Limestone

The key to soil building and higher crop yields

By C.M. Linsley

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COLLEGE OF AGRICULTURE AND AGRICULTURAL EXPERIMENT STATION
CIRCULAR 375
LIMESTONE LOSSES FROM ILLINOIS SOILS MUST BE REPLACED IF CROP YIELDS ARE TO BE INCREASED OR EVEN MAINTAINED

This familiar type of spreader is sometimes equipped with a stub tongue so that it can be pulled behind the loaded wagon. On plowed land, two teams are necessary to pull the loaded wagon and spreader, and an extra man is required on the wagon to keep the spreader filled. Pages 28-31 give further information about methods of unloading and applying limestone.

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Limestone the Key to Soil Building and Higher Crop Yields

By C. M. LINSLEY, Assistant Chief in Soils Extension

LIMESTONE is the key to any successful soil-building program for the acid soils of Illinois. Such soils need clovers and clovers will not thrive without limestone. These facts have long been recognized; they are based on the experience of hundreds of farmers as well as on scientific investigation. (The word "clovers" in this discussion is used in the general sense to designate red, alsike, mammoth, and sweet clover, and even alfalfa, which possesses soil-building power similar to that of the clovers.)

There are still many farmers, however, who have not put their knowledge about limestone into practice; others are not wholly convinced of the necessity or advantage of liming; others have not learned how to recognize an acid soil. The facts and figures presented in this circular it is hoped will be the means of interesting many more farmers in this essential step in building up or maintaining the fertility of their soils and increasing the acre-yields of all their crops.

Rapid Increase in Use of Limestone

That Illinois farmers are rapidly becoming convinced that farming acid land is poor business is shown by the fact that they have used more than 5 million tons of limestone during the past ten years. These figures include only the limestone sold by commercial producers. In addition a large tonnage produced by local limestone quarries is used each year.

Evidently Illinois farmers can and are raising money to buy limestone. They realize that during a period of low prices it is more important than ever to produce good crop yields if taxes, interest, labor costs, and other expenses are to be met and a living wage obtained in return for their labor and management. In many cases it is either a question of liming the land and growing higher crop yields or quitting the farm.

Land Needs Clover

The greatest immediate need of most Illinois soils is nitrogen and active organic matter. Years of cropping without clovers have gradually reduced the supply of these materials and the result has been that crop yields have declined year by year.
In spite of hard times Illinois farmers increased their purchases of limestone from 300,000 tons in 1920 to 925,000 tons in 1929. This was the largest tonnage yet used in Illinois in a single year.

Large amounts of nitrogen are annually removed in crops and carried away in drainage water. A 50-bushel crop of corn, for example, takes from the soil, for grain and stalks, 75 pounds of nitrogen. Drainage water may carry away 100 pounds or more in addition. These losses must be replaced if good yields are to be maintained.

In the spring of the second year, a good growth of sweet clover often contains in the tops and roots 150 pounds or more of nitrogen to the acre. This is as much as is carried in 15 tons of average farm manure or as is contained in a 100-bushel crop of corn.
Fortunately there is an unlimited supply of nitrogen in the air, which can be used to replace this constant drain. Every clover plant properly inoculated gathers from this free supply approximately two-thirds of the nitrogen it takes up. Thus when properly inoculated clovers are plowed under or are fed and the manure returned to the soil, large quantities of nitrogen are added at comparatively small cost.

In addition to nitrogen, clovers also contain phosphorus, potassium, and other plant foods. These they take from the soil. Then as the clover plants decay, these elements are released in forms that are readily available for the grain crops that follow.

Furthermore clovers supply large amounts of active organic matter. Not only does this organic matter improve tilth, but it also supplies food for certain soil organisms which help to convert plant-food materials locked up in the soil into forms available for the grain crops that follow.

Thus clovers perform three distinct services in a soil-building program.

**Clover Needs Limestone**

Unfortunately most Illinois land is too "acid," or "sour," to grow clover crops successfully. Many farmers have stopped sowing clovers altogether, repeated failures having taught them that they are only wasting their seed. Others, in spite of repeated failures, continue to sow a field of clover every year. If their soil is not too acid and the season is favorable, they may get a fair crop; but in the usual season, when it turns hot and dry after harvest, the clover burns out. The unfavorable season, therefore, often
receives all the blame. While it is true that weather conditions have much to do with the success or failure of the clover crop, the real cause of many failures is an acid soil.

Even in a single field, differences in the growth of clover may be due simply to differences in soil acidity in different locations in the field. It is a common sight in central and northern Illinois to see a field seeded to sweet clover in which there

is a good growth on the lower land and no clover at all, or at best only a few scattering plants, on the higher land. The seed was sown at the same time, exposed to the same hot, dry weather after harvest, and to the same freezing and thawing in the winter. A test of the lower land will almost invariably show that it is “sweet”—in other words, that it still contains plenty of limestone for a vigorous growth of sweet clover—while a test of the higher land will show that it is acid. The strong vigorous clover plants on the lower land have been able to withstand the weather hazards, while the weaker plants on the acid soil of the higher land have succumbed.

How soil acidity affects the growth of clover is clearly demonstrated on the University of Illinois experiment fields. On the
medium-acid soils in central and northern Illinois red clover is seeded on both limed and unlimed plots. Even in unfavorable seasons the red clover will come thru with a good stand and produce a good crop of hay on the limed plots, while on the adjoining unlimed plots it will either die out entirely or produce only half a stand. In the most favorable seasons, when both limed and unlimed plots show good stands, the limed plot often produces half a ton to a ton more hay to the acre than the unlimed plot.

