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LIMING for ALFALFA in SOUTHEASTERN MINNESOTA

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The soils of the southeastern counties of Minnesota are the oldest in the state and most of them are ill-adapted to the growing of alfalfa unless lime is first applied. The results on the University's four experimental fields on these older soils indicate that as high yields can be secured after proper liming as on the younger soils to the west.

The area of old soils practically coincides with the nine southeastern counties, including all of Houston, Fillmore, Winona, Olmsted, Wabasha, Goodhue, nearly all of Mower, Dodge, and Dakota, and small parts of Rice and Freeborn (Fig. 1). These occupy one fourteenth the area of the state, have one-ninth the number of farms, and are among the longest-settled and most highly developed counties in Minnesota, there being 418,500 cattle, of which 202,800 are milk cows, on the 19,938 farms, 67 per cent of which are operated by the owners. At present their acreage of alfalfa is small, only 9925 acres, according to the 1925 census. Fillmore County has the least—170 acres—altho its 3080 farms have 73,300 cattle, 100,500 hogs, and 87,611 acres of clover-timothy hay.

This area is favored by good natural drainage and by having everywhere, usually at no great depth below the surface, beds of limestone rock which crop out in the valleys and ravines. For crops other than alfalfa and sweet clover there is no evidence of lime-deficiency. Most of the farms are either within convenient hauling distance of railroads that connect with commercial plants producing ground limestone or screenings, or are near limestone outcrops from which liming material may be prepared by portable grinders.

CHARACTER OF THE SOILS

The soils of the southeastern counties in general are heavy (fine textured), naturally well drained, and deep. They are silt loams, clay loams, and loams, except for a considerable area of sandy soils in Dakota County and small tracts in some of the other counties. Solid rock is seldom encountered within 10 feet of the surface, except along the sides of the valleys in the most hilly sections, and there limestone outcrops.

The surface soil and the upper subsoil are generally lime-deficient toward alfalfa and sweet clover, but the deeper subsoil is almost everywhere rich in very finely divided limestone,[1] the change to this being quite abrupt. In the extreme southeastern corner, embracing Houston and the adjacent parts of Fillmore and Winona counties, on the more level uplands the limey subsoil is usually from 6 to 10 feet below the surface, but elsewhere it is only from 3 to 5 feet and in a few places is even less. The approximate limits of these two subdivisions may be

[1] This limey subsoil effervesces like limestone when a drop of acid is applied. (See p. 22.)

seen from Figure 2, in which is shown also the boundary between the area of older soils (low-lime area) and the younger soils to the west. The latter generally show no deficiency of lime for even alfalfa and sweet clover, and the small areas that do show a deficiency belong to the sandiest types, which are of very limited extent. For the present we may consider that the typical older soils are separated from the younger by a belt 5 or 6 miles wide, that in this about half the fields are lime-deficient, and that in starting with alfalfa the same precautions should be taken as on the farms definitely within the area of older soils.

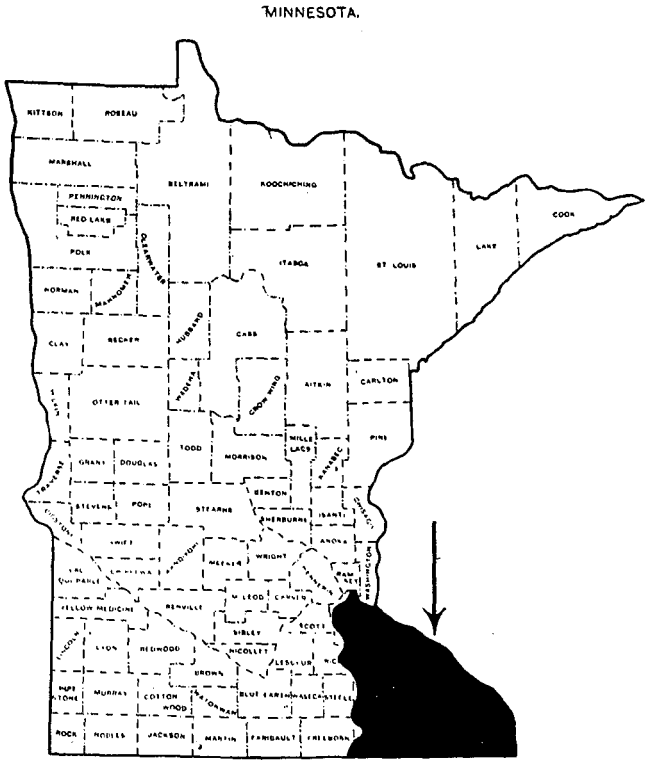


Fig. 1. Area of Old Soils in Southeastern Counties

The limey deep subsoil is exposed in many of the roadside ditches and cuts, and on this volunteer sweet clover grows luxuriantly. This may mislead the observer into believing that the adjacent fields are always well supplied with lime.

Table 1. Farming Data for the Nine Counties Compared with the Rest of the State*

County	No. of farms	Number of cattle		Clover-timothy hay, 1925	Alfalfa				
		Total	Milk cows		1920	1922	1923	1924	1925
				Acres	Acres	Acres	Acres	Acres	Acres
Dakota	2,071	28,100	18,800	29,037	291	690	969	1,571	2,208
Dodge	1,651	37,400	20,500	29,140	23	82	257	416	711
Fillmore	3,080	77,300	27,200	87,611	16	60	89	115	170
Goodhue	2,900	56,600	30,300	46,280	350	575	1,039	1,756	3,602
Houston	1,891	41,000	20,200	40,360	24	62	134	292	447
Mower	2,479	43,700	22,100	57,531	25	169	318	233	630
Olmsted	2,301	55,900	26,600	50,336	40	51	202	371	799
Wabasha	1,647	35,200	15,600	32,522	47	143	202	320	600
Winona	1,918	43,300	21,500	42,286	68	103	170	548	758
Total for 9 counties	19,938	418,500	202,800	415,103	884	1,935	3,380	5,622	9,925
Total for 78 other counties	154,577	2,444,500	1,360,200	983,500	40,422	77,817	107,168	190,774	304,379

* Data from 1925 census.

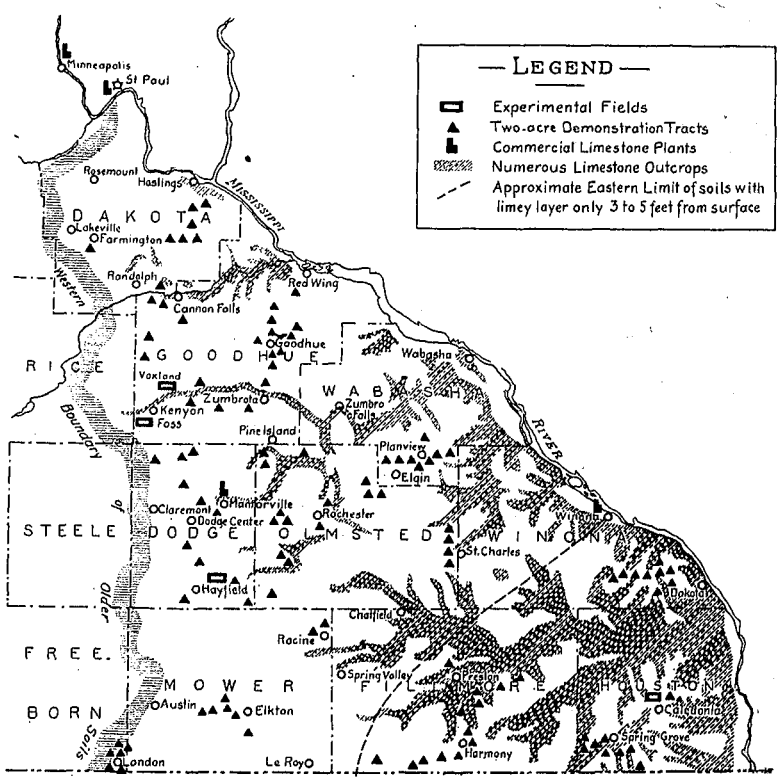


Fig. 2. Area of Older Soils, Showing Location of Commercial Limestone Plants, Experimental Fields, Demonstration Tracts, and Limestone Outcrops

DISTINCTION BETWEEN LIME-DEFICIENCY AND SOIL ACIDITY

Lime-deficient soils are those upon which liming will improve the growth of a crop. Alfalfa and sweet clover are the most sensitive of the farm crops to a deficiency of lime; medium red, mammoth, and alsike clovers are much less sensitive. Oats, rye, corn, and potatoes represent the least sensitive crops. Thus, a soil may have sufficient lime for maximum yields of the common clovers and still be very lime-deficient toward alfalfa and sweet clover. There is a considerable range in the degree of lime-deficiency shown by soils. On some fields, 2 tons per acre of ground limestone cause as high yields as heavier applications, while on others 3 or 4 tons may be required. Liming fields that need no lime does not injure alfalfa or any other farm crop.

