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Liming Western Oregon Soils

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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, especially those of the Willamette Valley and Coast counties, are acid and in need of liming. Recent bottom-land 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 200 to 300 or more pounds a year and a 5-ton crop of alfalfa removes between 300 and 500 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 microorganisms, 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 74 pounds of hydrated lime or 100 pounds of good ground limestone. The solubility rate increases with fineness, and liming material should at least be ground fine enough for all to pass through a 10-mesh screen. It would be desirable to grind it sufficiently fine so that 60 per cent will pass a 50-mesh screen and 30 per cent will pass a 100-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 1 to 2 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.

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

Liming Western Oregon Soils

By

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and

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SOILS in humid areas often need liming, while soils in arid and semi-arid sections do not need such treatment. Western Oregon, especially the Willamette Valley and the Coast counties, is decidedly humid, with open winters that favor leaching; the soils in this part of the state 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 acid, (2) on soils of medium to low fertility, and (3) especially on soils where legumes are to be grown.

The primary purpose of applying lime is to correct acidity. Lime sweetens the soil so that favorable bacteria may develop and aids 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, such as phosphates, to make them more readily available for plant nutrition. Liming will increase the concentration of calcium, an essential plant nutrient, which may be unfavorably low in acid soil solutions.

Lime tends to make heavy soils more friable, thus aiding granulation, aeration, cultivation, and drainage. Lime conditions the plant-root membrane for absorption of nutrients and neutralizes acids formed within the plant. Lime conserves the soil against deterioration or loss of nutrient (base) absorbing capacity. Lime favors decomposition of organic matter and liberation of plant nutrients. Lime improves the nutritive value of food and forage crops grown on acid soils.

Cause of soil acidity. Soil acidity is a more or less general term applied to any soil that may be benefited by the use of lime.

Soils become acid or sour because of leaching, which is accelerated by cultivation. Acid soils and leaching prevail 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, back cover page, on which precipitation and the most acid sections of the state are shown.) Use of acid-residue fertilizers and removal of lime by crops increase soil acidity. Any acid decomposition products in the soil increase acidity.

A mean annual temperature of 11° C. (the approximate average at Corvallis) and 25 to 27 inches of rainfall results in a neutral soil. About 10 inches of additional rainfall produces one pH change toward increased acidity. The normal rainfall at Corvallis is 40.27 inches. Under these conditions the older soils should show an acidity of about pH 5.5, which is near the average of the leached hill formations. Soils along the Coast, with 50 to 60 inches of rainfall, have correspondingly higher acidities.

In Table 1 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).

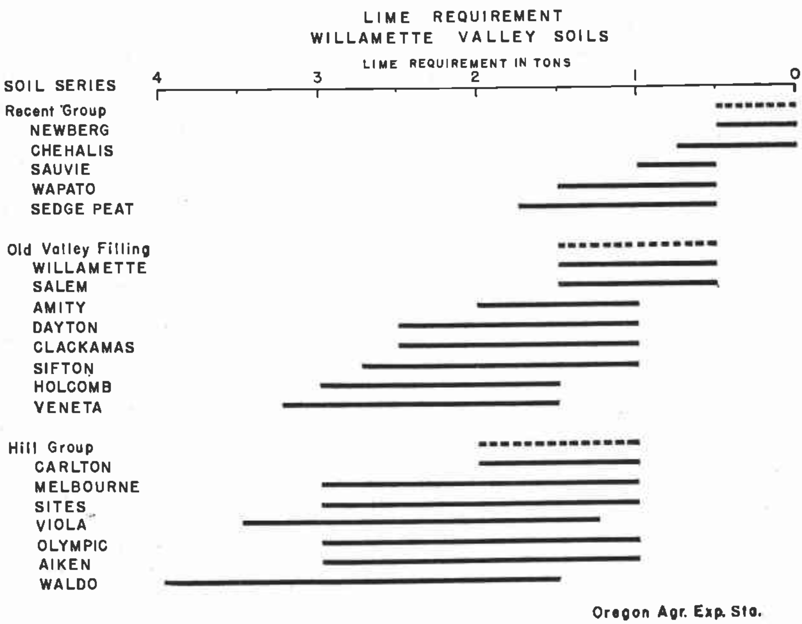
*Table 1. ANNUAL LOSS OF LIME ($CaCO_3$) IN WATER FROM DRAINAGE BINS
(Oregon Agricultural Experiment Station)

Soil	Treatment			
	1 Check	2 Lime and manure	3 Manure alone	4 Limestone alone
	Pounds	*Pounds*	*Pounds*	*Pounds*
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 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 medi-

CHART I



um 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.