![Sweet CloverSeedersted on Acid Land](image)

FIG. 5.—SWEET-CLOVER SEED WASTED ON ACID LAND
At the left, no limestone was applied. No limestone meant no sweet clover. (LaSalle county)

Sweet clover seeded on limed and unlimed plots shows even more striking differences than red clover, for sweet clover will seldom grow on soils that are even slightly acid. Where the soil is medium-acid, unlimed plots seldom produce more than a few scattered plants; on limed plots a good stand and a heavy growth are produced.

On the more acid soils of southern Illinois limestone means the difference between a good crop and a failure, whether the crop is red clover or sweet clover. Even in the most favorable seasons soils in southern Illinois, with the exception of some bottom land and "slick" spots, are too acid to grow red clover, sweet clover, or alfalfa without limestone.

**Does Limestone Pay? Farmers Say It Does**

This question is answered in the affirmative, not only by years of careful experimentation but by the experience of farmers as well. In all sections of the state worn, acid soils have been transformed into fertile, high-producing land by the limestone-clover combination. Some farmers have left unlimed strips thru their fields in order to find out
for themselves whether limestone is a paying investment on their farms. They have kept records of their yields and know definitely how much their limestone applications have been worth to them.

On a farm in Morgan county, central Illinois, an application of limestone and a crop of sweet clover plowed under increased corn yields 35 bushels an acre in 1928 and 25 bushels an acre on the same field in 1929. When the first carload of limestone was applied in 1926, an unlimed strip was left thru the middle of the field. Sweet clover

![Image of corn field]

**Fig. 6.—Good Soil Treatment Including Limestone Promotes Early Growth and Maturity**

Corn like that growing on the treated land to the left, where limestone, manure, and rock phosphate were applied, is less likely to be damaged by either drouth, wet weather, or early frost than is corn such as shown on the untreated land to the right. Thus better quality of corn, as well as higher yields, results from good soil treatment. Left—75 bushels to the acre; right—38 bushels. (Dixon field)

was seeded on the entire field in the spring of 1927. No clover grew on the unlimed strip; on the rest of the field, where limestone had corrected the acid condition, a heavy growth was produced. This crop of sweet clover was plowed under in the spring of 1928 and the field planted in corn. The corn that year made over 70 bushels an acre on the limestone-sweet-clover land, while only 35 bushels of poor-quality corn were produced on the untreated land. This same field was planted in corn again the following year. Where sweet clover had been plowed under, the yield of corn was 55 bushels an acre; the yield on the untreated strip was only 30 bushels.

Thus an application of 3 tons of limestone an acre and one sweet-clover crop produced in the two corn crops an increase of 60 bushels
an acre. Since this one application of limestone will probably last at least ten years, increases in clover and grain crops on this farm can reasonably be expected for several years to come without any further investment in limestone.

The owner of this farm says that in addition to these higher yields, the corn on the limestone-sweet-clover land grew more rapidly than that on the untreated strip, and was at least 18 inches higher at the time it was laid by. The difference in the quality of the corn was also outstanding. Good, sound corn was produced where sweet clover was plowed down, while the corn on the untreated strip did not mature and was poor in quality.

Judge C. W. Raymond, of Iroquois county, northern Illinois, began using limestone fifteen years ago. In order to demonstrate to his tenants what limestone would do for acid soils, he left a 2-rod unlimed strip thru the middle of one of his fields. He has seeded sweet clover on this field several times since the limestone was applied, and altho he seeds across the unlimed strip he has never been able to get a stand there. The limed land has always produced a good crop of sweet clover which is plowed under in the spring for corn. According to Judge Raymond, the limed land that has grown sweet clover has averaged 70 bushels of corn to the acre while the untreated strip has never produced more than 40 bushels. The corn on the limestone-sweet-clover land also makes more rapid growth, matures earlier, and is of better quality than that on the untreated strip. Judge Raymond says that a farmer cannot afford to farm unless he applies limestone to his acid land so that clovers can be grown.

J. D. Stice, of Warren county, northern Illinois, spread 660 tons of limestone on his farm during the summer of 1929, a total of 13 car- loads. A demonstration on Mr. Stice’s own farm showed him that he could not afford to farm acid land. Fifteen acres of a 35-acre field were thin land on higher ground and had always produced a much smaller corn crop than the remaining 20 acres of lower land. Limestone and sweet clover were recommended by the farm adviser as a soil-building combination for the poorer 15 acres. A test of the soil showed that 3 tons of limestone to the acre was needed before sweet clover could be grown. After these 15 acres were limed and sweet clover plowed under, the corn crop made 30 bushels more to the acre than the crop on the 20 acres that previously had been the more productive.

Edwin Hoffman, of Monroe county in southern Illinois, started with his first carload of limestone eight years ago and since then has applied limestone to all his fields. Mr. Hoffman’s farm is located on
the thin, acid timber land of southern Illinois. Four years ago, when he limed a 26-acre field, he left a 2-rod strip unlimed. He then sowed wheat on the field and seeded sweet clover in the wheat. Mr. Hoffman had this to say about the effect of limestone on this field: "A slight difference could be noted in the wheat crop the first year. A fair stand of sweet clover was secured except on the unlimed strip. The clover stood over a year and the ground was plowed for corn. The corn crop made 60 to 65 bushels to the acre; the unlimed strip was good for about 5 bushels. Wheat followed this corn, with as distinct a difference in it as in the corn crop. The wheat on the unlimed strip was too low to catch with the binder."

An untreated strip in the middle of a limed field on the farm of C. F. Barlemeyer, of Washington county, southern Illinois, further demonstrates the value of limestone on the acid land of the southwest section of the state. In 1928 when this field was in sweet-clover pasture, scarcely a sweet-clover plant could be found on the untreated strip, while the rest of the field produced a heavy growth. The sweet clover was plowed under for wheat in the fall of 1928. The following year the wheat made 25 bushels to the acre on the limestone-sweet-clover land and about 10 bushels on the untreated strip.