Acid soils are those which respond to certain chemical tests used for the detection of acids. Blue litmus paper turns red when brought into contact with acids, and this is the oldest test for soil acidity. If a soil shows no acidity it is described as **neutral.** It is commonly believed that all soils which show an acid reaction are deficient in lime and, accordingly, that if a farmer wishes to find out whether a field will need lime for alfalfa, and if so how much per acre, he simply needs to have samples of the surface soil tested for acidity. However, **soil acidity and lime deficiency,** altho more or less closely related, **are not one and the same.** There are decidedly acid soils that do not need liming, even for alfalfa and sweet clover. All, or nearly all, lime-deficient soils are acid, but many acid soils are not lime-deficient. While there are delicate and accurate methods for detecting and measuring soil acidity, no really satisfactory laboratory method has so far been devised for detecting and measuring lime-deficiency.

It is safe to consider that all the fields in the southeastern counties that have a neutral surface soil will not need liming for any crop; while with those showing more or less acidity, a simple field experiment, as described in the following section, should settle the question of the need of liming for alfalfa. In order to insure the proper use of lime on all fields that need it, to avoid this expense on fields with acid soil that do not need liming, and to be able to dispense with even a trial on those with neutral soil, both laboratory tests and field trials need to be considered.

The litmus test is no longer considered as satisfactory as several other comparatively simple tests developed in recent years, as these not only detect acidity but also show several different degrees, so that a soil, if found acid, may be reported as of very strong, strong, medium,

slight, or very slight acidity. These methods—the Truog, sulphocyanate, and Soiltex—do not give results that are fully concordant, but usually agree well enough that a soil found strongly acid by one will be of either strong, very strong, or medium acidity by the others; while a soil that appears neutral with one will be found either neutral or only slightly acid by the others.

The Division of Soils of the University places no limit on the number of samples of Minnesota soils that it will test for acidity without charge, when these are taken according to the directions in the following section. County agricultural agents will either test samples or forward them to the University.

DIRECTIONS FOR COLLECTING SAMPLES OF SOIL

Surface Soil Samples

How many samples from a field?—Each sample of surface soil sent to the experiment station for an acidity test should be a **composite sample,** made up of approximately equal amounts from 10 to 12 separate samples. If a farmer thinks there are several different kinds of soil in the same field, he should take a composite sample from each. If the soil is very much alike in all parts of the field, 4 or 5 composite samples should be collected—one from near the center and the others from near the corners.

How to take the samples.—If the field has recently been plowed or cultivated, pick up a handful of soil in 10 or 12 places, 5 paces or more apart. Throw them into a clean pail or box as taken, mix thoroly, and save about half a pound as the sample. If the field is in sod or the surface is hard, the soil should be loosened before taking each sample. A clean cup or large spoon is better than the hand for sampling, and it is important to take just about the same amount of soil from each of the 10 or 12 places.

If the samples, when examined at the laboratory, are found to differ greatly in acidity, further sampling may be advisable, in order to locate more definitely the boundaries of the least acid soil.

Subsoil Samples

With a spade or post-hole digger make a hole to the depth desired and take about half a pound from the bottom of the hole. Thus, when a sample of the subsoil at a depth of 12 to 15 inches is to be taken, dig the hole 12 inches deep, remove any surface soil that may have fallen in and then, using a knife or spoon, take the sample from the bottom, being careful to avoid mixing any surface soil with the subsoil. It is desirable to have subsoil samples to a depth of both 12 inches and 3 feet from 3 or 4 places in the field.

How to Send Samples to the Experiment Station

The Division of Soils will make free tests for acidity on all Minnesota soil samples received, if they are accompanied by a letter giving the name of the sender, whether owner or tenant of the farm, and the legal description of the land from which they were taken—county, township, section, and part of section. Place each sample, of about half a pound, in a **clean** cloth sack, paper bag, box, or can. Mark each plainly with a number and the name of the sender, as often many samples reach the laboratory by the same mail. Send the samples by parcel post in a package marked with the sender's name and address. Do not place the letter describing the soils in this package, but mail it separately. Address both package and letter to Division of Soils, University Farm, St. Paul, Minn.

HOW TO DECIDE WHETHER TO LIME FOR ALFALFA

A field in which the surface soil is neutral or only very slightly acid does not need even a trial of liming.

A field with a surface soil which shows only slight or medium acidity, and with a subsoil, at a depth of 12 to 15 inches, neutral or only slightly acid, will usually show no benefit from liming, but if it is the first alfalfa to be tried on the farm, it is advisable to **lime a strip** about a rod wide through the center of the field so as to secure definite information for use with later seedings on the same farm.

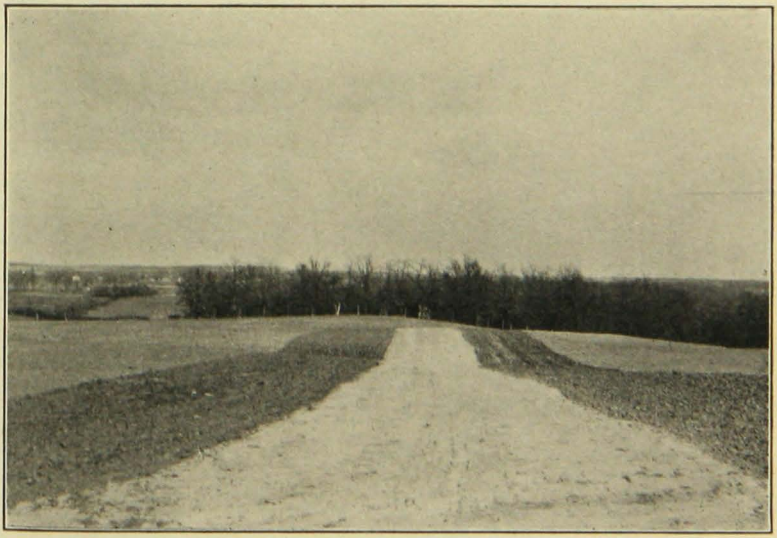


Fig. 3. Limed Strip One Rod Wide Through the Center of a Field to Be Sown to Alfalfa

If the surface soil is of medium or strong acidity and the subsoil also of medium or strong acidity, the land should be limed, leaving a strip about one rod wide unlimed, as an experiment.

Even where the subsoil is of medium or strong acidity to as great a depth as 5 feet or more, it is desirable **in the case of the first field** of alfalfa on a farm, to leave a strip without liming. There are exceptional fields in which, altho both surface soil and subsoil to a depth of 5 feet are very strongly acid, as good yields of alfalfa and sweet clover are obtained without as with liming.

WHAT IS MEANT BY LIME

The term "lime," as used in connection with the liming of soils, includes any of the various materials that may be used to overcome a lime-deficiency—limestone, burnt lime, hydrated lime, water-slaked lime, air-slaked lime, marl, acetylene sludge, and waste lime from sugar factories and paper mills. When used in sufficient quantity these materials overcome the lime-deficiency and at the same time partly or wholly neutralize the acidity of the surface soil. In southern Minnesota, limestone is nearly always the most economical form.

Fig. 4. Strip One Rod Wide Left Without Lime in a Field to Be Sown to Alfalfa

Most Minnesota limestones are known as magnesian or dolomitic limestones, because they contain a considerable amount of magnesium carbonate, but this is no disadvantage when the material is to be used for liming soils, as the magnesium carbonate in limestones is as valuable as an equal amount of calcium carbonate.

In addition to the carbonates, limestones carry more or less of impurities—flint, sand, and clay—which are of no value in liming, altho

harmless. In Minnesota limestones they seldom fall below 15, and usually amount to from 15 to 25 per cent. The more impurity present the heavier must be the application to overcome the lime-deficiency of a soil, 2 tons of a limestone with 15 per cent of impurities (85 per cent carbonates) supplying as much lime as 2½ tons of another limestone with twice as much impurity (70 per cent carbonates).

Usually the differences in the amount of carbonates in the ground limestone and limestone screenings from the crushing and grinding plants in Minnesota are so small that a determination of the purity is unnecessary in deciding between samples.

Gypsum, often called "land plaster," is without value as a liming material and, so far as known, has no beneficial effect upon alfalfa or any other crop in the southeastern counties, altho it shows striking benefits on alfalfa and the clovers on certain soils in northern Minnesota that are deficient in sulphur. Gypsum is almost pure calcium sulphate.

