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Liming Western Oregon Soils

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Lime Spreader (Courtesy Ind. Exp. Sta.)

Agricultural Experiment Station
Oregon State Agricultural College
CORVALLIS, OREGON

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†Resigned 1934

SUMMARY

1. The purpose of this bulletin is to summarize and place in available form the results of plot and farm trials of liming and of soil acidity surveys and studies conducted by the Oregon Agricultural Experiment Station during the past twenty years.

2. Soils of Western Oregon and especially those of the Willamette Valley and Coast counties are acid and in need of liming. Recent bottomland soils are least acid or leached, those of the old Valley fillings show moderate acidity, and those of the residual "red hill" lands show relatively strong acidity. Acidity is usually higher in the poorly drained types of these groups. Lime is leached from Western Oregon soils at the rate of two hundred to three hundred or more pounds a year and a five-ton crop of alfalfa removes between three hundred and five hundred pounds.

3. Analyses of official samples have been made from every soil type in each county where soil surveys have been conducted. These provide a fund of information of help in advising farmers.

4. Response to liming on recent river-bottom soils is slight; on old Valley filling soils it is medium and on "red hill" lands it is marked.

5. Use of lime on acid soils of humid regions, especially for legumes, is regarded as fundamentally sound. Lime makes soil sweet, improves tilth and water capacity, promotes growth of desirable soil micro-organisms, renders more plant nutrients available, and increases yields, especially of legumes.

6. The relative cost of lime should be calculated on its neutralizing value. Fifty-six pounds of burned lime is equivalent to seventy-four pounds of hydrated lime or one hundred pounds of good ground limestone. The solubility rate increases with fineness, and liming materials should at least be ground fine enough so that all will pass a ten-mesh screen. It would be desirable to grind it sufficiently fine so that 60 per cent will pass a fifty-mesh screen and 30 per cent will pass a hundred-mesh screen.

7. It is recommended that lime be used before growing legumes on soils that are known to be acid (pH below 6.0) or of medium fertility, and especially on soils of heavy texture.

8. A practical rate of application is one to two tons an acre. The heavier application may be needed on soils of strong acidity or for an initial treatment.

9. Lime is best applied after plowing and should be harrowed in before seeding to legumes. Directions for building a home-made lime spreader are given.

10. Lime requirement tests, when needed, may be obtained through the county agent's office or the Soils department of Oregon Agricultural Experiment Station, provided soil samples are collected and submitted according to directions.

Prices given in a circular by State Lime Plant, Salem, Oregon, are:

In bulk by truck..............$4.75 per ton f.o.b. Salem.
Sacked..............................$5.75 per ton f.o.b. Salem.

(Terms: Two per cent discount for cash; or four months time without interest, after which 6 per cent will be charged; covered by trade acceptance [note]).

Freight per ton to Albany, $0.60; Eugene, $1.00; McMinnville, $0.70; Hillsboro, $0.90; Toledo, $1.20; Marshfield, $1.70; St. Helens, $1.30; Astoria, $2.10.

Liming Western Oregon Soil

By

R. E. Stephenson

and

W. L. Powers

THE use of limestone as a soil treatment is a familiar practice over almost the entire eastern half of the United States. In the western half of the country the practice is known only locally. The reason is found largely in the difference in precipitation in the two sections of country. In general, soils in humid areas need liming, while soils in arid and semi-arid sections do not need such treatment. Western Oregon, and especially the Willamette Valley and the Coast counties, are decidedly humid, and it is the soils in this part of the state that are most in need of liming. Little or no lime is needed or used on soils in any other section of Oregon.

Why soils need liming. Experience and experiments indicate that liming will be helpful (1) on soils that are found to be acid, (2) on soils of medium fertility, (3) on soils of heavy texture; and (4) especially where legumes are to be grown.

The primary purpose of applying lime to a soil is to correct acidity. Lime sweetens the soil so that favorable bacteria may develop and aid in making plant nutrients available for the growing crop. Lime aids proper development of legume nodule bacteria. Lime may also combine with some materials already in the soil to make them more readily available for plant nutrition. Liming will increase the concentration of calcium, which is an essential plant nutrient, the concentration of which may be unfavorably low in certain soil solutions for best growth.

Lime may tend to make heavy soils more friable, thus aiding aeration, cultivation, and drainage. Lime is supposed to condition the plant root membrane for absorption of nutrients and to neutralize acids formed within the plant. Lime may tend to conserve the soil against deterioration or loss of nutrient (base) absorbing capacity.

Lime in soils. Comparatively few humid soils contain limestone or $CaCO_3$. Practically none is found in Western Oregon. The lime which most of these soils contain is already in combination with the complex soil minerals known as acid silicates. Acid silicate is a chemical name used to describe the clay now often called also soil colloid. Though no Western Oregon soils contain free limestone all, however, contain lime in combination with the clay material. It is this lime which comes into solution in the soil moisture and which supplies growing crops. Soils may remain near neutrality and yet contain only this combined form of lime. Some very fertile soils contain only this form of lime. Poor acid soils either never possessed a sufficient amount of the combined lime, or it has been gradually lost by leaching until high acidity has developed.