A. M. Spitznass, Williamson county, began his liming program twenty-two years ago and since then has limed his entire farm of 260 acres. According to Mr. Spitznass, this land before it was treated produced about 12 bushels of corn to the acre and 10 bushels of wheat. Limestone and sweet clover have put new life into this soil. It now produces 40 to 50 bushels of corn to the acre and between 20 and 40 bushels of wheat. Mr. Spitznass used his forty-second car of limestone last year. Hundreds of Illinois farmers who have used limestone and grown sweet clover have secured similar results.

These farmers are all feeding limestone to sweet clover, and the sweet clover in turn is feeding the corn and small grain crops that follow.

The cases cited above are not unusual. These men are only a few of the farmers in the state who have left unlimed strips in their fields so they might know with certainty what the soil-building combination of limestone and sweet clover would do on their farms.

Limestone-Clover Gains on Experiment Fields

Limestone and sweet clover on the University of Illinois soil experiment field at Clayton, in Adams county, central Illinois, have increased corn yields 13.7 bushels an acre, oats 10.2 bushels, wheat 7.8 bushels, and red clover approximately \( \frac{3}{4} \) ton as an average for the
four years 1927 to 1930. These increases have been worth $10.78 an acre a year. Applying more recent prices, there is still an increase of $8.53 for limestone (Table 1).

The limed plot on the Clayton field received 4 tons of limestone when the field was started in 1912. Further applications were made until, over a period of seventeen years, a total of 8 tons an acre had been applied. This is equivalent to about half a ton an acre a year. Thus each half-ton of limestone, costing about $1, has returned $10.78 in increased yields.

**Table 1.** Effect of Limestone on Clayton Soil Experiment Field, Adams County, 1927-1930

<table>
<thead>
<tr>
<th>Soil treatment</th>
<th>Wheat</th>
<th>Corn</th>
<th>Oats</th>
<th>Red clover</th>
<th>Sweet-clover hay</th>
<th>Average annual acre value of crops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bu.</td>
<td>bu.</td>
<td>bu.</td>
<td>tons</td>
<td>tons</td>
<td></td>
</tr>
<tr>
<td>Limestone</td>
<td>32.5</td>
<td>59.7</td>
<td>55.4</td>
<td>1.60</td>
<td>1.24</td>
<td>$32.53</td>
</tr>
<tr>
<td>No limestone</td>
<td>24.7</td>
<td>46.0</td>
<td>43.2</td>
<td>0.89</td>
<td>0.10</td>
<td>$21.75</td>
</tr>
<tr>
<td>Increase for limestone</td>
<td>7.8</td>
<td>13.7</td>
<td>10.2</td>
<td>0.71</td>
<td>1.14</td>
<td>$10.78</td>
</tr>
</tbody>
</table>

Note.—Red clover yields include only the first crop; the second was plowed down on both plots.

1The prices used in this column in figuring the value of the crops are the December 1 farm price for corn and September 15 farm prices for wheat, oats, and clover hay for each year of the four-year period. The averages of these prices are: wheat, $1.10; corn, 69¢; oats, 37¢; clover hay, $13.40.

2The prices used in this column in figuring crop values are the December 1 farm price for corn and September 15 farm prices for wheat, oats, and clover hay for 1930; namely, wheat, 80¢; corn, 62¢; oats, 34¢; and hay, $13.20.

Sweet clover has been an important factor in making limestone a profitable investment on this field. The limestone corrected the acidity of the soil so that sweet clover could be grown, and sweet clover in turn supplied the much needed nitrogen and organic matter for the grain crops that followed. The soil on this field is medium acid and will not grow sweet clover successfully without limestone.

On the more acid soils of southern Illinois limestone has been worth even more than in central and northern Illinois. On the Toledo experiment field in Cumberland county it has made a difference in clover between a good crop and no crop at all. Limestone and clover together have increased corn yields 15.9 bushels an acre, oats 9.7 bushels, and wheat 11.2 bushels. The rotation practiced is wheat, corn, oats, and mixed clover hay, with sweet clover seeded in the wheat and plowed under the following spring as green manure for corn.

The apparently smaller increases resulting from the use of limestone and sweet clover on the Clayton soil experiment field as compared with increases obtained by farmers are due to the fact that on that field the second crop of red clover and a sweet clover catch crop are plowed down on the unlimed plot. Altho the soil on the unlimed plot is acid, fair crops of red clover are grown and in favorable seasons half crops of sweet clover.
FIG. 7.—THIN, ACID LAND IN SOUTHERN ILLINOIS RESPONDS TO LIMESTONE

On the lower field limestone was applied and sweet clover plowed under as a green manure. Limestone corrected the soil acidity so that sweet clover could be grown, and sweet clover in turn supplied the corn crop with the needed plant food. The upper picture tells the story of no lime. (Newton field)

On this field limestone and sweet clover have been worth almost as much as the land itself in producing crops, the value of the crops grown on the unlimed plot having averaged $11.47 an acre a year and on the limestone-sweet-clover plot $21.60 a year, which is an increase of $10.13 an acre a year. Based on 1930 prices, there is still an increase of $9.24 (Table 2). The cost of the limestone that brought about this increase has been about $1 an acre a year.

Most of the land in southern Illinois is as strongly acid as the soil of the Toledo experiment field and, unless it lies so nearly level as to
have practically no surface drainage or underdrainage, it should respond to liming as does this soil. Because of a tight subsoil and consequently poor drainage, some of the flat areas are limited in their ability to produce crops. While on these areas limestone and clover will produce increases that are large in proportion to previous yields, production at best is low.