Where acid soils are found. 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. See Chart I.

Effect of acidity. Plants such as alfalfa and legumes in general, which are heavy lime feeders, are most sensitive to an acid condition. The root-nodule bacteria are even more sensitive to acidity. Alfalfa is so sensitive to acid condition that it usually fails to grow in highly acid soils low in available calcium. Removal of three tons of alfalfa hay per acre each year for 10 years will remove as much lime as 1 ton of limestone supplies.

Legumes do best on soils well supplied with lime, partly 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. Such plants suffer from nitrogen starvation and make only a sickly yellow growth, or finally die.

Acidity may affect the availability of nutrients other 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. The effect of acidity upon soluble and available nutrients is indicated by Chart II (Virginia Station Bulletin 136. Reproduced by permission of the copyright owners).

CHART II

Relation of soil pH to availability of nutrients for plant growth.

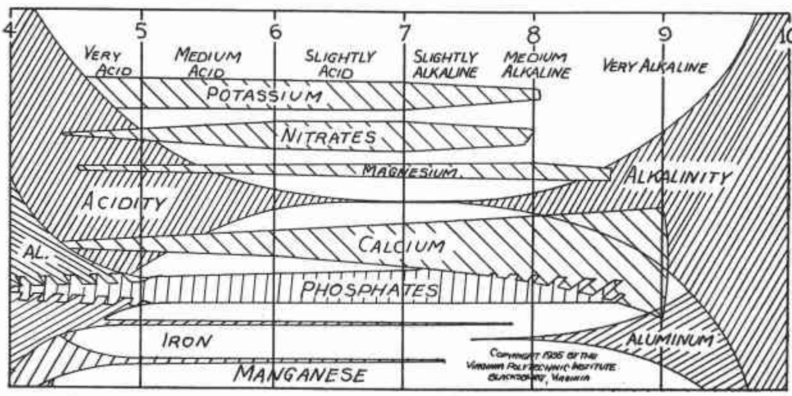


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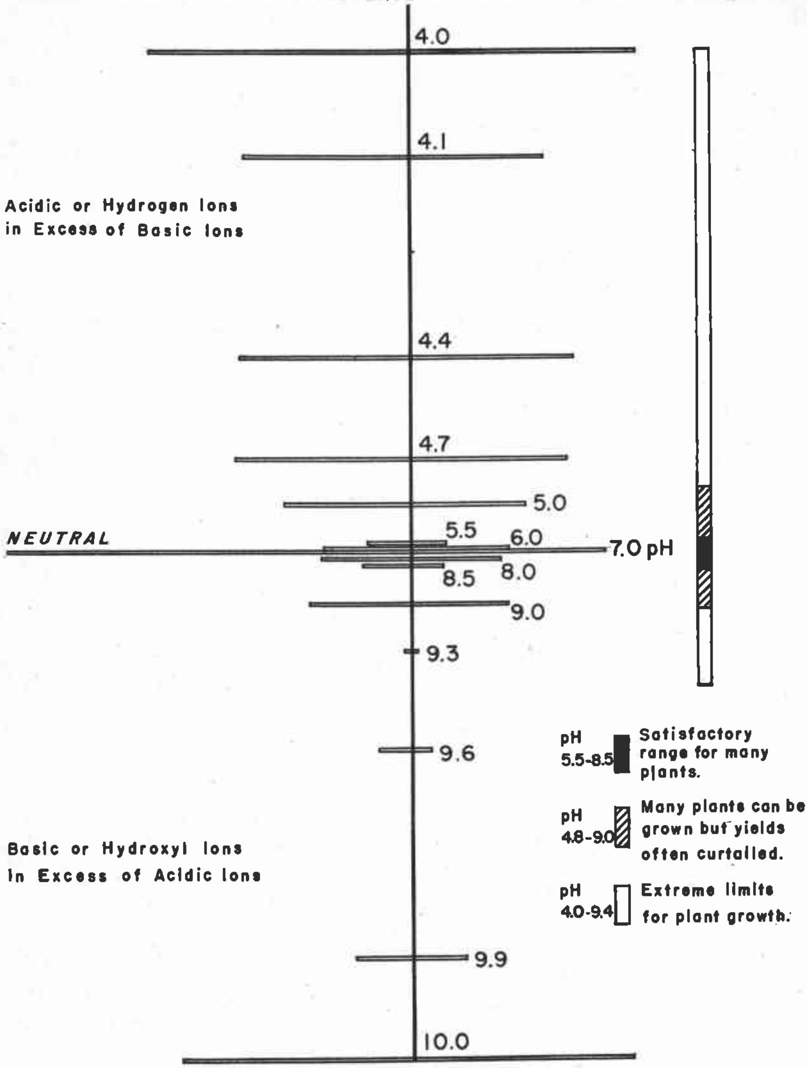
CHART III