Cause of soil acidity. Soil acidity is a more or less general term applied to any soil which may be benefited by the use of lime. Liming, likewise, is a general term used to indicate the application of any material applied to the soil to correct acidity.

Acids are best known by their sour taste, and tasting was once employed as a method to determine an acid soil. Acid soils may not necessarily taste sour, however, though they possess other properties characteristic of acidity.

Soils become acid or sour due to severe leaching. Hence their prevalence in humid climates. For the same reason, the higher the rainfall, the more severe is the leaching and development of acidity. (See the accompanying map of Oregon, page 20, in which precipitation and the most acid sections of the state are shown.)

Figs. 1 and 2. Effect of lime on vetch and oats, Lincoln county. Above, unlimed plot where vetch failed. Below, increased hay yield of one ton per acre on limed plot. On this land lime is essential to production of legumes and maintenance of soil nitrogen and humus. Lime was effective here for five years.

As water falls on the fields and passes through the soil, it takes with it the common soil bases; namely, calcium, magnesium, potassium, and sodium. These bases, with the exception of sodium, are essential plant nutrients. Calcium in particular is very important, not only as a nutrient, but as a soil and plant conditioner, serving somewhat the same purpose in the soil as a tonic to the individual. It is in solution in normal soils in higher concentration than the other nutrients, and is consequently lost by leaching more rapidly than the other bases; i.e., potassium and magnesium. The amount lost varies from a few pounds per acre annually, in soils that have already lost most of this nutrient, to several hundred pounds per acre annually in soils rich in lime.

In Table I is shown the loss of calcium in the percolate from lysimeters used to study two typical Oregon soils. The data are the average of four years' results calculated to the limestone equivalent ($CaCO_3$) in pounds per acre to plow depth (2,000,000 pounds of soil).

*TABLE I. ANNUAL LOSS OF LIME ($CaCO_3$) IN WATER FROM DRAINAGE BINS
(Oregon Agricultural Experiment Station)

Soil	Treatment			
	1 Check	2 Lime and manure	3 Manure alone	4 Limestone alone
	lbs.	*lbs.*	*lbs.*	*lbs.*
Willamette Silt Loam	173	324	227	266
Dayton Silty Clay Loam	178	349	180	238

*Loss is expressed as pounds per two million pounds of soil.

A study of these data indicates that if leaching occurs under normal field conditions at a comparable rate, the soil-regulating base, calcium, is lost rather rapidly. As this calcium is removed in the drainage water, there remains a constantly increasing amount of insoluble acid clay material in the soil. This clay, formerly made sweet and favorable to the growth of plants by its combination with calcium, is now sour and a much less favorable medium for the growth of many agricultural crops. The first loss of calcium produces only a mild effect, and only the most sensitive crops may show injury, but in time the sour condition develops to so marked a degree that many farm crops may be injured by the condition. The soil is then badly in need of lime to furnish a new supply of calcium to combine with the acid clay and thus render it again sweet and wholesome for the growth of farm crops.

Where acid soils are found. Sour soils may be found in any section where rainfall is sufficient to produce appreciable leaching. As rainfall increases, leaching to remove bases likewise increases and, roughly speaking, the degree of acidity increases with increased rainfall. Reference to the map (page 20) indicates this to be true, although the degree of acidity developed in different sections of Oregon is not shown in detail. The most acid soils of the state have been found along the Coast, and especially in the northern section of the coastal region, where rainfall is heaviest. In general, the recent river-bottom soils in Western Oregon are less leached or acid and give less response to liming. The old Valley filling soils of the Willamette region give fair response to liming, especially where needed tiling has been installed. The "red hill" lands usually show relatively large lime requirements and give rather marked response to lime applications.

There is, however, a great variation in the degree of acidity developed in any locality, due to the nature of the soil itself and to the general farm practice. Nature made some soils more deficient in calcium (the element supplied when limestone is added) than others. Some farmers likewise use a better system of farming to prevent leaching losses. Some farmers return more calcium to the soil in the form of crop residues than others. All crops remove calcium from the soil, the legumes an especially large amount. Each ton of alfalfa grown removes the equivalent of about 70 pounds of limestone. The constant sale of alfalfa hay would therefore exhaust the calcium of the soil, while feeding and return of the manure to the soil would remove relatively little. The use of certain commercial fertilizers, such as superphosphate, constantly renews the supply of calcium in the soil, though "super" has no neutralizing value. Other fertilizers, such as ammonium sulfate, may gradually increase the acidity of the soil. (It should not be inferred, however, that ammonium sulfate is not a suitable fertilizer.) In general, any farm practice which exhausts fertility increases the need for lime, and the poorest soils are most in need of liming. Synthetic fertilizers are frequently acidic. The use of fertilizer having a basic residue is helpful on acid soils.

Effect of acidity. The general result of a high degree of soil acidity is to make the soil less suited to the production of common farm crops. This is due to various direct and indirect effects. All plants need calcium as a nutrient, and very acid soils are so depleted that they no longer supply this nutrient in adequate quantities. Consequently, those plants such as alfalfa and legumes in general, which are heavy lime feeders, are most sensitive to an acid condition. Alfalfa is so sensitive to this condition that it usually fails to grow in highly acid soils low in available calcium.