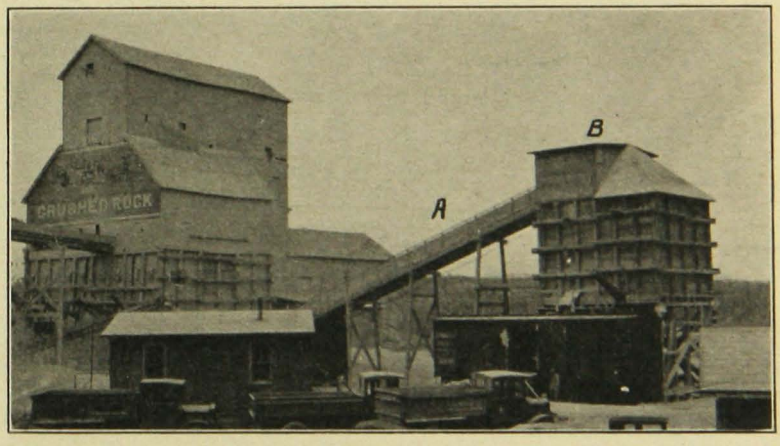


Fig. 5. A Commercial Crushed Limestone Plant.

Crushed rock and screenings are ground and elevated through A and into B, from where they fall into a railroad car.

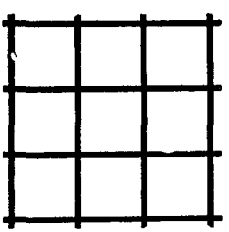
WHAT FORM OF LIME TO USE

In the southeastern counties it will nearly always be a question only of deciding between limestone screenings and ground limestone, because of their cheapness and the dearness or scarcity of other liming materials—marl, burnt lime, sugar factory waste, acetylene sludge—which in other places may be more economical.

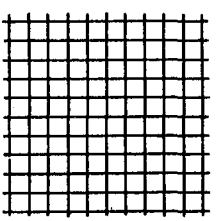
The more finely divided the limestone the more quickly it overcomes the lime-deficiency of soils and hence the more desirable it is, especially where alfalfa is to be sown soon after the land is limed. Limestone is generally considered sufficiently fine if it has been ground so that all

of it will pass a 10-mesh screen, provided that none of the finer material produced in the grinding has been removed. Then the largest particles will be less than one-tenth inch in diameter and usually 50 per cent or more of the product will pass a 50-mesh screen. The finer the limestone the higher is the cost of grinding, and beyond a certain degree of fineness the increased effectiveness does not justify the increased expense.

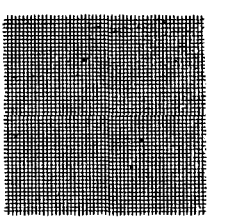
Limestone screenings are the finer portions obtained in crushing limestone rock for building and road construction, including all the particles that pass a 5/16-inch screen, but different lots from the same plant may vary much in the proportion of the very fine particles and these form the most valuable part. The proportion of fine material is higher when the stone is crushed in dry weather. Formerly screenings were a by-product for which there was no sale, but recently the crushers have found a market for all or most of their screenings, independent of their agricultural use. They are usually sold at 50 cents or $1 per ton in carload lots at the plant.



5/16-Inch Screen
Wires 5/16 inch apart. Limestone screenings pass through this.



10-Mesh Screen
Ten wires to the inch. Ground limestone should pass through this.



50-Mesh Screen
Fifty wires to the inch. At least 50 per cent of ground limestone should pass through this.

Fig. 6

Ground limestone, frequently called **pulverized limestone,** is like the screenings in chemical composition and differs only in the proportion of fine material. It is prepared both by large industrial plants and by small portable grinders or pulverizers. Usually large plants that are equipped with special grinders (See Fig. 5) pass through these all their screenings, with the result that they have only ground limestone for sale. This is sold in 30- or 40-ton carload lots f.o.b. place of manufacture by some firms at $1 per ton, and by others at $1.50 to $2.

One Twin City firm prepares a very finely pulverized limestone, for use in asphalt pavement construction, of which 90 per cent will pass a 200-mesh screen, but to obtain this extreme fineness the limestone screenings must be dried by artificial heat before grinding, making the cost too high for field use. The company puts up a mixture of this very fine material and limestone screenings, selling it under the trade name of **neutralizer.**

A farmer should not purchase screenings simply because the price per ton at the plant is low, as the cost of the material may amount to less than one-fifth of the total expense of liming a field. Unless the coarser of two products is considerably the lower in price, it is usually more economical to buy the finer and use a lighter application.

When applied at a sufficiently heavier rate per acre, the limestone screenings, if none of the finer material has been removed from them, give as satisfactory results as ground limestone.

Before ordering screenings or ground limestone the purchaser would do well to secure a sample of the product, and by comparing the samples from different sources he can decide closely enough whether there is any important difference in fineness.

WHEN TO LIME

In spreading limestone one should aim to get it on evenly, with the least possible handling, and well in advance of seeding. It may be applied at any season of the year and on any crop without fear of damage, as direct contact with it does not injure seeds or the most sensitive young plants. Its effectiveness is much increased by thoro mixing with the soil, and it is much better if applied and mixed with the soil several weeks or months before seeding the alfalfa, and usually still more effective if put on a year in advance. It may be applied two or three years before seeding without loss of beneficial effect.

Usually it is best applied after plowing. Then the disking and harrowing necessary to prepare the seedbed and destroy the weeds, will provide for the necessary thoro mixing of the limestone and soil. If spread on unplowed land and well disked in before plowing, the result may be expected to be as satisfactory as when applied after plowing. If alfalfa is to be the first crop following sod, the limestone should not be spread before plowing, as it can not be disked in. When spread on corn stubble that is to be seeded without plowing, the limestone should at once be thoroly disked in.

When a farmer decides a year in advance to seed to alfalfa a field that needs liming, he may well spread the limestone and put the field into corn. This early application will usually so increase the effectiveness that it will far more than pay for the year's interest on the investment in material, freight, and labor, and the early planning will permit the eradication of many of the weeds.

Fall liming has many advantages. Usually limestone supplies are plentiful, roads are good, and there are lulls in the farm work. On the stubble fields before the ground freezes, the disk can follow the spreader and even after freezing the surface will be smooth enough to use a

spreader, while the stubble will prevent risk of loss through washing and blowing.

While it is often easiest to provide labor for such work in winter, in some places the limestone is not available and sometimes the snow is drifted or too deep. On the frozen fall-plowed fields, the rough surface will hinder the use of the lime-spreader but it will prevent blowing and washing. Wherever there is risk of much washing or blowing of the fine material, liming should be postponed until the spreader can be followed by the disk.

In places where crushing plants carry a reserve supply of ground limestone, it is less difficult to get prompt delivery in the fall and winter, as the most of it is shipped during March, April, and August.

Top-dressing an established field of alfalfa with limestone is seldom to be recommended. It is so difficult to get the limestone worked in that if the soil is really very lime-deficient the plants are likely to die from lack of lime before the application becomes effective.

HOW MUCH LIMESTONE PER ACRE TO APPLY

Where limestone is applied only shortly before the alfalfa is to be sown, 2 tons per acre of ground limestone or 3 tons of limestone screenings is recommended. Where the application is made a year in advance, somewhat lighter applications will probably suffice, except on the wind-laid (stone-free) upland soils in the southeastern corner—Houston, and adjacent portions of Winona and Fillmore counties, east of the broken line shown in Figure 2, where the application should not be reduced.

HOW TO SPREAD LIMESTONE

Ground limestone and limestone screenings may be spread by hand with a shovel or by means of a manure spreader, but a lime-spreader applies the material more evenly and with so much less labor that it should be used where available. However, in starting with alfalfa it is more important to get the limestone on early and evenly than to economize on labor. It is seldom that on one farm there will be sufficient work to justify the purchase of the lime-spreader, costing from $50 to $90, but if several farmers co-operate in the purchase and rent the implement to their neighbors at a fair rate (50 cents per acre or $5 per day), all will have the convenience of it and the rental will soon repay the cost. There are two styles of limestone spreaders and several makes of each. One style, the endwheel or hopper type, is built much like a grain drill (Fig. 7), the hopper being carried on two wheels. By levers it may be set to spread at different rates, from a few hundred pounds to 3 tons or more per acre. When

the material is dry, this style, which can be operated by one man, is generally regarded as the more satisfactory implement, doing good work even in considerable wind.

