td>228</td>
<td>142</td>
<td>121</td>
<td>177</td>
<td>224</td>
<td>908</td>
<td>432</td>
<td>240</td>
<td>399</td>
<td>321.6</td>
</tr>
</tbody>
</table>

*Data from National Lime Assoc. Reports

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Looking to the future it seems very apparent that profitable farming will depend more than ever upon efficiency of production of adapted crops which are required for feed, conservation and soil improvement. The production of grain crops and legumes on soils maintained at a high level of fertility, the improvement in the carrying capacity of pastures and the protection of erodible soils against the destructive forces of erosion are fundamental to the future prosperity of Iowa agriculture. The accomplishment of these objectives will depend in very large measure on the degree to which the following benefits of liming are realized.

**BENEFITS OF LIMING**

1. Neutralizes soil acidity, resulting from the loss of lime by leaching, crop removal, etc.

2. Supplies available calcium to plants and animals. Lime is a direct source of calcium for building up plant tissues. Legumes in general require larger amounts of calcium than other crops in the rotation. Through the consumption of pasture grasses, forage crops and feed grains, animals derive the calcium needed to form bones and to develop normally.

3. Stimulates desirable biological action. Important groups of microorganisms are responsible for the decomposition of organic residues in soils and the release of nitrogen in available forms. Others, bringing about nodulation of legume crops or living independently in the soil, are capable of fixing atmospheric nitrogen. Since these organisms are generally sensitive to soil acidity, liming makes conditions more favorable for their reproduction and activity.

4. Increases the availability of mineral nutrient elements in the soil. Part of the beneficial results of liming may be due to liberation of soil phosphorus by chemical and biological action.

5. Increases the efficiency of manures and fertilizers. High soil acidity coupled with poor drainage, poor tilth or other adverse soil conditions minimizes the
returns from farm or green manures and commercial fertilizers.

Several or all of these beneficial effects may operate in the soil at the same time.

**LIME PAYS ON ACID SOILS**

The data presented in table 2 are based on the results from 51 cooperative field experiments on the major acid soils of the state over a period of 15 to 20 years. Limestone was applied at varying rates sufficient to neutralize soil acidity. Assuming that it costs 50 to 75 cents a year to keep the soils neutralized, the value of the crop increasing at normal prices has returned a large profit on the investment in liming materials. Much larger increases than those shown in the table are often obtained, especially with legumes on soils lower in fertility.

**TABLE 2. RESPONSE OF SOME IOWA SOILS TO LIME.**

<table>
<thead>
<tr>
<th>Crops</th>
<th>No. of crops</th>
<th>Manure</th>
<th>Lime and manure</th>
<th>Increase for lime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>255</td>
<td>58.5</td>
<td>63.5</td>
<td>5.0 bu. per acre</td>
</tr>
<tr>
<td>Oats</td>
<td>131</td>
<td>48.9</td>
<td>52.6</td>
<td>3.7 bu. per acre</td>
</tr>
<tr>
<td>Wheat</td>
<td>22</td>
<td>25.5</td>
<td>28.9</td>
<td>3.4 bu. per acre</td>
</tr>
<tr>
<td>Mixed hay</td>
<td>94</td>
<td>1.4</td>
<td>1.7</td>
<td>.3 ton per acre</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>11</td>
<td>1.2</td>
<td>2.7</td>
<td>1.5 ton per acre</td>
</tr>
</tbody>
</table>

**USE SUFFICIENT LIME TO GROW LEGUMES EFFICIENTLY**

There is a wide variation in the demands of plants for calcium and in their tolerance toward soil acidity. A partial grouping of crops according to their tolerance toward acidity is shown in table 3. The sensitive crops are those which may be expected to respond most to lime. Slight acidity may not be particularly harmful, but it is advisable to maintain the soil reaction close to neutral. The most tolerant crops may show less response to lime, but it should be kept in mind that lime is essential for the efficient production of all crops on extremely acid soils. Therefore enough lime should be used in the rotation to satisfy the needs of the least tolerant crop to acid soil conditions.