It is believed by many also that legumes do best on soils well supplied with lime because the legume organism demands a sweet soil. On sour soils the organism is either absent or is so weakened that it fails to inoculate the roots of the plants, and under such conditions the legume, like grasses or other non-legumes, must obtain nitrogen directly from the soil. The plant then suffers from nitrogen starvation and makes only a sickly yellow growth, or finally dies.

Acidity may affect the availability of other nutrients than calcium. Phosphate, especially, may be rendered insoluble and unavailable on acid soils. This is probably the result of phosphate precipitation by iron and aluminum, which are often brought into solution rather profusely by the development of high acidity.

In general, all nutrients are rendered less available to those crops which are appreciably retarded by the acid condition. The weakened plant is less able to take up and assimilate such nutrients as are in solution, due to the diminished root system and generally retarded functions of the plant.

Not only the higher plants, but also many of the lower organisms of the soil, including the bacteria bringing about changes favorable to plant growth, are retarded or seriously injured by acidity. The most important non-symbiotic nitrogen-fixing organisms (azotobacker) are not found in highly acid soils. These organisms do grow in soils more acid than pH 6.0. There is less biological action in general in acid soils, an unfavorable condition for crops, since such action is essential to destroy soil toxins and to bring essential nutrients into solution.

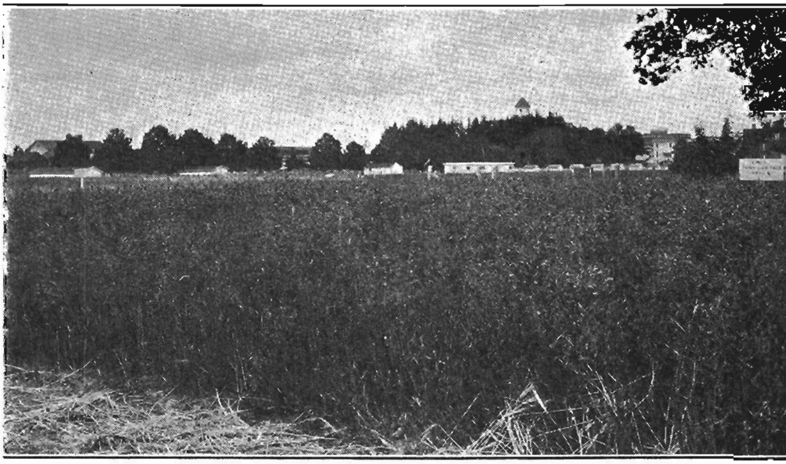

Fig. 3. Limed. Barley yield 1922 was 65 bushels per acre.

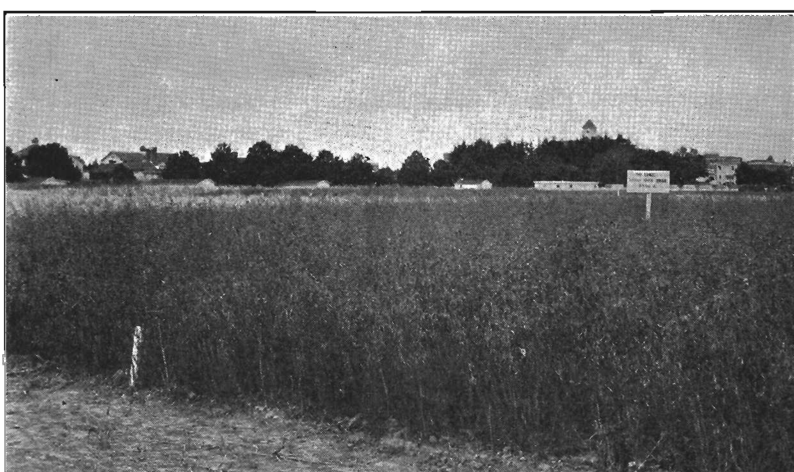

Fig. 4. No lime. Barley yield 1922 was 55 bushels per acre. Oats and vetch 1923 yielded a half-ton increase, due to lime.

Measuring acidity. In general, there are two kinds of acidity in soils: (1) the soluble, ionized, or active portion which causes the injury to plants and soil organisms; and (2) the insoluble, inert acidity which causes no immediate trouble, but simply indicates the extent to which calcium has been removed by leaching.

Defining the harmful or active acidity is accomplished by the use of a mathematical scale. The degree of acidity is designated as pH, which is an expression for concentration of acid hydrogen, this element being the only true acid. Neutral or sweet soils are designated by the number 7, which is written pH7. This expression indicates that the soil is no more acid than pure water, the best illustration of neutrality. All numbers below 7 indicate acidity. Thus, pH6 indicates one degree of acidity; pH5, two degrees. Likewise, there are fractional degrees, as pH5.5. Numbers above 7 indicate alkalinity, the opposite condition from acidity. Thus pH8 represents one degree of alkalinity. It should be stated, also, that highly productive soils rarely run below pH5.5 or above pH8.5. Extremely acid soils may run below pH4, while soils troubled with black alkali may run above pH10.