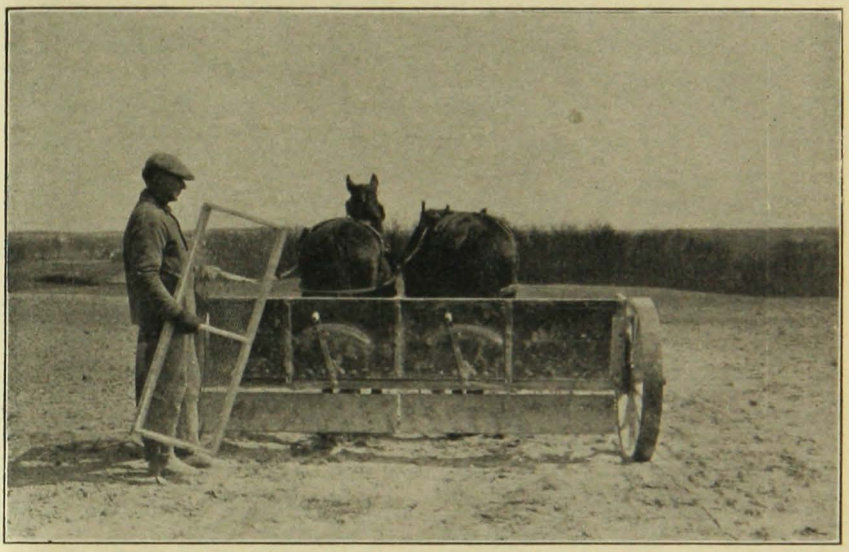


Fig. 7. An Endwheel Limestone Spreader
The man is holding the screen which keeps out large objects liable to break the machinery.

In the other, or endgate type, the machine is fastened to the rear of a wagon box (Fig. 8), and operated by a chain from driving sprockets attached to one rear wheel and will spread from 500 pounds to 3 or more tons per acre. This type, which requires two men, one to

Fig. 8. An Endgate Limestone Spreader

drive the team and the other to shovel the limestone into the hopper as the wagon is driven across the field, handles wet material better than the other, but on windy days much of the fine material, if dry, may be blown to one side. There is further a tendency to get the limestone on in alternately heavy and light strips. If driving sprockets are provided for a rear wheel on each of several wagons, they can all be used in hauling limestone from the railroad car, the spreading attachment being transferred to each wagon in turn as it arrives at the field, thus avoiding extra handling of the material. The extra equipment for each wagon costs only about $5.

A manure spreader may be used, but is less satisfactory than a lime-spreader. It should be set at the lowest rate, the bottom of the box covered with a few inches of manure and enough limestone spread evenly on top of this to give the desired rate per acre. The amount needed for each spreader load may be found by dividing the desired rate of liming (in tons) by the rate (in loads) at which the spreader is set. If 2 tons per acre of limestone is to be applied and the spreader is set at 4 loads per acre, half a ton of limestone will be needed on each load. As a bushel of ground limestone weighs about 110 pounds, the material for the first spreader load may be measured and spread evenly over the whole of the bottom. By noting the depth, the limestone for the following loads may be filled in to that depth without weighing or measuring.

When manure spreader is set at	To spread limestone at rate of	Use on each spreader load
4 loads per acre	2 tons per acre	1000 pounds or 9 bushels limestone
4 " " "	3 " " "	1500 " " 13½ " "
5 " " "	2 " " "	800 " " 7½ " "
5 " " "	3 " " "	1200 " " 11 " "

Fig. 9. Spreading Limestone with Shovels

Some spread with shovels directly from a wagon or sleigh, a method which permits spreading when there is snow on the ground and when the frozen surface of a plowed field is too rough for a lime-spreader. A man can soon learn to spread it evenly and rapidly, but when this method is used it is important for the farmer himself to be in the field to make sure that the spreading is even and that it is not put on too heavily at first. An instance that has just come under the writers' observation illustrates this. A man, owning a farm 10 miles from his home, purchased a 30-ton car of ground limestone for a 10-acre field and arranged for it to be hauled from the railroad by trucks, from which neighbors unloaded it onto sleighs and from these spread it over the field with shovels. Not until the car was nearly empty was it found that, while putting it on evenly, the men had been spreading it so heavily that only 6 acres could be covered. As a result, if the whole field is to be limed as intended, another carload will have to be ordered.

On small fields the limestone can be put in piles at regular intervals and from these scattered with shovels. Half-bushel piles (55 pounds) placed 24 feet apart, will give approximately 2 tons per acre.

Fig. 10. Spreading Limestone with a Shovel from Half-Bushel Piles 24 Feet Apart

Rather than leave a pile of limestone in the field or at the barn waiting long for a lime-spreader, it is usually better to use a more laborious method, provided that this will ensure a moderately even application at the desired rate. After having once decided to go to the expense of liming, get the limestone on your field as soon as you can.

PLANNING THE SPREADING TO SAVE LABOR

When a lime-spreader is used, much time and labor may be saved by planning the work in advance. The endwheel spreaders are 8 to 9 feet wide, the hoppers will hold about 1000 pounds (10 to 12 bushels), and when liming at the rate of 2 tons per acre the hopper will need to be refilled every 80 rods. If the field is 40 rods long a hopperful will be enough for one round trip and all the limestone can be filled in from either end of the field. If the field is 80 rods long, the hopper would be filled at both ends of the field, in which case it would be necessary to haul half the limestone to the far end. In such a case it is better to fill the hopper every time the spreader comes to the middle of the field. If the limestone has to be hauled to the field in advance of spreading, the shape of the field and rate of application will determine where it should be piled.

If conditions are favorable, and the work can be so arranged, it is more economical of labor to spread the limestone as fast as it is hauled from the railroad or grinder, shoveling it from the wagon or truck directly into the spreader hopper.

If the endgate type is used, the limestone can be spread directly from the wagon in which it is hauled to the farm. This type covers a strip about a rod wide and at the rate of 2 tons per acre a ton load would cover a strip 80 rods long. As on good roads a good team should be able to haul 2 tons, on reaching the field with soft ground a second team should be hitched to the wagon as they begin to spread, or part of the load may be transferred to another wagon.

A minimum carload in box cars is 30 tons and in open cars (gondolas) 40 tons. When the limestone is brought in by railroad, the car must be unloaded when it arrives. If the fields are near and all conditions are favorable, it can be hauled directly to the field and spread. If a farm is far away, the roads bad, the fields too wet to work on, or the car arrives in a rainy period, a storage bin at the station is a great convenience. From this a load of limestone can be brought home every time the wagon or truck goes into town for other purposes. In many places farmers can well afford to pay a commission to a local elevator man or coal dealer for unloading and storing the limestone in bins, in which it will be kept dry until it is convenient to haul it home and spread it.

COST OF LIMING

The cost of liming land in the southeastern counties will usually lie between $4 and $17 per acre. This includes the cost of the limestone at the plant, the freight when shipped by rail, the wagon or truck haul from station to field, and the spreading. The cost of spreading, which

is about the same everywhere and not much higher for 3 tons per acre than for 2, may be assumed to be about $1 per acre where a spreader is to be had at $5 per day or 50 cents per acre, and man labor is placed at $3 and team labor also at $3 for a 10-hour day.

The ground limestone loaded in carload lots at the plant costs from $1 to $2 a ton and limestone screenings from 50 cents to $1.

At these rates for men and teams, or using a truck, the cost from railroad to field may be as low as 50 cents per ton for a 2-mile haul and $2 for 17 miles over good roads. This would give a range from $1 to $6 per acre. In some places, in addition to the distance, we must take into consideration a climb of 300 to 500 feet between the railroad and the farm.

The freight per ton in carload lots, 30 to 50 tons, will vary from 60 cents per ton for the shortest haul to $1.40 for the most remote station in the southeastern counties. The higher amounts include switching charges if the limestone plant is not on the railroad that is to make delivery. So the freight cost per acre may vary from nothing for a farm within hauling distance of the limestone crusher, to $6 for the station farthest from a limestone plant.

Table 2 indicates the range and cost per acre if the limestone can not be hauled directly from the grinder to the field. Where it can be so hauled, the cost may be less than the lowest indicated. From the table it is evident that if 2 tons per acre of ground limestone will serve as well as 3 of screenings, it will be more economical to purchase the former, even at a much higher price per ton, wherever the railroad, wagon, or truck haul is long. Under the low-cost conditions, ground limestone at $1 is cheaper than screenings at 50 cents per ton, and with a high freight charge and a long haul to the field it is more economical even at $2 per ton.