### Table 2.—Effect of Limestone on Toledo Soil Experiment Field, Cumberland County, 1927-1930

<table>
<thead>
<tr>
<th>Soil treatment</th>
<th>Wheat</th>
<th>Corn</th>
<th>Oats</th>
<th>Clover-timothy</th>
<th>Average annual acre value of crops¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone</td>
<td>27.4</td>
<td>37.2</td>
<td>26.5</td>
<td>1.97</td>
<td>$21.60</td>
</tr>
<tr>
<td>No limestone</td>
<td>16.2</td>
<td>21.3</td>
<td>16.8</td>
<td>7.4</td>
<td>11.47</td>
</tr>
<tr>
<td>Increase for limestone</td>
<td>11.2</td>
<td>15.9</td>
<td>9.7</td>
<td>1.23</td>
<td>$10.13 $ 9.24</td>
</tr>
</tbody>
</table>

¹The prices used in figuring the value of farm crops in these two columns are the same as given in Table 1, footnotes 1 and 2, except for mixed hay, which is priced at $11.47 for the period 1927-30 and at $12 for 1930.

### Higher Yields Lower Unit Costs

The individual farmer does not at present have much to say about the price at which his crops sell, but he does have something to say about the cost of growing these crops. Profit obtained by reducing the cost of producing a crop is worth just as much as a profit obtained by an increase in the selling price.

Higher yields are sometimes obtained at little or no profit because the cost of soil treatment may be as much as or more than the value of the increase in the crop. In case of limestone, however, the annual acre-cost is so low and the crop increases so large when it is used in connection with clovers, that it is the most profitable treatment for acid soils. Altho the initial cost of a limestone application may seem high, yet considering its lasting effect the annual acre-cost is comparatively low. Assuming that limestone costs $2 a ton and that a 3-ton application will last in the soil approximately ten years, the cost is only 60 cents an acre a year.

The advantage of growing higher yields of corn on good soil is illustrated by the records of three farms in central Illinois presented in Bulletin 329 of this Station, "Organizing the Corn-Belt Farm for Profitable Production."

<table>
<thead>
<tr>
<th>Farm</th>
<th>Cost of corn per acre</th>
<th>Yield per acre, bushels</th>
<th>Cost per bushel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm 1</td>
<td>$28.84</td>
<td>63</td>
<td>45¢</td>
</tr>
<tr>
<td>Farm 2</td>
<td>27.63</td>
<td>50</td>
<td>55¢</td>
</tr>
<tr>
<td>Farm 3</td>
<td>28.45</td>
<td>34</td>
<td>81¢</td>
</tr>
</tbody>
</table>
Altho the cost per acre is almost the same on the three farms, the yield on Farm 1 was approximately twice as large as on Farm 3 and consequently the cost per bushel was cut almost in half. These three farms are located on similar soils and the increases in yield were due mainly to improved methods of soil and crop management.

On the limestone-sweet-clover plot on the Clayton soil experiment field, Adams county, 60 bushels of corn have been grown as a four-year average at a cost of 49 cents a bushel for growing, harvesting, and marketing. On the untreated plot on the same field, 46 bushels have been grown at a cost of 57 cents a bushel. Labor, and taxes and interest on land valued at $150 an acre are the principal items of cost. On the limed plot there is the cost of limestone and sweet-clover seed in addition. It is perfectly clear that a farmer who, by using limestone and growing clover, is able to grow 60 bushels of corn to the acre, has a much better chance for profit than a farmer who grows only 46 bushels. Low corn prices are not so serious to the limestone-sweet-clover farmer because his low cost of production still allows him a fair chance for profit.

The cost of producing wheat on most of the light-colored acid soils of southern Illinois can be similarly reduced by increasing the acre-yields thru the use of limestone and clovers. On the Toledo field, Cumberland county, for example, a plot without limestone has grown...
16 bushels to the acre as an average for the last four years. On another plot where limestone has been applied to correct the acidity and sweet clover has been grown, wheat has averaged 27 bushels to the acre during the same period. If taxes and interest are allowed on $35 land, and a labor wage and other costs of growing, harvesting, and marketing the crop are included, a bushel of wheat on the untreated land has cost approximately 90 cents. Adding the cost of applying limestone and growing sweet clover, a bushel of wheat on the limed land has cost only 66 cents. The farmer who can produce wheat for 66 cents has a much better chance of making a profit than has one whose cost is 90 cents a bushel.

The other crops in the Toledo field—corn, oats, and clover—have been produced at similar differences in cost under the limestone treatment as contrasted with no treatment.

**Four Common Reasons Offered for Failure to Lime Soil**

In spite of the rapid increase in the use of limestone, there still are thousands of farmers who are putting off liming from year to year. Mistaken ideas about soil acidity or the value of limestone often account for this delay. There are four reasons commonly offered by farmers for not using limestone. Sometimes these are honest reasons, but more often they are merely excuses given by those who have not carefully analyzed their business of farming.

"**Limestone is not needed on my land.**" Most farmers who offer this reason are guessing, and guessing wrong. Only a comparatively small percentage of the farm land in the state is sweet. Enough money is frequently thrown away in clover seed over a period of ten or fifteen years to pay for limestone for the entire farm.

Many farmers deceive themselves in regard to the acidity of their land and their clover yields. A fair crop on their own land looks like a bumper crop; the same crop on a neighbor's farm would be called a failure. "I did not know what a good crop of clover looked like until I had seen clover growing on my limestone land" is a statement often made by farmers who limed only part of their field. Fair crops of clover half the time and failures the rest of the time do not build up the soil very rapidly. Limestone for acid soils is the best clover insurance against unfavorable seasons.