Since it is very important to know the degree of acidity, simple methods have been devised for its measure. A very simple method is by the use of indicators which have different colors, with different degrees of acidity. By placing the moistened soil in contact with a suitable indicator and comparing the color produced with a standard color chart, the pH may be determined. Field sets are put up which are convenient and satisfactory for use. In the laboratory the measure may be more accurately made by the use of electrometric methods.

For practical purposes, it is not necessary to measure the insoluble and inert acidity. It is this kind of acidity, however, which enables soils to take up and hold large amounts of lime against leaching. Likewise, in correcting acidity by special treatment, it is necessary to satisfy at least part of the inactive acidity in order to reduce the active acidity to a point more favorable to crop growth. It is not possible to neutralize the one form entirely independently of the other.

Determining lime requirement. The more common field methods for testing acid soils measure what is termed the lime requirement, which is a very indefinite quantity. For this purpose, the Truog method is much used. The procedure is familiar to those accustomed to making soil tests. A more convenient test for field use is the Comber or potassium thiocyanate method. This is a simple and satisfactory means of measuring lime requirement on most soils. Such lime requirement methods when properly standardized serve the very necessary purpose of indicating roughly the need for lime on acid soils.

It is not necessary to neutralize all the acid in soils to prepare them satisfactorily for most farm crops. Even for alfalfa, when the soil is in a good state of general fertility, a reaction expressed by pH6 is quite satisfactory.

Correcting acidity. To neutralize acidity requires treating the soil with some alkaline material. Limestone is most commonly used. The reaction is not extremely rapid under field conditions, for the reason that it is difficult to bring the soil and lime into sufficiently intimate contact. If lime can be applied to freshly plowed land and thoroughly worked into the soil by tillage methods, it is a decided advantage. Likewise, lime applied several months in advance of the seeding of a legume is an advantage.

Soils of the same degree of acidity do not necessarily have the same need for correction. As a rule, soils of high fertility may indicate an appreciable amount of acidity without any serious results to most crops. A soil in a low state of fertility may be badly in need of liming, even though the degree of acidity appears to be no greater than in the fertile soil. This indicates that other factors, rather than the acid itself, may be partly responsible for non-production in acid soils.

A very effective way to overcome the indirect results of acidity is to build up general fertility by rotating crops, adding organic matter to supply humus, and making wise use of commercial fertilizers. Organic matter itself will, to a limited extent, overcome the acid condition of the soil.

Liming materials. There are several alkaline materials that are useful in correcting acidity. These materials in nearly every case, however, owe their value to the lime which they contain.

But lime is a very general term, and is often loosely used. Thus there is lime carbonate ($CaCO_3$), lime sulfate ($CaSO_4$), lime silicate ($CaSiO_3$), lime hydrate ($Ca(OH)_2$), and caustic lime (CaO). Only three of these forms are suitable for correcting acid in soil; the carbonate, hydrate, and oxide. The sulfate and silicate are of little help to correct acidity.

The most common and generally satisfactory form of lime for field use is the carbonate. It is usually cheaper and more convenient to handle. In neutralizing value, however, 100 pounds is equivalent to only 74 pounds of hydrate or 56 pounds of oxide. Where freight is a very important item, it is conceivable that the least bulky material might be more economical. It is rather unpleasant, however, to spread either caustic lime or the hydrate.

Measuring neutralizing value. Since there are several waste products which contain some lime and which may be used on the soil, it is quite important that they be purchased on the basis of their neutralizing value.

Shells, which contain 90 to 95 per cent of lime, have a very high neutralizing value and are as suitable for use when finely ground as the limestone itself. Wood ashes, on the other hand, though they contain considerable lime, have a neutralizing value only about one-third that of pure limestone. Ashes may be worth a little more than their value on that basis, if unleached, due to the potash which they contain. Many limestones are of low grade, and should be either tested for neutralizing value or bought on a guarantee. Where freight charges are a consideration limestones of lower neutralizing value than 85 per cent should seldom be purchased. Waste products, such as the spent carbide residue from the acetylene lighting systems, have a high value.

Fineness of grinding. Before limestone rock, or shells containing lime, can be used to neutralize soils, they must be ground. The finer the material is ground, the more quickly it will act, and the lighter the application that will give immediate results. On the other hand, the coarser the material, the longer it will remain in the soil.

But since the lime is not effective until it goes into solution in the soil, there is a limit to the coarseness which will prove satisfactory. When limestone is ground so that all material passes a 10-mesh sieve (100 meshes to the square inch), it will usually prove satisfactory. Such stone contains enough fine material for quick action, and yet there is coarser material which remains longer, to maintain a sweetened condition. In cases where, for any reason, very light applications of 500 to 1,000 pounds per acre must be used the material should be both very high grade and very finely ground and flour-like. The action is then very rapid and a light application may have an appreciable effect.