The major considerations involved in determining a de-
sirable liming policy are (1) the crops to be grown, (2) the reaction of the soil, (3) the soil type and (4) depth to subsoil layer containing lime. Generally speaking, when the requirements for calcium have been met for the legume crops in the rotation, there is sufficient for the other crops. The reaction of the soil should be maintained at such a level as to permit efficient growth of desirable crops and permit normal biological action to proceed.

**TABLE 3. GROUPING OF PLANTS ACCORDING TO TOLERANCE OF SOIL ACIDITY**

<table>
<thead>
<tr>
<th>Least tolerance (highest lime requirement)</th>
<th>Medium tolerance (medium lime requirement)</th>
<th>Greatest tolerance (lowest lime requirement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field crops and grasses</td>
<td>Truck crops and fruits</td>
<td>Field crops and grasses</td>
</tr>
<tr>
<td>alfalfa</td>
<td>asparagus, beets, cauliflower, celery, leek, lettuce, muskmelon, onion, parsnip, rutabaga, salsify, spinach, squash</td>
<td>aslike cl., bluegrass, corn, crimson cl., mammoth cl., orchard gr., rape, red clover, soybeans, sudan grass, timothy, wheat, white cl.</td>
</tr>
<tr>
<td>sugar beets</td>
<td>field crops and grasses</td>
<td>cabbage, cantaloupe, carrot, chard, cucumber, eggplant, endive, garden peas, gooseberry, grape, kale, kohlrabi, lima beans, parsley, pepper, pumpkin, radish, raspberry, rhubarb, snap beans, sweet corn, sweet pot, tomato, turnip</td>
</tr>
<tr>
<td>sweet cl.</td>
<td>truck crops and fruits</td>
<td>bent grass, buckwheat, fescue, flax, lespedeza, millet, oats, redtop, rye</td>
</tr>
</tbody>
</table>

*The above list has been restricted to those economic crop plants and grasses grown in the state. A recent publication (Sp. Bul. 306, Mich. St. Col., East Lansing, Mich.) gives the reaction preference of a very extensive list of plants including flowers, shrubs, and trees.*

Although soil reaction is considered a major factor in good soil management practices, there are many other important factors of plant growth acting in conjunction with it which may also need adjustment and cannot be neglected. Best crop growth is obtained with the most favorable coincidence of all the factors of plant growth.
TESTING SOILS FOR LIME NEEDS

Soil testing may be done locally by county agents or vocational agriculture instructors; or samples may be sent directly to the Soils Department at Iowa State College where they will be tested without charge.

If the tests are to be of value, the samples should be taken so that they are representative of the area in question. It is also important that the person who is to make recommendations for treatment has a knowledge of the soil type characteristics, crops to be grown and past liming treatments. Samples may be obtained with a spade, trowel or auger. After scraping away all trash, a clean hole should be dug to permit taking samples to plow depth. At least 10 such samples should be taken from various parts of the field, thoroughly mixed together, and \( \frac{1}{2} \) to 1 pint of this composite sample saved for testing. In case different parts of the field have received different treatments in the past, have different kinds of soil or reveal differences in plant growth, one composite sample should be taken from each part. The samples should be placed in clean sacks or other containers and clearly labelled by letter or number, and a record should be kept of the location of each sample. After air-drying (do not heat on a stove or in an oven) they are ready to be submitted for testing.

SOIL ACIDITY AND LIME REQUIREMENT

Soil acidity or reaction can be tested by a number of different methods, some being much more accurate than others. The Iowa testing solution has been used for many years as a general field and laboratory method of measuring the approximate lime requirement of soils in terms of tons of pure ground limestone required to neutralize the soil. The intensity of the red color of the solution after coming into contact with an acid soil is due to the reaction of soluble iron and the chemical (potassium thiocyanate) dissolved in the testing solution. Other methods employed in the field and laboratory involve the determination of the pH of the soil.