Table 2. **Lowest and Highest Probable Cost per Acre of Liming Within the Southeastern Nine Counties**

	With material costing 50 cents per ton		With material costing $1 per ton		With material costing $1.50 per ton		With material costing $2 per ton	
	2 tons	3 tons	2 tons	3 tons	2 tons	3 tons	2 tons	3 tons
A. Under conditions of lowest cost, as at Rosemount								
Limestone	$1.00	$1.50	$2.00	$3.00	$3.00	$4.50	$4.00	$6.00
Freight	1.20	1.80	1.20	1.80	1.20	1.80	1.20	1.80
Hauling to field	1.00	1.50	1.00	1.50	1.00	1.50	1.00	1.50
Spreading	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	$4.20	$5.80	$5.20	$7.30	$6.20	$8.80	$7.20	$10.30
B. Under conditions of highest cost, as at Caledonia								
Limestone	1.00	1.50	2.00	3.00	3.00	4.50	4.00	6.00
Freight	2.80	4.20	2.80	4.20	2.80	4.20	2.80	4.20
Hauling to field	4.00	6.00	4.00	6.00	4.00	6.00	4.00	6.00
Spreading	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total	$8.80	$12.70	$9.80	$14.20	$10.80	$15.70	$11.80	$17.20

In the territory south of the Twin Cities both limestone screenings and ground limestone are included in the lowest freight schedule, the same that applies to gravel and crushed stone for road construction. The minimum carload is 90 per cent of the marked capacity of the car, but not less than 20 tons.

From most of the plants the material is to be had only in open cars of 40 tons or more, but at least one firm is now equipped to load into 30-ton boxcars and makes no extra charge for this. The open car has the advantage of being easier to unload, while the boxcar keeps the material dry and does not require so large an order to get full advantage of the carload freight rate. In an open car with a minimum of 40 tons, as much as 50 or 60 tons may be shipped at the ton rates given in the table; but if it should be loaded with only 20 tons, the freight would be the same as for 40 tons, and accordingly the charge per ton would be twice as high. For this reason, if a farmer can not make use of a minimum carload, 30 or 40 tons according to the kind of car, he had better induce some neighbors to order with him so that all may receive the advantage of the lowest freight rate.

Table 3 shows the freight charges in carload lots from the 6 commercial plants at present supplying agricultural limestone, to 27 representative stations in the southeastern counties. If a limestone plant is located on the same railway that delivers the car to its destination, there is no switching charge. When it is on another, which must transfer the car to the railway that delivers it to its destination, the latter will absorb either all the switching charge accruing at the point of origin, or as much of it as will leave the railway a net revenue of $18.50 per car, when this is moved over only the one railway after switching, and a net revenue of $30.50 per car when it is moved over two or more railways after switching. If the car has to be switched to another railway after arrival at its destination, there will be an extra charge. Considering the 27 stations and the 6 sources of liming material given in the table, there would be a transfer charge on a 40-ton car in only one or two cases, and even on a 30-ton car in only a few. If all the plants should produce material of equal quality, and offer it at the same price f.o.b. plant, one could look at the table for the rate, make sure whether there would be any transfer charge at the place from which the freight rate is lowest, and if not, place his order with this firm with the assurance that he was making the most economical purchase.

In considering the cost of liming for alfalfa, one should remember that one application is likely to be sufficient for at least 5 or 6 years, even in Houston, Winona, and Fillmore counties. Whenever a second application on the same land becomes advisable, it need not be as heavy as the first. So the original cost per acre should be spread over a period of from 5 to 10 years.

Table 3. Freight Rates per Ton in Carload Lots on Ground Limestone and Limestone Screenings from Commercial Plants to 27 Representative Stations in the Southeastern Counties, When Shipment Is Made by Most Direct Route and All Unnecessary Transfers from One Railway to Another Are Avoided

	Kasota	Mankato	Mantorville	Minneapolis	St. Paul	Winona
To						
Austin	$1.00	$1.00	$0.60	$1.00	$1.00	$1.20
Caledonia	1.40	1.40	1.40	1.30	1.30	0.70
Chatfield	1.10	1.10	1.00	1.40	1.40	0.70
Claremont	0.70	0.70	0.90	1.20	1.20	0.90
Dodge Center	0.90	0.70	0.60	0.90	0.90	0.90
Elgin	1.10	1.10	1.00	1.40	1.40	0.70
Farmington	0.70	0.70	0.90	0.60	0.60	1.10
Goodhue	1.30	1.10	1.00	0.90	0.90	1.00
Hastings	0.90	0.90	1.10	0.60	0.60	1.00
Hayfield	1.10	1.10	0.60	1.00	1.00	1.20
Kenyon	1.00	1.00	0.60	0.90	0.90	1.00
Lakeville	0.70	0.70	1.10	0.60	0.60	1.10
LeRoy	1.10	1.10	0.70	1.20	1.20	1.00
Pine Island	1.00	1.00	1.00	1.10	1.10	0.90
Plainview	1.10	1.10	1.10	1.40	1.40	0.70
Preston	1.20	1.20	1.10	1.30	1.30	1.00
Randolph	1.10	0.90	0.60	0.60	0.60	1.20
Red Wing	1.00	1.00	0.90	0.60	0.60	0.70
Rochester	1.00	1.00	1.00	1.10	1.10	0.70
Rosemount	0.70	0.90	1.10	0.60	0.60	1.10
St. Charles	1.10	1.10	1.00	1.20	1.20	0.60
Spring Grove	1.40	1.30	1.40	1.30	1.30	0.70
Spring Valley	1.10	1.10	0.90	1.20	1.20	0.90
Wabasha	1.10	1.20	1.30	0.90	0.90	0.60
Winona	1.20	1.20	1.30	1.10	1.10	...
Zumbrota	1.10	1.10	1.00	1.00	1.00	0.90
Zumbro Falls	1.20	1.20	1.00	1.10	1.10	0.70

PORTABLE GRINDERS MAY BE PROFITABLE

Large commercial plants can grind limestone so cheaply that even if a farmer has an outcrop of good limestone on his own land, it is usually the best business policy to purchase the material from a large plant wherever the freight and wagon haul are not too great. Fortunately, most farms in the southeastern counties that have a long haul over uphill roads from the nearest railroad have limestone outcrops near by, and for these a portable grinder may be more economical. A machine bought by a farmer for his own use only is likely to be of the smallest size and to be idle most of the time. It is better for a group of farmers to co-operate in the purchase of a larger outfit, which can grind at a lower cost per ton, and even then the machine is likely to be idle the greater part of the year. So it appears better for all concerned to have one man own the outfit and make a business of grinding, moving from place to place and charging so much per ton or per day. In this way the machinery can be used a larger part of the time and usually is more skillfully operated. Farmers in the southeastern counties with their large number of cattle, usually have enough work to occupy most of their time, even in winter, and any time they have might be used in

getting rock from the quarry and hauling it to the farm to be ground later, or in hauling the ground limestone from the machine, where this is at some central point in the community. At least during the early stages of the general introduction of liming in these counties, the purchase of portable grinders by individual farmers for their own exclusive use seems inadvisable.

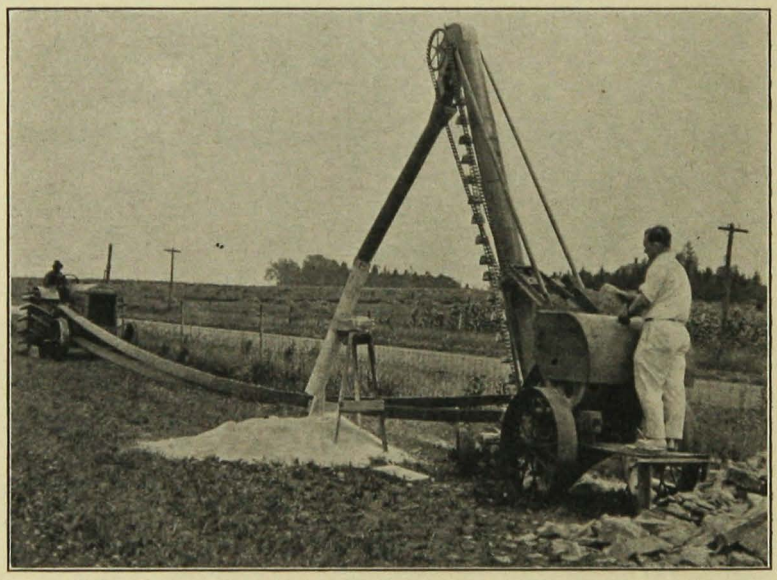


Fig. 11. Portable Grinder at the Voxland Experimental Field "Pulverizing" Limestone Blocks from an Old Wall for Use on the Adjacent Field

The grinding costs more in this case, but there will be no freight bill or long haul from the railroad.