Any farmer can avoid guesswork failures by making an acidity test of his soil.

"**Can't afford to buy limestone.**" This is sometimes an honest reason. However, bankers usually would rather lend money to a farmer
for limestone than for any other purpose. They know that an investment in soil-building is a sound investment and one of the most profitable a farmer can make. As one limestone user said, "When a farmer reaches the point where he feels that he cannot afford to buy limestone, that is just the time when he should either buy limestone or quit farming." Another farmer had this to say, "If some one would offer the farmers who say they cannot afford to buy limestone, stock in a business concern which was guaranteed to return $15 for every $2

![Image](Fig. 9.—It Is Usually A Mistake To Blame Unfavorable Seasons For Poor Clover Crops)

A fair crop of clover can now and then be grown on soils of medium acidity, if the land is fertile and the season favorable (left). But even under these conditions, limestone would increase the yields on such soils as much as a ton or more to an acre (right).

invested, most of them would manage to scrape together at least $100. Yet $2 invested in limestone for acid land will return $15 or more in increased crop yields."

Many farmers who are now using limestone were compelled either to go in debt or to save and sacrifice in order to buy their first carload, but they were willing to do so because they realized that this was the surest and most profitable way of increasing their future income. As pointed out above, $6 invested in limestone in order to grow sweet clover made it possible for a Morgan county farmer to increase his yield of corn 35 bushels an acre in the first crop and 25 bushels in the second. This 60-bushel increase to the acre at 70 cents a bushel, was
worth $42. Could this farmer afford not to buy limestone? Most of us can afford to make a good investment.

"Have to wait too long for results." Farmers who use limestone say that this is not a sound reason in face of the fact that most of the men who offer this excuse have already waited at least fifteen to twenty years. They should not object to waiting a year or two longer; as a matter of fact they will probably delay liming for another ten years and forget they are still waiting.

FIG. 10.—LAND MUST HAVE CLOVERS AND CLOVERS MUST HAVE LIMESTONE

There is no instantaneous or magic way of building up soils that have been drained of their fertility thru years of cropping without clovers. No substitute has been found for limestone and clovers. The field at the left, treated with limestone, sweet clover, phosphorus, and potassium, yielded 30 bushels of wheat to the acre. The plot to the right, treated with mixed fertilizer containing nitrogen, phosphorus, and potassium, but without limestone or clover, yielded 4 bushels to the acre. (Ewing field)

Altho a farmer does have to wait one or two years before he cashes in on his limestone for the first time, he secures the benefit for the next ten to fifteen years without additional applications and without any further waiting. The sure profits from one application of limestone over a period of ten to fifteen years make it worth while to wait two years for the first cash returns. Besides, there is no instantaneous or magic way of building up soils that have been drained of their fertility thru years of cropping without clovers. No substitutes have yet been found that will take the place of limestone and clovers. The land must have clovers and clovers must have limestone.

"Too hard work to haul and spread." Hauling and spreading limestone is hard work, everyone will admit, but no harder than many other jobs that must be done each year. There is perhaps no farm work that will pay as high wages per hour as that of applying limestone to acid soil.
Thousands of farms in central and northern Illinois produce perhaps 40 bushels of corn an acre after a season of hard work preparing the ground, planting, and cultivating the crop. With corn at 70 cents a bushel such a yield will usually cover overhead expenses, such as taxes and interest on two-hundred-dollar land, labor, and other costs of growing and husking the crop. Growing and harvesting a 40-acre field of corn yielding 40 bushels to the acre requires about forty-eight days of labor. Four to six days more spent in hauling and spreading limestone will often increase the yield 30 bushels to the acre. Thus these few days of work may produce almost as much corn as all the rest of the season's work combined. Furthermore the job of applying limestone is finished for the next ten years.

It is not so much the amount of work a man does on the farm that brings him money as it is doing those jobs that pay the highest wages.

Landlords and Tenants Find Fair Adjustments

On many rented farms there are difficulties that have tended to discourage the use of limestone even where it is badly needed. When both landlord and tenant are thoroughly convinced of the need for limestone, the problem can be solved with little trouble; the landlord usually buys the limestone and the tenant hauls and spreads it. This seems a fair arrangement when the distance of hauling is not too great. Often, however, a tenant will not agree to haul and spread limestone because he has no assurance that he will remain on the farm long enough to receive his share of the benefit. This difficulty can be avoided by an agreement providing that the tenant shall be paid for hauling and spreading the unused part of the limestone should he move from the farm before he has received full benefit. Some landlords will not rent to one who will not agree, under some such arrangement, to haul and spread a certain amount of limestone each year.

Often landlords not well informed on farming problems do not see the need for limestone. Tenants have frequently convinced doubting landlords of the need for limestone by buying a few tons and spreading it on a strip thru the middle of a field. Others have tested and mapped the land and have used the results of the test to demonstrate the need for limestone.

Why Soils Become Acid

Soils become acid because the lime is used by crops and carried away in drainage water. Calcium, which makes up 40 percent of pure limestone, is a plant-food element necessary for the growth of all plants.
Average acre-yields of corn, oats, wheat, and red clover remove from the soil an amount of calcium that it would take 208 pounds of limestone to replace. Where these crops are grown in rotation, this means an average loss of 52 pounds an acre a year. Losses that result from rains vary, but easily amount to 500 pounds or more an acre a year.

An amount of calcium equivalent to 208 pounds of limestone is removed from an acre of soil over a period of four years when average yields are obtained in a four-year rotation of corn, oats, wheat, and clover. This is equal to 52 pounds an acre a year. A greater loss occurs as the result of rains, which dissolve the lime and carry it away in the drainage water. The loss that occurs in this way varies but may easily amount to 500 pounds or more from an acre each year.