Lime and fertilizer. Limestone does not in any way take the place of commercial fertilizers, as is sometimes believed. Since lime is most needed on a poor soil, it is often highly profitable to supplement the application with fertilizer. Since soils badly in need of lime are often also low in organic matter, a nitrogenous fertilizer may very profitably be used, sometimes even when a legume is to be grown. Highly acid soils are also nearly always low in available phosphorus, and for this reason a superphosphate could be profitably used with limestone. A separate application of the fertilizer should be made, however, rather than mixing it with the limestone, which mixing may produce less available phosphorus compounds.

Similarly, commercial fertilizers do not satisfactorily take the place of lime. Some fertilizers, however, either contain a little lime or leave an alkaline residue. In this class may be placed nitrate of soda, nitrate of lime, lime cyanamide, and basic slag phosphate.

Selection of crops for acid soils. It is sometimes impractical to sweeten sour soils with lime, and there is always the alternative of selecting a crop adapted to the acid condition. The following list is taken from Ohio State University Extension Service Bulletin 64, and shows the pH below which the various crops do not thrive well:

DEGREE OF ACIDITY CROP WILL TOLERATE

Reaction (pH) value	Crops
6.5	Alfalfa Sweet clover
6.0	Lettuce Cabbage Cauliflower Spinach Barley Sugar beets
5.5	Red clover Corn Wheat Cantaloups Timothy Canada field peas Kentucky blue-grass
5.0	Oats Soy-beans Cow peas Potatoes Tobacco Red Top Canada blue-grass Alsike clover Mammoth clover
4.5	Strawberries Watermelons Buckwheat Rye

The above figures should be considered only as an indication or rough guide. They may be used in a limited way, therefore, for correcting acid soils to produce a reaction favorable to crop growth. Few crops, however, are directly injured by sweetening a sour soil to near neutrality, although indirect effects may make it advisable to maintain a certain degree of acidity.

In some lime-deficient soils, especially certain highly acid low-lime peats, the use of lime to correct mal-nutrition rather than to correct acidity seems the dominant need. Some such soils, due to high buffering of the organic matter, may show little change in reaction after sufficient lime has been added to satisfy crop demands. On mineral soils, however, the addition of sufficient lime to get satisfactory results with legumes usually results in changing the reaction appreciably toward neutrality.

Effects of liming. The use of lime on acid soils increases directly the available supply of an essential nutrient, calcium (Table II).

TABLE II. CHEMICAL EFFECTS OF LIMING THE OREGON AGRICULTURAL EXPERIMENT STATION ROTATION PLOTS
(Willamette Silty Clay Loam)

Treatments	Plot and depth	Replaceable calcium pounds per acre	pH	Comber test for acidity	Replaceable hydrogen equivalent to $CaCO_3$
3 Tons $CaCO_3$	17a Surface	6,960	6.6	Very slight	3,520
	17b Subsurface	5,040	6.4	Medium	3,520
	17c Subsoil	8,160	6.5	Medium	....
Check	18a Surface	5,840	6.1	Strong	5,680
	18b Subsurface	4,880	6.3	Medium	3,520
	18c Subsoil	8,640	6.7	Medium	....
6 Tons $CaCO_3$	19a Surface	9,600	7.2	None	2,880
	19b Subsurface	5,360	6.3	Slight	4,200
	19c Subsoil	9,280	6.8	Strong	....
9 Tons $CaCO_3$	20a Surface	11,660	7.7	None	920
	20b Subsurface	5,680	6.8	Slight	....
	20c Subsoil	8,480	6.7	Strong	....
Check	21a Surface	6,960	6.5	Medium	4,320
	21b Subsurface	5,520	6.2	Medium	....
	21c Subsoil	8,000	6.6	Medium	....
12 Tons $CaCO_3$	22a Surface	12,000	7.3	None	1,160
	22b Subsurface	5,120	6.3	Medium	....
	22c Subsoil	8,480	6.6	Strong	....

Note:
Calcium replaced with N/20 HCl.
Hydrogen replaced with N/10 Calcium acetate.

Lime is credited also with the indirect effect of increasing the availability of other essential nutrients in the soil. Thus the potassium and phosphorus nutrition of the plant may be improved by the use of lime.

Lime has a very marked effect in stimulating the action of beneficial soil micro-organisms. This increased action both directly and indirectly brings more nutrients within reach of the growing crop. Since micro-organisms are active principally under the presence of abundant organic matter, it is very important to build up the organic content of the soil to receive full advantage of the biological benefit. Nitrogen is made available almost wholly by soil organisms, but it is self-evident that organic matter well supplied with nitrogen is essential before such benefit occurs. Manure and every form of crop residue, and especially legume residues, should be fully utilized. For the effect of lime on nitrification, see Table III (data by W. V. Halversen).