THE pH SCALE AND RANGE FAVORABLE TO PLANT GROWTH

ALSO SHOWING GEOMETRIC INCREASE IN ACIDITY WITH DECREASING pH



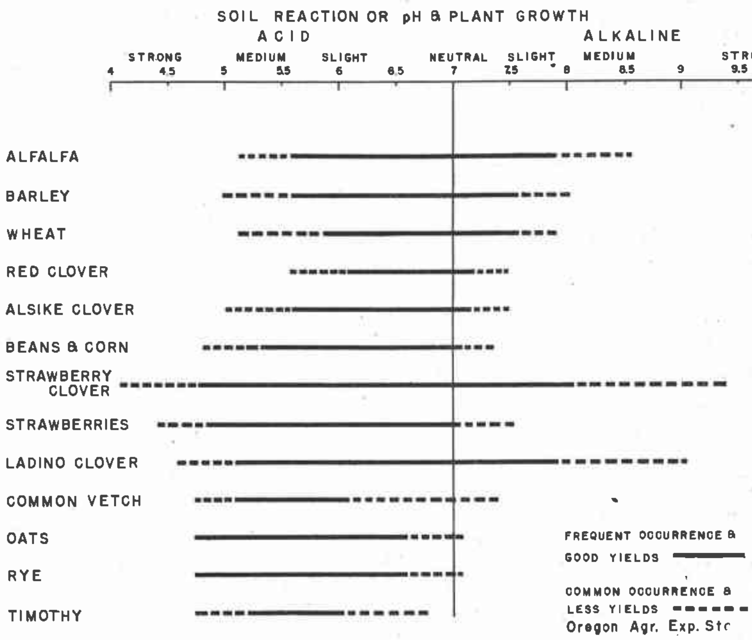
SCALE: One pH on either side of Neutrality is indicated by one mm. The range from 5 to 6 or from 8 to 9 is indicated by 10 mm. The range from pH 5.0 to 6.0 and from pH 9.0 to pH 10 is indicated by 100 mm.

Measuring acidity. There are two forms of acidity in soils: (1) the soluble, ionized, or active portion; and (2) the insoluble, inert acidity that indicates the extent to which calcium has been removed by leaching.

The degree of acidity is designated as pH, which is an expression for concentration of acid hydrogen, which is the only true acid. An atom of hydrogen with a slight positive electrical charge is called an ion, and is said to be ionized. Neutral or sweet soils are designated by the number 7, which is written pH 7. 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, pH 6 indicates one degree of acidity; pH 5, two degrees. Likewise, there are fractional degrees, as pH 5.5. Numbers above 7 indicate alkalinity, the opposite condition from acidity. Thus pH 8 represents one degree of alkalinity. Highly productive soils rarely run below pH 5.5 or above pH 8.5. Extremely acid soils may run below pH 4, while soils affected with black alkali may run above pH 10.