Soil acidity denotes a deficiency of the basic elements,
calcium and magnesium. As these elements are leached out, hydrogen replaces them in the clay or colloidal complexes in the soil, causing an acid reaction in the soil solution. The most common method of measuring soil reaction depends on the determination of its concentration of the hydrogen ions expressed as pH. Figure 2 shows the pH scale, with pH 7.0 representing the neutral point or dividing line between acidity and alkalinity. Values below 7.0 denote increasing acidity, whereas those above 7.0 denote increasing alkalinity.

The numbers on the scale or the pH values are logarithmic values and do not refer to amounts of liming material needed to correct acidity. From these pH values and a knowledge of the texture and organic matter content of soils, however, it is possible to estimate the amount of lime required to correct the acidity of the soil. Thus when an acid soil is limed, the pH value will be raised, and if enough lime is added to correct all the soil acidity, the pH value will be 7.0.

It is known that the higher the content of organic matter or colloidal materials in soils, the greater amount of lime is necessary to change the reaction of a given pH range. Thus the reaction or pH of sandy soils can be changed with the smallest applications of liming materials. It requires progressively more for loams, silt loams, silty clay loams and clays, due to increasing colloidal content. An increase in organic matter content would have the same effect.
SOURCES OF LIMING MATERIALS IN IOWA

Fortunately there are unlimited quantities of lime in the state which are readily accessible at relatively low cost. The major deposits likewise are located in the areas of the state where the problem of soil acidity is more acute. A recent survey of producers indicates that a large percentage of the material is delivered within a radius of a few miles of the source by truck and that the amount delivered by rail has been constantly decreasing. Due to the opening up of many privately owned quarries, the operation of county or community crushers under the County Limestone Act, Ia. H. F. 147, 1937, and the increased emphasis on the value of liming, much more ground agricultural lime undoubtedly will be used in the future than has been used in the past.

The various kinds of liming materials are as follows:

1. Ground Agricultural limestone—containing varying proportions of coarse and fine material according to specifications.
2. Screenings from:
   a. Building and road bed materials—coarser materials used for construction, roadbeds or surfacing; finer screenings for agricultural use.
   b. Cement plants—finer material used for manufacture of cement; coarser materials crushed or screened for agricultural use.
3. Water purification sludges from railroads, cities or towns; extremely variable in purity and water content.
4. Beet sugar sludge "lime cake"; generally higher in purity than water purification sludge but variable in physical condition and water content.
5. Button dust—available in limited quantities in poor physical condition.
6. Slaked or hydrated lime and burned lime, used primarily in the building trade. These forms are too high in price to compete with the other forms for agricultural use.

There is extreme variability in the neutralizing value of the limestones occurring in the state. Most of the deposits are principally calcic limestone, while others may contain...
variable amounts of magnesium carbonate (dolmitic limestones) or consist essentially of calcareous shales, extremely variable and generally lower in quality.

**FACTORS GOVERNING THE VALUE OF LIMING MATERIALS**

The two main properties that govern the efficiency or determine the value of liming materials are total neutralizing power and fineness. Producers of agricultural lime should furnish a statement of analysis to the consumer who should purchase on the basis of the above named properties.

The purity or neutralizing power of liming materials is expressed in terms of total calcium carbonate equivalent.

**NEUTRALIZING POWER OF CHEMICALLY PURE MATERIALS**

- Calcium carbonate or calcium limestone - 100
- Calcium oxide—burned lime (quicklime) - 179
- Calcium hydroxide (hydrated lime) - 135
- Calcium-magnesium limestone (dolomitic limestone) - 109

The loss of carbon dioxide in making burned lime, the addition of water to calcium oxide to make hydrated lime and the presence of magnesium in the dolomitic stones are responsible for the differences in neutralizing power. This means that it would require approximately 1,120 pounds of burned lime, 1,480 pounds of hydrated lime or 1,840 pounds of dolomitic limestone to equal the neutralizing value of 2,000 pounds of pure calcium carbonate.