The machines cost from $600 to $1500, according to size and make, and have an output of one ton per hour and more when working efficiently. In southwestern Wisconsin they are being used extensively and the agricultural experiment station of that state advises the purchase of a machine with not less than 30-tons capacity for a 10-hour day, a size that can be operated with a 15-30 gas tractor. A crew of 4 men ordinarily is needed to operate to the best advantage, but the exact number required depends upon the difficulty of getting the rock to the machine. The cost of limestone from such commercially operated portable grinders will vary from $2 to $3.50 per ton. The usual charge for limestone by the owner of the quarry is 10 cents per ton, the purchaser loosening and removing it from the quarry.

The most convenient outfit includes a crusher to crack the rock for the grinder, as this will reduce the cost of the output. Both crusher and grinder can be mounted on the same frame and in such a way that the crushed rock from the former is delivered by an elevator directly to the grinder, both machines being operated by the same tractor. Where a small grinder is used without a crusher much more hand sledging is necessary.

Prospective purchasers should insist upon a demonstration with a machine of the size they intend to buy, using limestone at least as hard as what they propose to grind and with a run of several hours. Otherwise, after they have learned to operate the machine to its full capacity they are liable to be seriously disappointed in the output per hour.

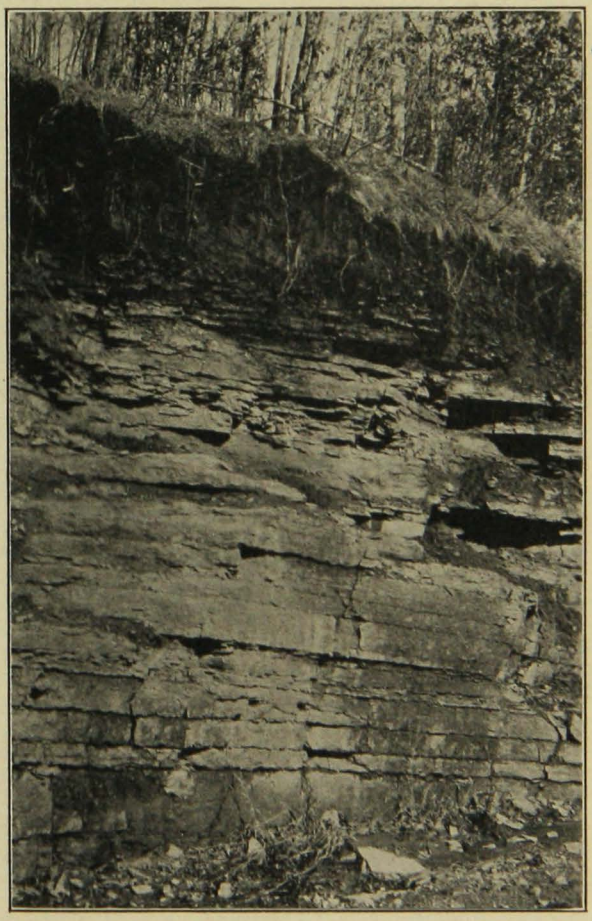


Fig. 12. Limestone Ledges Exposed in Road Cut

The surface soil is lime-deficient, but recovery of alfalfa plants would take place the second season.

The grinder may be set permanently near the center of the community that is to be supplied and at an outcrop that is easily reached by wagon, or it may be moved from farm to farm, the rock having been quarried, hauled, and piled in advance at or near the field to which the ground limestone is to be applied.

It is unwise to grind a low grade limestone when one of better quality is to be had. The exposed rock ledges should be thoroly sampled and the samples analyzed for purity (per cent of carbonates), and the best rock accessible used.

While the farmer can not determine the purity of his limestone, he can easily distinguish between the ledges of limestone and of other rocks—shale and sandstone—that occur in the southeastern counties, because only the limestone effervesces (foams, or gives off bubbles of gas) when a drop or two of dilute muriatic or hydrochloric acid is applied to it. A 10- or 15-cent bottle of the acid may be obtained at any drug store and is enough for a great many tests. The rounded boulders and cobblestones found on the surface and in the subsoil, except in Houston and parts of Fillmore and Winona counties, seldom are limestone, having been carried in by ice from far to the north during past ages.

RELATION OF TIME OF SEEDING TO TIME OF LIMING

Alfalfa may be seeded in the spring with a grain crop—barley, wheat, oats, or flax—or in the summer without a grain crop.[2] On the rolling and hilly lands of the southeastern counties the latter method sometimes results in severe injury by washing before the alfalfa plants become established.

Where the land is not lime-deficient, or where the limestone has been applied and well worked in during the previous season, alfalfa may be sown with oats, barley, or spring wheat at the most favorable time for seeding these crops, which is as early in spring as the land can be worked to advantage.

If the lime was not applied and worked in before winter, it should be well mixed with the soil as early in spring as conditions are favorable. The greater the lime-deficiency of the soil the longer should be the time between the application of the lime and the seeding.

If alfalfa is to be sown alone, seeding should be done the first or second week in June. Cultivation of the land each week or ten days as needed from early spring until June assures the thoro mixing of the limestone with the soil and usually a comparatively weed-free, firm seedbed. Seeding may be delayed as late as the middle of July if

[2] For a full discussion of seeding alfalfa on soils that either are naturally well supplied with lime or have been properly limed see Special Bulletin 104, Alfalfa Aids Progress in Minnesota, by A. C. Arny.

necessary in order to bring the weeds under control. If the surface soil is dry, altho everything else is favorable, seeding should be delayed until after a rain. Where the soil has become firm and frequent cultivation has been practised in order to control the weeds, the surface most of the time will be moist enough, and if it should become too dry a light shower will put it into condition for seeding. This procedure makes as certain as possible the securing of a good stand of alfalfa.

If the alfalfa is to be seeded with a grain crop after the spring liming, it is necessary to decide how long seeding should be delayed after the lime has been applied in order that this may act upon the soil to such an extent that a successful stand of alfalfa may be expected. A delay of ten days or two weeks in the time of seeding of spring grains will not seriously reduce their yields, but any further delay with spring wheat, oats, and barley will result on the one hand in a marked reduction in yield of grain but on the other hand in a greater probability of a successful stand of alfalfa. As securing a stand of alfalfa is the primary object, a delay in seeding with spring wheat or oats is practical for 10 to 20 days and with barley for 30 days beyond the usual seeding time for these grains. With flax, alfalfa may be sown to good advantage up to and including the first week in May of an ordinary season, but with a delay of a week or more beyond that time the weeds usually become so thick that the alfalfa plants have too much competition to succeed.

A third method, that of sowing the alfalfa in August on fields that have produced grain the same season, should be considered an emergency method to be tried only on fields which are not lime-deficient or which have been limed before seeding the grain and only when the grain crop can be removed promptly and conditions for the growth of the alfalfa appear exceptionally favorable. For such a trial, barley is to be preferred to oats or spring wheat, as it matures earlier. Sometimes a heavy rain just as the grain is ripening moistens the soil so thoroly that if the crop is cut at once and the land plowed and worked down, conditions will be excellent for seeding. If conditions should appear favorable for prompt germination of the alfalfa, the grain should be cut four or five days before it is fully ripe in order to reduce shattering to a minimum and in this way reduce the amount of volunteer grain in the new seeding. The crop should be shocked off the field and shallow plowing, disking, and harrowing should proceed immediately, followed by sowing and covering the alfalfa seed. The importance of promptness in performing each of these operations will be evident when it is kept in mind that seedings of alfalfa made in August are, under average conditions, much less successful than those made during the last half of July. While it is desirable to keep down the number of volunteer plants, a small

number will usually prove of great advantage during the following winter by holding the snow and so protecting the young alfalfa plants. If the fall should be exceptionally dry, this advantage may be more than offset by the competition of the grain plants for moisture.

Winter rye or winter wheat fields limed the previous year may be used in the same way as barley fields. The alfalfa is likely the following summer to be able to hold its own against the volunteer plants, which may be cut and used as hay, freeing the alfalfa from further competition.

RELATION OF PROPER SEEDBED PREPARATION TO LIMING

A well prepared seedbed for alfalfa may be defined as one that is firm, comparatively free from weeds, and moist when the seed is sown. In southeastern Minnesota, when alfalfa is sown properly on a well prepared seedbed, it will seldom be necessary to reseed unless the plants are later injured by a nurse crop (better called a **companion crop**), or by washing on rolling or hilly land. The proper preparation of the seedbed is important, even where the soil is naturally supplied with an abundance of lime, and it is much more important to make sure of this where a farmer has had the extra expense of liming.