The acidity intensity increases geometrically, but inversely, with the pH measurement. The pH 5.0 represents ten times the acidity of pH 6.0 and pH 4.0 represents ten times the acidity of pH 5.0. Increased acidity represented by 0.1 pH change or from pH 4.6 to pH 4.5 is ten times as great an increase as the similar change from pH 5.6 to pH 5.5, and 100 times as great an increase as the change from pH 6.6 to pH 6.5. A similar relationship is indicated in that the concentration of hydrogen ions doubles with each decrease of 0.3 pH in the reaction. See Chart III.

CHART IV



Use of enough lime to reduce the soil from pH 4.8 to pH 5.8 corrects ten times as much active acidity as would be corrected by an additional amount of lime to change the reaction from pH 5.8 to pH 6.8. Thus, a moderate amount of lime neutralizes the strongest acids of the soil and 1- to 2-ton applications per acre may be enough to put the soil into condition to grow legumes. These relationships may be observed by a study of Charts III and IV.

Since it is important to know the degree of acidity, simple methods have been devised for its measurement. One method is by the use of indicators that have different colors for 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 that are convenient and satisfactory for use are put up. In the laboratory, the measure may be made more accurately by the use of electrometric methods.

Before applying lime to the soil, it is helpful to measure the insoluble and inert acidity. The capacity of soils for this kind of acidity enables them to take up and hold large amounts of lime against leaching. In correcting acidity, it is necessary to satisfy a large 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 independently of the other. The total amount of inactive acidity is much greater than the amount of active acidity in the soil.

The Comber, or potassium thiocyanate method, among others, is used to determine the inactive acidity and to serve as a guide for the amount of lime to apply to acid soils, as shown on Chart V.

Liming materials. Lime is a very general term, and is often loosely used. Thus there is lime carbonate ($CaCO_3$), lime sulphate ($CaSO_4$), lime silicate ($CaSiO_3$), lime hydrate ($Ca(OH)_2$), and caustic lime (CaO). Chemists commonly limit the term "lime" to caustic lime (CaO). Only three of these forms are suitable for correcting acid soils, the carbonate, hydrate, and oxide. The sulphate and silicate are of little help in correcting acidity.

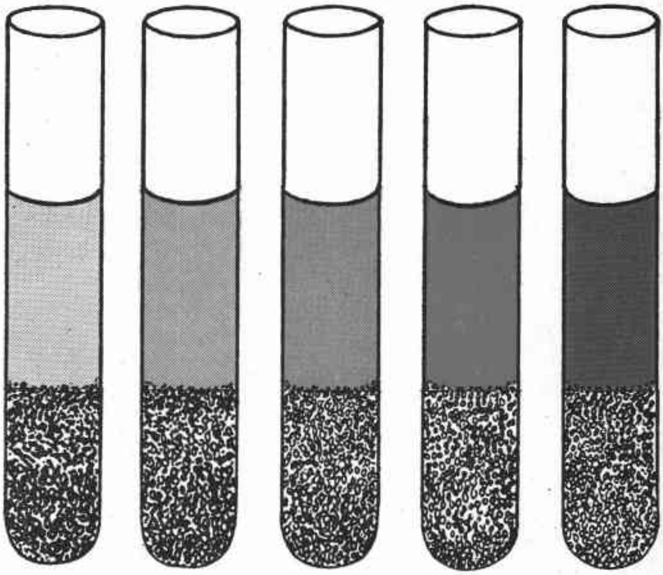
The most common and generally satisfactory form of lime for field use is the carbonate, which is usually cheaper and more convenient to handle than the other forms. In neutralizing value, however, 100 pounds of lime carbonate is equivalent to only 74 pounds of lime hydrate or 56 pounds of oxide. Where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

Neutralizing value. Since there are several waste products that contain some lime and that may be used on the soil, purchase on the basis of their neutralizing value is important.

Shells that contain 90 to 95 per cent of lime have a 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 to one-half that of pure limestone. Ashes may be worth a little more than their value on that basis, if unleached, because of the potash 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 neutralizing value lower 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, after the gaseous products have been eliminated.

CHART V

DEGREE OF ACIDITY
Emerson Method



	Very Slight	Slight	Medium	Strong	Very Strong
Good Soils	½	1 to 1½	2 to 2½	2½ to 3	4
Poor Soils	1	2	3	4	5

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 needed to produce immediate results. On the other hand, the coarser the material, the longer it will remain in the soil.