TABLE III. PARTS PER MILLION OF NITRATE IN FALLOW PLOTS

	April 13, 1923	June 11, 1923	June 27, 1923	July 11, 1923	July 26, 1923	Aug. 8, 1923	Nov. 5, 1923	Mar. 19, 1924	April 23, 1924	May 26, 1924
0 lime	1.7	9.2	8.6	15.0	12.7	9.7	14.1	1.3	3.1	8.0
2 T. lime per A.	3.2	8.8	7.4	14.1	8.1	14.8	23.3	2.1	3.5	6.0
4 T. lime per A.	3.4	14.7	10.7	13.6	23.3	16.1	18.6	2.6	5.5	12.3
6 T. lime per A.	4.1	17.8	12.3	22.5	19.9	29.2	26.1	3.2	7.8	12.8

Besides the chemical effect of lime, there may be very appreciable effects upon the physical condition of the soil. Heavy soils that are sticky when wet and hard when dry are made more open and friable. Thus drainage is improved and tillage is made easier. This type of improvement is still more marked when lime is used to grow a legume, such as clover, which has a decided loosening effect upon compact soils.

Applying lime. Limestone can be applied at any season of the year and upon any crop without injury. A good time to do the liming is when it is most convenient. Caustic limes, however, such as the hydrate or the oxide, should not be applied to green and growing crops since burning may occur from contact. Preferably, lime should be applied at a time when it can be thoroughly cultivated into the soil.

Lime may be spread by hand with a shovel. It is more convenient and easier to do a good job, however, if a spreading machine can be used. A very satisfactory spreader is the end-gate type made to attach to the rear end of the wagon-box. There is also the grain-drill type—a long box spreader supported by two wheels. These give good satisfaction. The manure spreader may be used to distribute lime if some straw is placed in the bottom of the spreader to prevent lime from sifting through.

Home-made limestone spreader. Farmers sometimes construct their own lime spreaders, and specifications for a home-made sower are therefore included here.

Make a hopper like that of an ordinary grain drill—8¼ inches apart at the top—all inside measurements. Truss the sides with ⅜-inch rods running from the bottom at the middle to the top of the ends of the hopper. Make the bottom of the hopper 5 inches wide in the clear. This main or upper bottom should be ⅛-inch sheet iron. Cut in the bottom a row of rectangular holes 2 inches wide and 3 inches long. The center of the first hole should measure 4½ inches from the end of the bottom, bringing the others 6 inches between centers.

A second bottom with holes made the same size, shape, and space as those of the main bottom, should be snugly fitted under the main bottom, but arranged to permit shifting so that the holes register in any degree or completely close, as desired. The supports for the movable second bottom should be bands of strap iron 18 inches apart, carried from one side to the other under the hopper to strengthen it. The movable lower bottom should be smooth, seasoned hardwood 1 inch thick, reinforced with strap iron to prevent splitting or warping.

To this wooden bottom firmly attach a V-shaped arm with the point of the V extending 1 inch in the rear of the hopper. The point of the V-shaped arm should have a ½-inch hole in which the lower end of a strong lever may be dropped. The lever should be bolted securely to the side of the hopper about 4 inches above the bottom. This lever, extending above the top of the hopper sufficiently to afford a good hand-hold, serves as the shift lever which regulates the size of the openings by moving the wooden bottom back and forth. A strap-iron guide with holes through which a small bolt or key may be thrust prevents the lever from shifting from the position set and also regulates the feed.

Make a frame for the hopper, with a tongue to it, similar to the frame or an ordinary grain drill. Get a pair of old mowing-machine wheels with the ratchets in the hubs and with pieces of round axles long enough to pass through the bearings bolted to the under side of the frame and through the ends of the hopper. To those round axles weld a 1½-inch

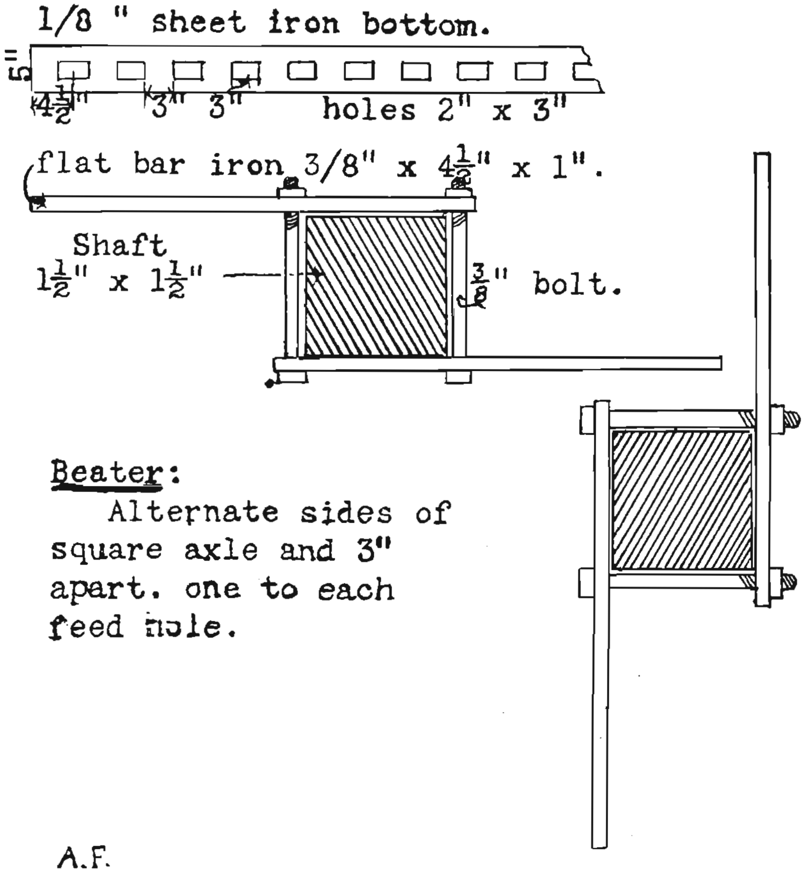

Fig. 5. Details of limestone spreader.