A firm seedbed appears to be much more important for alfalfa and sweet clover than for the common clovers. With spring plowing, firmness may be secured by the frequent use of a harrow, supplemented by the use of a corrugated roller if one is available. Fall plowing requires less of such cultivation, because of the winter settling of the soil, and disked corn land still less.

Freedom from weeds may be secured by thoro cultivation of the land in corn or potatoes the preceding season, or by cultivation of the field about every ten days from the beginning of the season until the middle of June or early July. If a sod is used, it should be fall plowed, worked down early in the spring, and cultivated frequently until the time indicated.

If the surface is not in the necessary moist condition when everything else is favorable, it is to be secured only by waiting for a rain. The upper subsoil also will nearly always be moist except at times soon after removing a grain crop.

Sometimes a farmer wishing to seed alfalfa with a small grain will find that the surface is too dry for alfalfa, altho everything is favorable for the grain. Under such conditions, if both are seeded, the grain, being put down much deeper, will germinate and may make considerable growth before rain comes to start the alfalfa. Then, even if the alfalfa

at first makes a full stand, it will be at a disadvantage in competition with the grain, should dry weather set in before harvest. It would be better to delay the seeding of the grain with which the expensive alfalfa seed is to be sown, until a rain gives the desired moist surface to the soil.

RELATION OF INOCULATION TO LIMING

Any one who has gone to the expense of liming land for alfalfa should not neglect to make sure of the inoculation, as explained in Special Bulletin No. 104. Liming does not take the place of inoculation, but on lime-deficient soils it is much easier to secure full inoculation after liming, especially if the lime has been worked into the soil some months in advance of seeding. The more lime-deficient the soil the more helpful in securing full inoculation does early liming appear.

RELATION OF MANURING TO LIMING

While manuring may be very helpful in getting a stand of alfalfa on some lime-deficient soils, it is not only unnecessary after liming but may even prove detrimental unless the great number of weeds usually introduced by the manure have been disposed of in advance of seeding. In any case it is not likely to be as profitable as using the manure on corn or as a fall top-dressing on an established alfalfa field. On lime-deficient fields which have been cropped and otherwise treated alike, except that some parts have been much more heavily manured, the alfalfa often does much better on the manured parts.

As the beneficial effect of manure upon alfalfa in the southeastern counties is usually due to its phosphate content, a phosphate fertilizer may be used instead.

Because of the frequent profitable response of alfalfa and clover to an application of phosphate, especially on the darker soils, every farmer with a field of alfalfa is wise to try some on a strip or two across the field. As 100 pounds of treble superphosphate or 275 pounds of 16 per cent acid phosphate is enough for an acre, and a strip 80 rods long and half a rod wide contains a quarter of an acre, the fertilizer for such a trial would cost less than $1. When bought in quantity it would cost not more than $2.75 per acre at present prices.

The phosphate may be spread broadcast by hand at any time when the alfalfa leaves are not wet with dew or rain. If the growth on the fertilized strip is distinctly better than on the adjacent parts of the field, it is safe to conclude that an application of phosphate on the whole field will be profitable. It is seldom wise to fertilize a whole field without having first used a trial strip, because on many fields no benefit is shown.

If one plans his alfalfa field a year in advance and both manures and limes it before planting it to corn and later takes extra pains to keep the weeds down, he is likely to be well repaid.

RECOVERY OF ALFALFA ON UNLIMED LAND

A sudden improvement of the alfalfa on unlimed fields is sometimes observed during the first or second season following seeding. Where inoculation has not been provided for at the time of seeding, a general spreading of the inoculation by mowing and raking is sometimes the explanation, but in the southeastern counties it is often due to another cause. Over most of these counties (see page 2) there is an abundance of limestone at a depth of 3 to 5 feet. At the Hayfield and Kenyon experimental fields, altho the surface soil and upper subsoil are strongly acid, it has been found that if the alfalfa on unlimed land survives the second winter after seeding it rapidly improves to such an extent during the following summer that the plants will become almost, if not quite, as vigorous, and the yields of hay will be almost as high, on the unlimed as on the adjacent limed land. This is due to the roots getting down to the limey subsoil, after which the plants no longer suffer appreciably from the lime-deficiency of the surface

A B A B A B

Fig. 13. Alfalfa Plants from Three Unlimed Plots on the Foss Experimental Field, August 1, 1923

The tall bundles are from five plants whose roots had already reached the limey substratum and the short ones from five whose roots had not yet penetrated so deep.

soil. Where the solid limestone rock is not far from the surface, a similar recovery has been observed.

This should not induce any farmer starting with alfalfa on land that is evidently lime-deficient to omit liming, in the expectation that such an improvement will occur on his fields, because the seasons may be so unfavorable that most of the plants will die before the roots reach the limey subsoil. However, where a fair stand of alfalfa has been secured on unlimed land but the crop is doing poorly, it should encourage the owner not to plow it up until the end of the third season unless before that time the plants should die out to such an extent as to leave too thin a stand.

This recovery is well illustrated by the plots on the Foss Experimental Field, near Kenyon. Alfalfa was seeded in June, 1922, on 112 plots, of which 7 were left unlimed and unfertilized. A good stand resulted and during the first season there was little difference between the limed and the unlimed plots. In the second season (1923), while on all the limed plots the plants were dark green and thrifty, those on the unlimed plots were short and yellow; during July the plants on a few small spots on the unlimed plots became green and vigorous, so that at the time of the second cutting of hay, August 1, most of the plants were small like those marked "A" in Figure 13, but on each plot there were a few vigorous groups like those marked "B." During August these spots increased in size. When growth started in the following May, the green patches were larger and steadily increased in size until by June 15 only vigorous green plants were to be found on all the unlimed plots and in height they averaged almost like those on the limed plots. The yield of hay in both 1924 and 1925 was practically the same on the unlimed and the limed plots. It is likely that there will be little difference as long as the stand survives, and it is likely to survive as long on the unlimed as on the limed plots.

Observations made on various dates may make this clearer:

Date	
1922	
June 15	Grimm alfalfa seeded on all plots without nurse crop.
Sept. 1	A good stand of plants with good color on all plots, but slightly more vigorous on limed plots.
1923	
June 15	Good stand on all plots. On limed plots plants tall and dark green; on unlimed plots, short and yellow. First cutting of hay gave 1.04 tons per acre on limed plots and 0.50 ton on unlimed plots.
Aug. 1	Good stand on all plots. Plants on limed plots tall and dark green, on unlimed plots short and yellow except for a few small patches on which the plants were as dark and tall as on the limed plots. Yield of second cutting of hay 1.10 tons per acre on limed plots and 0.44 on unlimed plots.

1924

May 20 Stand uniform, but much thinner on unlimed plots than on limed, on which there were many more plants than needed. On limed plots all plants were dark green and tall, on unlimed plots there were many large patches of dark green plants but the rest were shorter and yellowish green.

July 2 First cutting of hay. Plants alike in color and height on all plots. Yield on limed plots was 2.45 tons and on unlimed, 2.47 per acre. At second cutting plots were very similar: limed gave 1.53 tons per acre and unlimed 1.34 tons.

1925 Plots much alike throughout season. The two cuttings gave 4 tons of hay on both limed and unlimed plots. Stand still thicker on limed plots but on unlimed ones there was a sufficient number of plants and these were uniformly distributed.

LIMING EXPERIMENTS IN SOUTHEASTERN MINNESOTA

In this area of older soils, the Division of Soils is operating four experimental fields (Fig. 2), one near Hayfield, another near Caledonia, a third southwest of Kenyon (Foss Field), and the fourth northeast of Kenyon (Voxland Field)—about 35 acres in all, subdivided into about 1000 plots, including 700 of alfalfa, all Grimm; and 150 of the clovers—sweet, medium red, mammoth, and alsike. At Hayfield the first seedings were made in 1921, on the three other fields in 1922. On none of the plots where the liming was adequate has the stand failed.

On each of the four fields the soil is heavy—a silt loam or clay loam, the surface more acid than on the majority of fields in its neighborhood, and the limey subsoil farther from the surface. These fields were selected for experimental purposes only after the degree of acidity of surface and subsoil and the depth to the limey subsoil had been investigated in detail in a great many fields. Accordingly, as they are to be considered less favorable for alfalfa than the average run of fields, and as success has been attained with it on all four (Table 4), we may confidently conclude that alfalfa can be grown on practically any of the well drained fields in the southeastern counties, if proper methods are employed. Also, as they may be expected to show more response to liming and as the yields of the common clovers have not been appreciably improved (Table 5) by liming, we may conclude that liming will seldom be worth while for the common clovers, small grains, corn, or grass land in these counties.