Whenever the purity tests fall below 80 percent total calcium carbonate equivalent, the costs involved in handling the large percentage of impurities are generally too great to make it economical to use such low grade materials. It is a distinct advantage to use only high-analysis lime, unless the price is adjusted to make the use of the lower grade materials economical.

**FINENESS OR SCREEN TEST**

Liming materials applied to soils do no good until they dissolve, principally through the action of carbonated water. The coarser the materials used, therefore, the lower the rate
of solubility and the slower they act to neutralize soil acidity. The reaction between limestone and soil depends upon the diffusion of the dissolved calcium from the particles into the soil. Since the rate and distance of this diffusion determines the effectiveness of the material in neutralizing the acidity in the soil mass, the larger the number of particles of small size the greater the speed of neutralization and the smaller the area to be neutralized by each particle. Figure 3 by E. E. DeTurk of the University of Illinois illustrates the point very well. In evaluating limestones, therefore, on the basis of fineness, the particles retained on 8- to 10-mesh screens are of very little immediate benefit.

In the basis of the effectiveness of the different sized particles in relation to crop growth and rate at which the limestone disappeared or neutralized soil acidity a "screen fineness" score card has been devised to evaluate limestone in Illinois. A factor is assigned for each fraction of material retained on different screens and passing a 100-mesh screen. The sum of the products of the factor times the percent of material in each fraction equals the screen fineness.

On the basis of their investigations, W. H. Pierre and G. G. Pohlman reported that material failing to pass a 20-mesh screen has relatively little value in correcting soil acidity during the first few years after application. Material passing through 20- and 60-mesh screens, respectively, were increasingly more efficient as shown in table 4.

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Fig. 3. Cubic inches of soil each particle must neutralize.

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1Ill. St. Geol. Survey, Cir. 23-D. 1938.
TABLE 4. RELATIVE AVAILABILITY OF LIMESTONE PARTICLES OF DIFFERENT DEGREES OF FINENESS.

<table>
<thead>
<tr>
<th>Fineness of particles</th>
<th>Percent available within 1-3 years</th>
<th>Percent available within 8-12 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Held on 20-mesh screen</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Passed 20-mesh screen but</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>held on 60-mesh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passed 60-mesh screen</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Taking into consideration the percentage of the limestone available in 1 to 3 years, the amount of material retained on or passing the different mesh screens and the neutralizing value, the net value of the limestone can be determined. Assuming certain lime requirements in terms of pure, finely ground limestone for different crops, the equivalent tons of any limestone also may be calculated.

Regardless of the procedure employed in determining the efficiency of various liming materials, it is very apparent that more recognition should be given to the percentage of fine material. It must be remembered, however, that there is a point beyond which finer grinding is no longer economical. The increased costs of finer grinding must be considered in connection with the value of the benefits derived. Where 90 percent or more of the ground material passes through a 10-mesh sieve, a reasonably high percentage will usually be dust (finer than 40-60 mesh) and will be effective during the first 1 to 3 years. The remainder will gradually become available and will help during a longer period of time in maintaining the reaction at a desirable level and in supplying available calcium.

**RATES OF APPLICATION**

As brought out in the preceding discussion, the amount of liming material to apply is governed largely by the acidity of the surface soil, the requirements of the crops grown in rotation and the purity and fineness of the liming material used. Reference to table 3 indicates that the legumes, especially sweet clover and alfalfa, require the largest amount
of available calcium. Meeting the requirements of these crops will be beneficial to the other crops in the rotation. If lower analysis or somewhat coarse liming materials are used, larger applications should be made, since the lime requirement determinations and recommendations are based on the amount of pure, finely ground limestone or its equivalent. On soils showing a medium to strong acidity, $2\frac{1}{2}$ to 3 tons per acre of pure limestone or its equivalent are usually adequate. When tests indicate slight to medium acidity, $1\frac{1}{2}$ to 2 tons are generally sufficient, and if there is free lime in the sub-surface the application may be reduced to 1 to $1\frac{1}{2}$ tons. Where seeding mixtures for pasture improvement include alfalfa and sweet clover, the same rates of application should be recommended as for field soils. If the vegetation consists essentially of other clovers, bluegrass and redtop, the application may be reduced due to the lower lime requirement or the greater acid tolerance of the plants and the shallower penetration of the root systems.