square bar of iron the length of the hopper. To this square axle, above each opening in the permanent bottom, attach two short arms or feeders. These feeders are pieces of $\frac{3}{8}$-inch by 1-inch by $4\frac{1}{2}$-inch flat bar iron bolted to opposite sides of the axle. They should alternate on the sides of the square axle over the holes in the bottom. This makes a reel that is positive feed, so adjusted that it revolves freely between the sides of the hopper but almost scrapes the bottom at each turn. The accompanying illustration shows the arrangement of holes in the bottom and the plan for attaching the feeder arms to the axle. Any farmer with some mechanical skill can construct this limestone spreader with little cash outlay except for the blacksmithing. The spreader is strong, servicable and cheaply made.

Liming the lawn. Unless a clover lawn is desired, lime should not be used on the lawn. Creeping bent grass, which is very commonly used in Oregon, is not usually benefitted by the use of lime. Lime has the objection that it encourages certain lawn weeds, especially dandelion and plantain. To produce a weedless lawn, select a grass mixture adapted to acid soils, and not only refrain from liming but use a fertilizer, such as ammonium sulfate, which will increase acidity.

To grow clover and Kentucky blue-grass lawns, however, lime should be used. For those who burn wood, there is often sufficient wood ashes for the lawn.

Liming the garden. Many garden crops are benefitted by liming. Often the garden becomes a dumping ground for the furnace ashes. Wood ashes are a highly satisfactory form of lime, and yet many gardens are probably injured by their excessive use. Dumped in piles as the ashes often are year after year, a condition developes decidedly unfavorable to plants. To avoid this trouble, give care to obtain better distribution of the ashes and less frequent applications, lest a good treatment be overdone.

Lime in composts. Compost comparable in value to stable manure can be made from straw, leaves, weeds, and other refuse. To get quick rotting, limestone, 50 to 100 pounds for each ton of straw or other material, is needed to neutralize acids that may be produced. If not neutralized, the acids retard rotting. (About 75 pounds of ammonium sulfate and 25 to 50 pounds of superphosphate for each ton of straw is needed also to get quick rotting.)

Chicken grit. Coarsely ground limestone (one to five millimeters) is used as chicken grit. For this purpose any high calcium lime, whether calcium carbonate, marble, or oyster shells, is about equally satisfactory. Magnesium limes should be avoided. Dr. J. R. Haag states that additional grit, such as small river gravel should be provided also.

Results from liming. Lime should show most results on legumes and on soils that are quite acid. At the College Station at Corvallis, limestone has been used at various rates on the Willamette soil series. This soil is not very acid and is in a comparatively high state of fertility, so only moderate response from lime would seem probable. The results are shown in Table IV.

TABLE IV. LIMING IN RELATION TO CROP YIELDS
(WILLAMETTE SERIES)

Rotation P: corn, (manured or complete fertilizer), grain (fall), vetch, grain (spring)

Plot No.	Treatment	1921 Corn per acre	1926 Corn per acre	Average per acre	Gain	1918 Barley per acre	1919 Spring barley per acre	1922 Barley per acre	1924 Barley per acre	1927 Barley per acre
		Tons	*Tons*	*Tons*	*Tons*	*Bu.*	*Bu.*	*Bu.*	*Bu.*	*Bu.*
D 19	No lime	2.5	6.3	4.4	....	8.3	15.6	58.4	37.50	30.78
C 17	L. 3 T.	5.4	6.00	5.7	*1.3	....	12.4	66.5	29.12	....
C 19	L. 6 T.	5.7	6.35	6.53	*2.13	....	19.6	52.5	51.25	47.42
C 20	L. 9 T.	6.8	7.30	7.00	*2.6	....	19.6	66.7	50.83	42.02
C 22	L. 12 T.	6.0	6.25	6.12	*1.72	....	18.6	72.3	54.16	37.44
26 checks Grain continuous		24.3+	31.4+	27.85+	....	....	8.2	48.7	27.0	12.8

*Green weights.

Recommendations. Soils should not be limed without first testing to determine the need for lime. It probably would not prove profitable to lime soils the pH of which is above 6. At pH5.5 to 6.0, it may be necessary to lime in order to get good stands of alfalfa. By carefully maintaining a high state of general fertility, however, clover can probably be grown quite satisfactorily at these reactions without the use of lime. Below pH5.0, clover and many other crops will be greatly benefited by liming.

Such figures can be used only as general indications, however. Much depends upon the soil type. Such fertile types as Chehalis and Willamette are less likely to need lime than types like Dayton, Holcomb, and Carlton that have decidedly unfavorable physical properties to overcome.