Table 4. Yields of Alfalfa Hay per Acre from Properly Limed Plots on Experimental Fields, Two Cuttings Each Season

They had been neither manured nor fertilized.

Experimental field	1922	1923	1924	1925
	Tons	Tons	Tons	Tons
Hayfield	2.6	2.5	3.4	3.9
Foss	..	2.1	4.0	4.3
Voxland	..	3.8	5.2	5.6
Caledonia	..	..	2.8	4.3

Table 5. Effect of Liming Common Clovers

Yields reported as tons per acre of hay. The increase from heavy and early liming has averaged only one fifth of a ton of hay per acre each season.

	Alsike clover			Mammoth red clover			Medium red clover		
	1923 Two cuttings	1924 Two cuttings	1925 None	1923 Two cuttings	1924 Two cuttings	1925 Two cuttings	1923 Two cuttings	1924 Two cuttings	1925 Two cuttings
Voxland Field.—Four tons per acre of very finely pulverized limestone applied in Oct. 1921									
Unlimed plots	2.5	2.6	*	2.5	2.8	4.4	2.3	3.5	3.4
Limed plots	2.5	3.0	*	3.0	3.0	5.4	2.5	3.5	3.9
Gain from liming	0.0	0.4	..	0.5	0.2	1.0	0.2	0.0	0.5
Foss Field.—Four tons per acre of very finely pulverized limestone applied in Oct. 1921									
	One cutting	Two cuttings	One cutting	One cutting	None	Two cuttings	One cutting	None	Two cuttings
Unlimed plots	0.9	2.4	1.8	0.8	*	2.7	0.8	*	2.9
Limed plots	0.9	2.6	1.7	1.1	*	2.7	0.9	*	2.7
Gain from liming	0.0	0.2	0.1	0.3	..	0.0	0.1	..	—0.2
Caledonia Field.—Four tons per acre of ground limestone applied in July 1922									
	One cutting	Two cuttings	One cutting	One cutting	Two cuttings	Two cuttings	One cutting	Two cuttings	Two cuttings
Unlimed plots	0.5	3.5	1.7	0.6	4.3	3.1	0.5	5.1	3.0
Limed plots	0.6	3.7	2.0	0.7	4.6	3.5	0.6	5.5	3.0
Gain from liming	0.1	0.2	0.3	0.1	0.3	0.4	0.1	0.4	0.0

* Winterkilled.

At Caledonia conditions are the most unfavorable, the surface soil being strongly acid and the limey subsoil 8 feet or more below the surface. On the Hayfield and Foss fields the surface soil is strongly acid but the limey subsoil is only from 3½ to 4 feet below the surface. On the Voxland field the surface is about as acid and the limey subsoil 5 to 6 feet below the surface.

In order to test the general application of the conclusions drawn from the work on the **four experimental fields**, the Division of Soils

Fig. 14. One of the Two-Acre Demonstration Tracts of Alfalfa in Goodhue County

has started, in co-operation with farmers in this area, **110 two-acre demonstration tracts** of alfalfa, seeding 70 of these in 1924 and the rest in 1925—all with Grimm. On each tract most of the land was limed, but on every one a strip through the center, a rod or more in width, was left unlimed. These tracts were selected as representative of the average run of the fields of the district and not of the most acid, as was the case with the four experimental fields. Accordingly, some represent the most lime-deficient while others show little or no benefit from liming. On nearly all the surface soil is acid, varying from slight to strong. The yields of hay in 1924, the first crop season, from 10 representative tracts are given in Table 6. The distribution of these tracts is shown in Figure 2.

Table 6. Yields per Acre of Alfalfa on Representative Demonstration Tracts in 1925

Field	Acidity		Depth to limey subsoil	Unlimed land			Limed land			Increase from lime
	At surface	At 12-15 in.		First cutting	Second cutting	Two cuttings	First cutting	Second cutting	Two cuttings	
			Ft.	Tons	Tons	Tons	Tons	Tons	Tons	Tons
A	None	Medium	3	2.76	2.42	5.18	2.15	2.68	4.83	0.00
B	Slight	None	3	1.52	1.58	3.10	1.66	1.68	3.34	0.24
C	Slight	Slight	4	1.29	1.87	3.16	1.73	2.17	3.80	0.64
D	Slight	Medium	3	0.92	1.16	2.08	1.51	1.30	2.81	0.73
E	Medium	Slight	3	0.18	1.40	1.58	1.41	1.94	3.35	1.77
F	Medium	Medium	3	0.91	0.60	1.51	1.35	1.36	2.71	1.20
G	Medium	Strong	3	0.43	0.90	1.33	1.09	1.69	2.78	1.45
H	Strong	Medium	3	1.10	1.11	2.21	1.40	1.61	3.01	0.80
I	Strong	Strong	3	0.68	0.88	1.56	1.86	1.72	3.58	2.02
J	Strong	Strong	8	0.68	0.64	1.32	2.17	1.89	4.06	2.74

ALFALFA ON SANDY SOILS

As the above sections were written for the heavy soils—silt loams, clay loams, and loams—which occupy most of the southeastern counties, some of the statements need to be modified in dealing with alfalfa to be sown on the considerable area of lighter soils—sandy loams, loamy sands, and sands—which occur in Dakota County, or in small tracts in some of the other counties. On practically any of these lighter soils alfalfa can be grown successfully, but the yields are usually lower than on the heavy soils. They are usually more lime-deficient than the latter, but some of them naturally carry sufficient lime for alfalfa and the same methods of sampling and field trials are recommended. Not so high a degree of acidity is necessary in order to make a field trial of liming advisable. The limey subsoil is usually farther from the surface and the recovery of the plants on unlimed land is not so frequent. Manuring is no more important on properly limed fields.

With the first field of alfalfa on a farm of sandy land, seeding alone in June or July is recommended in all cases, as the danger of

losing the stand where alfalfa is seeded with a nurse crop is much greater, and there is little risk of injury from washing. Firmness of the seedbed is so much more necessary that the use of a cultipacker or corrugated roller is advised, and having the seedbed moist when the alfalfa is sown and also for several days after is so important that it is advisable to seed only right after a good rain. With everything else in readiness it is probably safer to seed after the first good rain in June rather than to wait for a second, altho only rarely will there not be at least one good rain between the middle of June and the middle of July.

The methods of dealing with sandy soils, so as to ensure success with alfalfa, have been worked out on the University's experimental fields on sandy land at Coon Creek, Crow Wing, Backus, and Bemidji. At the first place liming has been found greatly to increase the yields of the common clovers, as well as of sweet clover and alfalfa, but on all of the sand experimental fields alfalfa, after proper liming, has given so much heavier yields than any of the clovers that, after going to this extra expense, it does not seem advisable to seed any of the limed land to the common clovers until one has as much alfalfa as he needs.

ALFALFA ON PEAT SOILS

All of the small areas of peat soils in the southeastern counties so far examined, have an abundance of lime, but they are poorly adapted to alfalfa, because usually either the water-table is too close to the surface, or they are subject to flooding; and where neither of these objections applies, the bluegrass will soon choke out the alfalfa, it not being feasible on peat soils to control the grass by cultivation. Peat soils, when properly fertilized, give excellent yields of the common clovers and sweet clover.

Alfalfa has been tried on the University peat experiment fields at Coon Creek, Golden Valley in Marshall County, Karlstad in Kittson County, and Fens in St. Louis County.

LIME-DEFICIENCY ON THE YOUNGER SOILS TO THE WEST

Lime-deficient fields are rare on the younger soils, which occupy the state to the west of the broad boundary shown in Figure 2, and those that have been found are sandy. On these alfalfa may be established by the methods just outlined. Samples taken for examination at the laboratory should include, in addition to those of the surface

soil, several of the subsoils taken at one-foot intervals to a depth of 5 feet.

The surface of the heavy soils is frequently of medium acidity, but the limey subsoil occurs so close to the surface that even on the most acid, liming has been found to show no benefit. Difficulties experienced in securing a stand of alfalfa, while often attributed to a deficiency of lime, are probably in most cases due to an improperly prepared seedbed or lack of inoculation; while unsatisfactory yields, where there is a good stand, are usually due to a deficiency of phosphate. Phosphate-hunger with alfalfa and the clovers is so common on these black prairie soils that every farmer on them is advised to try a phosphate fertilizer on these crops as described on page 24.