As the lime is not effective until it goes into solution in the soil, there is a limit to the coarseness that 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. Some advise that a reasonable requirement is that 60 per cent should pass a 60-mesh screen and 30 per cent a 100-mesh screen. Such stone contains enough fine material for quick action, and yet there is coarser material that remains longer, to maintain a sweetened condition. In cases where, for any reason, light applications of 500 to 1,000 pounds per acre must be used, the material should be both high grade and finely ground. The action is then rapid and a light application may have an appreciable effect.

Lime and fertilizer. Limestone does not 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. Soils badly in need of lime are often also low in organic matter and a nitrogenous fertilizer may be used very profitably. Highly acid soils are also nearly always low in available phosphorus, and superphosphate could be used profitably with limestone. A separate application of the fertilizer should be made, however, rather than mixing it with the limestone, since 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.

Effects of liming. The use of lime on acid soils increases directly the available supply of an essential nutrient, calcium (Table 2).

Table 2. CHEMICAL EFFECTS OF LIMING THE OREGON AGRICULTURAL EXPERIMENT STATION ROTATION PLOTS
(Willamette Silty Clay Loam)

Treatments Plot and depth	Replaceable calcium per acre	pH	Comber test for acidity	Replaceable hydrogen equivalent to $CaCO_3$
	Pounds			
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.

Since microorganisms are active principally in the presence of abundant organic matter, it is important to build up the organic content of the soil in order to receive full advantage of the biological benefit of liming. 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, especially legume residues, should be fully utilized. For the effect of lime on nitrification, see Table 3 (data by W. V. Halversen).

Table 3. 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 tons lime per acre	3.2	8.8	7.4	14.1	8.1	14.8	23.3	2.1	3.5	6.0
4 tons lime per acre	3.4	14.7	10.7	13.6	23.3	16.1	18.6	2.6	5.5	12.3
6 tons lime per acre	4.1	17.8	12.3	22.5	19.9	29.2	26.1	3.2	7.8	12.8

Applying lime. Limestone can be applied at any season of the year and upon any crop without injury. Preferably, lime should be applied after plowing, at a time when it can be thoroughly cultivated into the soil. From 1 to 2 tons per acre every 4 to 12 years is probably adequate. Lime may be spread by hand with a shovel. It is more convenient and easier to do well, 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 a 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.

Liming the lawn. Unless a clover lawn is desired, lime should not be used on the lawn. Creeping bent grass, which is commonly used in Oregon, is not usually benefited by the use of lime, and lawn weeds, especially dandelion and plantain, are encouraged. 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 sulphate, which will increase acidity.

Lime should be used, however, to grow clover and Kentucky bluegrass lawns. For those who burn wood, there are often sufficient wood ashes for the lawn.

Liming the garden. Many garden crops are benefited by the use of lime. 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. A condition decidedly unfavorable to plants develops where ashes are dumped in piles year after year. Care should be used to practice better distribution and less frequent applications of the ashes. Ashes used at the rate of 35 to 40 pounds a square rod are comparable to 1 ton of limestone an acre.

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 sulphate and 25 to 50 pounds of superphosphate for each ton of straw are needed also to produce quick rotting.)

Chicken grit. Coarsely ground limestone (1 to 5 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.