These losses of lime thru leaching and crop removal explain why sweet clover will often grow along the roadside but will not grow when seeded on the same kind of soil in the field across the fence. In the cultivated field lime is removed in crops as well as in drainage water; in the roadside soil, cropping does not play a part and leaching is retarded by the protective covering of sod.
Some Crops Less Sensitive to Soil Acidity

Sweet clover and alfalfa are more sensitive to soil acidity than any of the other commonly grown farm crops. They are seldom a success on acid soils. Red clover often makes a fair growth on soils of slight to medium acidity, and alsike is less sensitive than red clover. Cowpeas and soybeans, the least sensitive of any of the legumes commonly grown in this state, will produce fair crops on medium-acid to strongly acid soils. The yields of these so-called acid-tolerant legumes are, however, usually increased appreciably by limestone when the soil is medium to strongly acid.

Grain crops, such as corn, oats, wheat, and barley, are less sensitive to soil acidity than are clovers, tho farmers often report that even these crops are benefited directly by an application of limestone. This may be true where the soil is strongly acid. Limestone does increase corn yields by reducing the damage from some of the corn diseases. The main benefit, however, from limestone comes thru better clover crops.

Limestone Not Necessary on All Soils

Altho much of the land in the state is acid, there is nevertheless a large acreage that still contains plenty of limestone. Sweet soils, still containing a sufficient supply of limestone from the rock material from
which the soil was formed, are found in all parts of Illinois in areas ranging from an acre or less in size to large tracts.

Included among sweet soils are “alkali” spots and “shell” land, usually found in relatively small, isolated areas. Altho sweet soils are usually fertile, these two types often contain excessive amounts of lime and basic material and require special treatment to make them productive. On the more level land in the southern and southwestern part of Illinois numerous “scalds” or “slick” spots occur, the surface soil of which may test either acid or sweet. Those testing sweet usually contain an excess of alkali salts, and the effect on crops is similar to that of the alkali spots of northern Illinois. Many have the mistaken idea that all soils, or at least all fields of the same general soil type in the same area or on the same farm, are alike in their need for limestone. On this assumption farmers have applied limestone uniformly over an entire field or farm when part of the land was well supplied with lime and other parts needed much more than was applied. As a matter of fact the soil within a single field often varies from sweet to strongly acid, with intermediate areas that are slightly or medium acid.

Simple Test Shows Where Limestone Is Needed

Because of the wide variation in the needs of soil for limestone, it is important to make a systematic test of every field. One or 2 tons applied where 3 or 4 are needed to correct acidity results in failures with sweet clover and alfalfa; on the other hand, it is a waste of time and money to haul and spread 4 tons where 2 tons will do the work. Fortunately there is a simple and inexpensive test that any farmer can make that will determine whether or not soil is acid. This test, known as the Comber or potassium thiocyanate test, shows not only where limestone is needed but it also indicates the approximate amount.

Equal amounts of soil and testing solution (potassium thiocyanate in alcohol or some other suitable solvent) are placed in a test tube or small glass vial and the vial shaken until soil and solution are thoroughly mixed. The soil is then allowed to settle. If the solution remains colorless, the soil is sweet and therefore does not need limestone. If the solution turns red, the soil is acid and the degree of acidity is indicated approximately by the intensity of the red color.

Detailed instructions for collecting soil samples, testing them, and drawing an acidity map are given in Illinois Circular 346, “Test Your Soil for Acidity.” This circular can be obtained by any Illinois farmer from the Experiment Station or from the farm adviser of his county.

Best Time to Apply Limestone

Limestone should be worked into the surface soil of plowed ground
at least six months, and preferably a year, before alfalfa or sweet clover is seeded. Many failures with these crops are due to delaying the application until just before seeding. The chemical action by which the acidity is corrected takes place rather slowly, especially if the limestone is not thoroughly mixed with the soil by disk ing, harrowing, or cultivating. Consequently when limestone is applied only a few days or a few weeks ahead of a clover or alfalfa seeding, there is not time for it to correct the soil acidity and the young plants are forced to put up a losing fight.

Corn ground is the ideal place to apply limestone, either before planting or after planting and before the corn is high enough to interfere with spreading. Limestone applied at this time not only has the advantage of a longer time to act but the cultivation of the corn mixes it thoroughly with the soil.

Where clover is to be seeded in wheat, a common and very satisfactory method is to apply limestone after the ground is plowed and before the wheat is seeded. This practice offers a good opportunity to work the limestone into the soil and allows six or seven months for it to act on the acidity before the clover growth starts.

Limestone is sometimes applied during the winter or early spring to cornstalk ground where oats and clover are to be seeded. Though this practice is often successful, it is not, in general, a very safe one, particularly if the soil is very acid and the legume is one of the more sensitive ones, such as sweet clover. The limestone is not given enough time to act, nor is there any way for it to become thoroughly mixed with the surface soil and insure quick action.
How Often Should Limestone Be Applied?

No hard and fast rule can be given for the renewal of limestone. How often fresh applications will be needed will depend on the original acidity of the soil, the amount of limestone previously applied, and the fineness of grinding. Where limestone has been applied in amounts called for by a definite test, another application may not be necessary for ten to fifteen years. A number of fields in the state that were limed fifteen years ago still contain enough limestone to grow good crops of sweet clover.

Various Kinds of Lime

There are several forms of lime that can be used to correct soil acidity. Ground limestone and hydrated lime are the more common. Ground limestone is the natural raw stone that has been crushed either especially for use on the land or as a by-product in preparing road stone or construction stone. Ground limestone is used almost exclusively by farmers in Illinois.