After testing the soil to decide whether the acidity is high or low, it seems practical to choose between only two approximate rates of application. It is not practical to spread limestone thinner than at the rate of about one ton per acre. On any soil for which less than one ton would prove sufficient, the same money could probably be spent more profitably for commercial fertilizer, such as superphosphate for grains. The super would also help the clover.

Because of the cost of material, including freight which amounts to considerable on any appreciable haul, it is not likely to prove profitable to apply more than two tons per acre. For highly acid soils, therefore, this should be the economic limit. Practice has shown that this rate of application will insure a stand of clover on soils which show a lime requirement as high as 6 tons per acre. Most Oregon soils run much lower than this, and very few run as high.

Soil once limed need not be relimed until it again shows the need, by poor growth of clover or other developments. The length of time for which one treatment should suffice will vary from 6 to 15 years. The heavier the application, the longer it should last, but less applied more frequently is probably advisable.

To make the best use of lime, use a crop rotation in which a legume, such as clover, comes once in 3 to 5 years. Feed as much of the crop as possible, and return the manure. Supplement the manure with superphosphate, and burn nothing that can be applied to the land.

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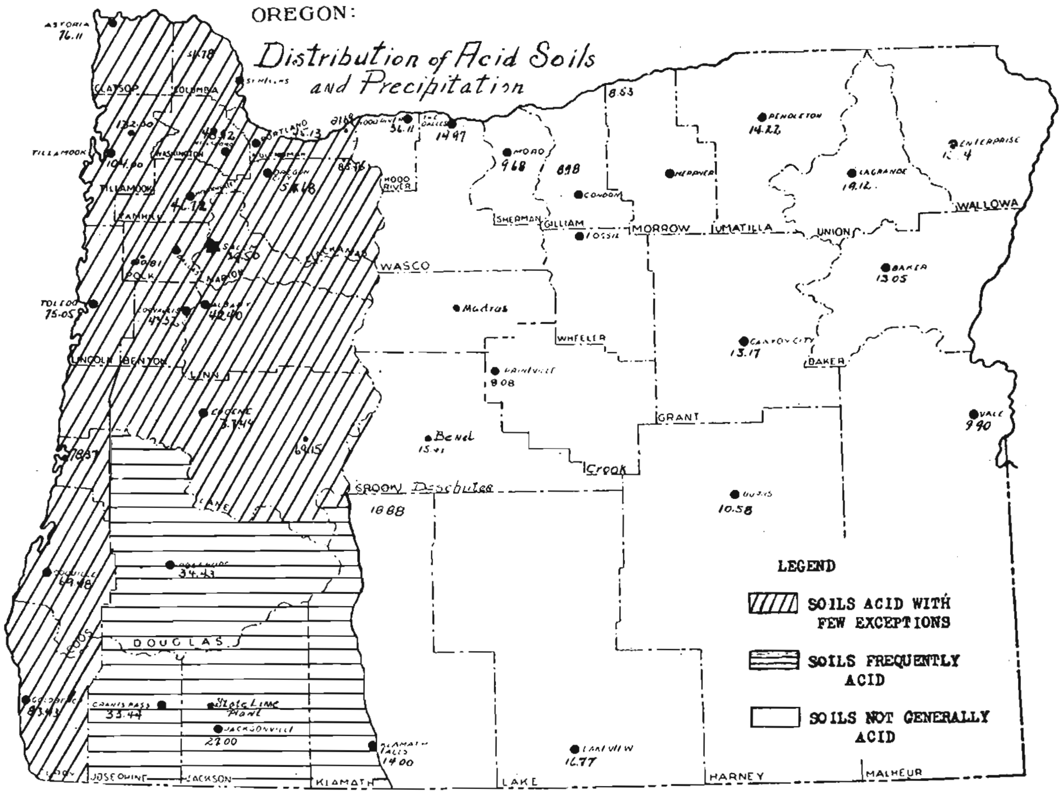
OREGON:
Distribution of Acid Soils and Precipitation
ASTORIA 76.11
CLATSOP
COLUMBIA
TILLAMOOK
104.00
132.00
WASHINGTON
PORTLAND
HOOD RIVER
THE DALLES
14.97
MORO
9.68
8.98
CONDON
PENDLETON
14.22
HEPPNER
LAGRANDE
19.12
ENTERPRISE
WALLOWA
SHERMAN
GILLIAM
FOSSIL
MORROW
UMATILLA
UNION
BAKER
13.05
WASCO
Madras
WHEELER
CANYON CITY
13.17
PRINEVILLE
8.08
GRANT
YAMHILL
POLK
MARION
CLACKAMAS
TOLEDO
75.05
ALBANY
42.40
LINCOLN
BENTON
LINN
EUGENE
LANE
Bend
15.41
Crook
Deschutes
18.88
BURNS
10.58
VALE
9.90
LEGEND
SOILS ACID WITH FEW EXCEPTIONS
SOILS FREQUENTLY ACID
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DOUGLAS
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GRANTS PASS
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JACKSONVILLE
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