Very often it has been found that soils which have been limed in accordance with lime requirement recommendations still show considerable acidity after 1 to 2 years. Since the recommendations are made on the basis of pure calcium carbonate, the use of low-grade or impure limestone might be the reason, for its solubility would be low, and only a small amount of material would be effective in so short a time. Another reason for such a condition is that where the soils are strongly acid the recommendations generally made do not call for sufficient lime to neutralize the soil but are based on immediate calcium needs of the crops to be grown. If approximately 75 percent of the total acidity of the soils is neutralized, however, there should be no serious difficulty in growing alfalfa or other high-lime-requirement crops.

In view of the above statements it is important to carry on a systematic liming program, checking the soil reaction after each rotation whenever clovers or alfalfa are seeded.

**TIME OF APPLICATION**

Since lime applications are determined very largely by the requirements of the legume crop in the rotation, the guiding
principle is to get the lime onto the land long enough ahead of the seeding to be effective. Provision for thorough mixing with the soil is another important consideration.

**SPRING**

The application of ordinary quarry-run limestone at the time of preparing the land for seeding is not advisable. This practice does not allow sufficient time for the material to correct acidity. If the situation is unavoidable, however, the use of very finely ground material or higher rates per acre is essential and may bring about fairly satisfactory results if moisture conditions are favorable. It would be better, however, to apply the lime on spring-plowed corn ground to be seeded the next year. Application before disk ing, planting or even after the corn has been planted and is up will allow 9 to 10 months for the lime to become available.

Although the rush of spring work and poor conditions of fields and roads for heavy hauling may be serious handicaps, the practice is becoming more popular over the state, and the results are most satisfactory.

**SUMMER AND FALL**

Liming just ahead of late summer seedings of alfalfa does not allow sufficient time for the material to become effective. It may be applied to better advantage on bean ground to be followed by wheat and seeded the following spring. The application should be made prior to planting beans where the ground is to be disked before seeding wheat in the fall, in order to allow more time for solution. Occasionally corn ground, cut for shock corn or silage, is available for fall-seeded wheat, and the lime may be applied the same way as when following beans. Fall application of lime is particularly applicable to pasture land in preparation for reseeding in the spring with legumes. Since permanent pastures are often on rolling land, if the lime is not to be lost by washing, it is very important that it be disked into the soil in the fall with at least one or two diskings on the contour.

**WINTER**

The possibility of bad weather conditions interfering with hauling and spreading, and the poor physical condition of
the lime due to lack of protection against the elements, often make winter distribution hazardous or impossible. There is also danger of loss by erosion in the early spring on rolling or steep land. Winter applications, therefore, should be restricted to materials in excellent physical condition on level to gently undulating land.

METHODS OF DISTRIBUTION

Commercial lime spreaders or distributors of the trailer or endgate types are available at reasonable cost. Most models are equipped with suitable agitators which permit the spreading of materials containing considerable moisture. Rental of spreaders from producers, local dealers, county associations or other agencies often helps solve the distribution problem in many communities. Truckers also frequently furnish a spreader and charge for distribution at a very nominal rate.

In the absence of better equipment, a manure spreader is often used to distribute limestone, but since the machine was never designed and constructed to serve the purpose, the practice is not to be generally recommended. It would be satisfactory, however, for wet sludge lime. The main objectives are to get uniform distribution and to work the liming material into the surface soil in contact with moisture. The lime particles must come into close contact with the soil in order to neutralize the soil acids. Thorough disking and cultivation help in mixing the lime with the soil but will not overcome poor distribution. Therefore, to avoid poor streaks or patches in legume stands the distribution of the lime should be as uniform as possible.