"Chats," a by-product of the lead-mine industry, are used extensively in the lead-mine district around St. Louis. Altho the chats from some lead mines contain no limestone, the chats from this district are dolomitic limestone and seem to be equal to ordinary limestone screenings for correcting acidity.

Hydrated lime, or the ordinary builders' lime sometimes sold as agricultural lime, is made from burned lime or “quick” lime by slaking with water or steam. Pound for pound, hydrated lime has a somewhat greater power to correct acidity than has limestone, about 1,500 pounds being equal to 2,000 pounds of pure limestone. Hydrated lime, however, costs four to five times as much as limestone and because of this fact, as well as the fact that it is disagreeable to handle, it is not of much practical importance to farmers in this state.

How Fine Should Limestone Be?

Illinois farmers are fortunate in having a cheap source of limestone. Most of the limestone used in this state consists of screenings which are the by-products of commercial plants that produce crushed road and building stone. These screenings are lower in price than they would be if ground especially for agricultural purposes. They range in size from one-fourth inch in diameter to fine dust, practically all passing thru a 4-mesh screen. The fineness varies not only with different quarries but with shipments from the same quarry.

The percentages of material of various grades of fineness found in limestone from nineteen of the quarries which produce most of the
Material that will pass thru the 8-mesh screen is very satisfactory. Containing a large proportion of fine dust, it corrects the acidity of the soil rapidly enough for all practical purposes. The advantage of extra-fine grinding is not enough to justify paying a much higher price for it.

limestone used by Illinois farmers are shown in Table 3. Eight and five-tenths percent of the coarsest sample in the test passed thru the finest screen (100 openings to the linear inch); 27 percent of the finest sample passed thru the screen. As an average of all 23 samples, 16 percent of the stone passed this fine screen.

Ton for ton, the more finely ground limestone will correct soil acidity more quickly than the more coarsely ground product. The greater number of particles to a given weight of the finer limestone means better distribution in the soil, and hence a quicker correction of the acidity. There is probably no great advantage, however, in crushing limestone finer than 8-mesh. Material that will pass thru

<p>| Table 3.—Results of Screen Tests of Limestone From 19 Commercial Quarries Selling to Illinois Farmers |
|---------------------------------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Passing 2½½-mesh screen</th>
<th>Passing 4-mesh screen</th>
<th>Passing 8-mesh screen</th>
<th>Passing 14-mesh screen</th>
<th>Passing 28-mesh screen</th>
<th>Passing 48-mesh screen</th>
<th>Passing 100-mesh screen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of 23 samples, 1929</td>
<td>100</td>
<td>97</td>
<td>74</td>
<td>52</td>
<td>34</td>
<td>24</td>
</tr>
<tr>
<td>Coarsest sample</td>
<td>100</td>
<td>83</td>
<td>50</td>
<td>30</td>
<td>19.5</td>
<td>13</td>
</tr>
<tr>
<td>Finest sample</td>
<td>100</td>
<td>100</td>
<td>96.5</td>
<td>77</td>
<td>53</td>
<td>37.5</td>
</tr>
</tbody>
</table>
this size of screen contains a sufficiently large proportion of fine dust to correct the acidity of the soil rapidly enough for all practical purposes. The advantage of extra-fine grinding is not enough to justify paying a much higher price for it.

Fertilizers Do Not Take Place of Limestone

Limestone is the only practical means of correcting the acidity of Illinois soils. Where the soil is not too acid, manure will often increase the chances of securing a stand of clovers or alfalfa; and where a stand can be secured, yields of these crops usually will be increased by applications of manure. This is not because manure corrects the acidity of soil, but rather because it adds needed organic matter and plant food. If the soil is medium acid or strongly acid, an application of manure is not usually of much benefit.

The fact that manure will not take the place of limestone is shown by the following results from the Mt. Morris experiment field in northern Illinois.
Here manure and limestone produced 1 ton more of clover hay to the acre than manure alone.

Rock phosphate, superphosphate, or mixed commercial fertilizers do not take the place of limestone in correcting the acidity of the soil. Although these materials may possess some power to counteract the unfavorable condition of an acid soil, they can have little effect on acidity in the amounts in which they are ordinarily applied. Superphosphate and mixed commercial fertilizers are seldom applied at a rate heavier than 200 pounds to the acre. It can hardly be expected that 200 pounds of these materials, or even 1,000 or 2,000 of rock phosphate, which has only a slight power to correct acidity, can take the place of 4,000 to 8,000 pounds of limestone.

Where the soil is deficient in available phosphorus, and is not too acid, an application of phosphate, like an application of manure, will increase the chances of securing a stand of clover or alfalfa. This is due not so much to the fact that the slight acidity is corrected as to the fact that a lacking element of plant food—phosphorus—has been supplied. Alfalfa and red clover do not have such strong feeding power for soil phosphorus as have sweet clover and some of the grain crops. Therefore on soils deficient in available phosphorus, phosphate will need to be applied before maximum yields of these crops can be grown.

If red clover and alfalfa are to be grown on soils that are both acid and low in available phosphorus, then both limestone and phosphate should be applied—the limestone to correct the acidity, and the phosphate to supply the needed phosphorus. The need for both limestone and phosphate on such soils is shown in the six-year average yields of alfalfa and red clover on the Davenport plots at the University of Illinois, given below:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Alfalfa, pounds per acre</th>
<th>Red clover, pounds per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>2,600</td>
<td>4,000</td>
</tr>
<tr>
<td>Manure and limestone</td>
<td>4,700</td>
<td>5,000</td>
</tr>
<tr>
<td>Manure, limestone, and rock phosphate</td>
<td>8,000</td>
<td>6,000</td>
</tr>
</tbody>
</table>

Although sweet clover is more sensitive to soil acidity than is either red clover or alfalfa, it is less sensitive to a phosphorus deficiency, probably because its roots have a stronger feeding power for the natural phosphorus of the soil. Sweet clover, therefore, does well on most all soils in this state, providing the soil is sweet.
That rock phosphate, superphosphate, or mixed commercial fertilizers will not insure a growth of sweet clover on soil that is even slightly acid has been demonstrated time and again on farms as well as on the University soil experiment fields.

**Limestone Not Complete Solution of Fertility Problem**

Altho on many acid soils limestone and clovers seem to be the only treatment needed to bring the land to capacity yields, on other soils additional treatment is necessary. Need for phosphorus, as noted above, and in some cases potassium in available forms, may also be deficient, and when such is the case, crop yields will be limited even tho sufficient supplies of nitrogen and other essential elements are present.

No general recommendation can be made for the use of a phosphate fertilizer on Illinois soils. Experiment Station studies, as well as the experience of farmers, have shown that the need for this plant-food element is almost as variable as the need for limestone. Some soils already contain large amounts in available form; on other soils a phosphate fertilizer must be added before the highest yields can be obtained. Often within a single field of the same general soil type there is wide variation in the amount of available phosphorus. A test recently developed at the University of Illinois will indicate whether a soil needs
phosphorus. This test is explained in Bulletin 337, "A Field Test for Available Phosphorus in Soils."

On the light-colored soils of southern Illinois, need for potassium often develops a few years after the application of limestone and the growing of sweet clover. The supply of available potassium is evidently reduced by the higher yields of crops following the limestone-sweet-clover treatment to a point where it becomes the limiting element in crop yields. This need for potassium is more likely to develop on soils where little or no manure is applied or straw returned.

Potassium does not seem to be deficient at present on most of the soils of central and northern Illinois. On peat and alkali soils, however, the corn crop is usually a failure unless a potash fertilizer is added.

Since there is no reliable test that will show where potash is needed, the only practical way of determining potash deficiencies is to try out applications on a small area of each of the various soil types on the farm. By observing these treated strips closely, a farmer should be able to determine whether it will pay him to use potash.

Before becoming concerned about fertilizers, however, farmers will find it worth their while to apply limestone to their acid lands and grow clovers. On almost all farms this combination is the most important part of a soil-building program.
TIME AND LABOR-SAVING METHODS OF UNLOADING AND SPREADING LIMESTONE

Farmers here and there have worked out methods of handling limestone that have taken much of the hard work out of the job. Some of these methods are described here, and while they may not fit all conditions, at least they may prove suggestive.

J. B. Rice, of LaSalle county, who lives four and one-half miles from the railroad, hauls and spreads a 40-ton car of limestone in one and one-half days with the aid of a dump truck, a manure spreader, and three men. Mr. Rice has worked out a plan which involves but one handling of limestone with a shovel. Thru the use of a loading platform, similar to the one shown in Fig. 19, placed at the side of the car, only a few minutes are required to load the truck. One man shovels a load of limestone on to the platform at the car. A second man drives the truck. The load on the dump truck is transferred to a manure spreader by taking advantage of a roadside ditch, the spreader being pulled into the ditch and the truck backed up to the edge of the bank where it can be unloaded directly into the spreader. The third man

Fred Pattee, Warren county, has spread a thousand tons of limestone on his farm during the past two years, and has worked out a scheme for saving both time and labor. Under his method, six men with two trucks easily can haul and spread a 60-ton car of limestone in one day. Two men in the car shovel the limestone into the hopper. The load is then dumped into the truck. The two trucks, equipped with endgate limestone spreaders, are driven directly to the fields, where two men on each truck shovel the limestone into the spreaders.
spreads this load while the truck goes back for another load. Even where wagons are used in hauling, this type of unloading platform can be used to advantage.

Where a dump truck is available and an endgate spreader or manure spreader is used, it will probably pay to build a movable platform, or an elevated runway similar to the racks used at gas stations for draining oil, on to which the truck can be backed in order to dump directly into the wagon or manure spreader. A trench into which a wagon or spreader can be pulled will serve the same purpose. A slip scraper can be used in excavating such a trench.

Edward Johnson, Henry county, using this platform, one truck, and an extra man, unloaded and hauled a 40-ton car of limestone five miles in one and one-half days. There is no waiting for a load to be shoveled—one man shovels a load on to the platform while the truck is delivering a load to the farm.

**Fig. 19.—A Platform Saves Time and Labor in Unloading Limestone**

Edward Johnson, Henry county, using this platform, one truck, and an extra man, unloaded and hauled a 40-ton car of limestone five miles in one and one-half days. There is no waiting for a load to be shoveled—one man shovels a load on to the platform while the truck is delivering a load to the farm.
According to farmers who have used them, limestone attachments for use on manure spreaders are proving very satisfactory. The apron carries the limestone back to the spreader attachment and thus does away with the need for shoveling into the spreader. A manure spreader without the limestone attachment is sometimes used.

When the endgate spreader is used, each wagon should be equipped with a sprocket so that the spreader can be shifted to the loaded wagon as it comes to the field. Two teams are usually needed to pull the loaded wagon on plowed ground, and one man is needed to shovel the limestone into the spreader. A number of farmers have fitted endgate limestone spreaders on their auto trucks.
FOUR STEPS IN SOIL BUILDING

1. Test for acidity and apply limestone where needed.

2. Grow clovers on at least a fourth of the crop land. They will put life into the soil by supplying nitrogen and active organic matter.

3. Test for available phosphorus and apply phosphate where the supply is deficient. Phosphorus will increase hay and grain yields and improve the quality of the grain.

4. On peat and alkali soils apply potash. On other soils, especially the light-colored soils of southern Illinois, try out potash on a small area of corn.