Table 4. REACTION RANGES FOR DIFFERENT PLANTS

	Optimum range	pH injuriously alkaline or acid
A. Thereon's results		
1. Alfalfa	pH 4.8–6.0	7.0
2. Cotton	pH 5.0–7.0	8.0
3. Cucumbers	pH 4.8–6.0	7.0
4. Barley	pH 4.5–7.0	8.0
5. Bermuda grass	pH 4.5–4.8	9.0
B. Arrhenius' results		
1. Timothy	....	9.0
2. Alfalfa, barley, birdsfoot-trefoil, and orchard grass	....	8.0
3. Alsike clover and sugar beets	....	7.5
4. Hop-lucerne, radishes, rutabagas, and wheat	....	7.0
5. Lupine, peas, and red clover	....	6.0
6. Oats	....	5.0
7. Flax and turnips	....	4.0
C. W. L. Powers' results		
1. Alfalfa	....	5.2–8.6
2. Hungarian vetch	....	4.5–6.3
3. Mint	....	4.0–7.0
4. Alsike clover	....	4.8–8.0
5. Ladino clover	....	4.2–9.5
6. Strawberry clover and alkali (Zawadki grass)	....	10.2
D. Tarr and Noble		
1. Wheat (maximum growth)	....	4.0
2. Soybeans	....	5.0
3. Corn	....	5.0
E. Salter and McIlvaine		
1. Wheat, soybeans, and alfalfa	....	5.94
2. Corn	....	5.16
F. H. P. Magnuson's results		
1. Zawadki's alkali grass	....	9.6+
2. White blossom sweet clover	....	9.0+
3. Meadow fescue	....	8.8
4. Alfalfa	....	8.4–8.6
5. Tall meadow oat grass	....	8.2
G. Joseph D. Haynes (Private Laboratory)		
1. Oranges	....	8.2
2. Lemons	....	8.0
3. Cotton	....	8.1
4. Barley	....	8.6
5. Wheat	....	8.3
6. Grapes	....	8.1
7. Beans	....	8.2
H. Hoaglund results (Concentration ranges)		
1. Barley seedlings	pH 3.5–8.4	....

Recommendations. To change the acidity of loam and silty clay-loam soils, one pH requires 3,000 to 3,500 pounds of limestone an acre. On the basis of these data from 1 to 2 tons of limestone will bring the reaction of most soils to pH 6.0 or 6.5, which is satisfactory for the growth of legumes. The graphs of Charts III and IV and the data of Tables 4, 5, 6, and 7, indicate favorable soil reactions for growing various crops. A soil test for acidity before liming will indicate whether the 1- or 2-ton application probably will prove adequate. Such fertile soil 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.

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 4 to 12 years. The heavier the application, the longer it should last, but lighter and more frequent applications are 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. Responses from the use of lime on Western Oregon soils are shown by the data in Table 8.

Table 5. RESPONSE OF CROPS ON SOILS* OF VARIOUS pH (ZIMMERLEY)
Virginia Truck Experiment Station Bulletin 91

Crop	pH range studied	pH range favorable to growth	pH giving highest yield
Sweet potatoes	4.9–6.7	5.0–5.5	6.7
Snap beans	5.0–7.0	5.3–6.0	5.6
Lima beans	4.4–6.8	5.2–6.8	5.9
Cabbage	4.3–6.9	6.0–6.2	6.0
Carrots	5.0–7.0	5.2–6.5	6.5
Collards	....	5.6–6.6	....
Edible cowpeas	4.5–7.1	5.9–6.2	5.9
Cucumbers	....	5.5–6.5	....
Eggplants	....	5.5–6.5	....
Kale	....	5.5–6.5	....
Parsley	....	....	6.2
Radishes	....	5.4–6.8	6.2
Salsify	....	5.5–6.5	....
Strawberries	....	5.7–6.3	....
Sweet corn	....	5.5–6.5	6.0
Tomatoes	4.5–7.0	6.0–6.5	6.0
Turnips	....	5.5–6.5	....
Beets	5.0–7.0	5.8–7.0	6.5
Celery	....	5.6–6.5	....
Lettuce	5.0–7.0	6.0–6.5	6.5
Muskmelons	....	6.0–6.5	....
Onions	....	6.0–6.5	....
Peas	4.4–6.9	5.5–6.5	5.6
Spinach	....	6.0–6.5	....
Chard	....	6.0–6.5	....

* Reaction of the soil adjusted with aluminum sulphate and lime.

Table 6. RESPONSE OF GARDEN FLOWERS ON SOILS* OF VARIOUS pH (SHEAR)
Virginia Station Technical Bulletin 63

Garden flower	pH range studied	Favorable pH range	pH of best growth
Calendula	4.5–7.5	5.5–7.5	7.0
Cornflower	4.5–7.5	5.5–7.5	5.4–6.2
Gaillardia	4.5–7.5	5.5–7.5	7.5
Larkspur	4.5–7.5	5.5–7.5	7.0
Scabiosa	4.5–7.5	5.0–7.5	7.0–7.5
Aster	4.5–7.5	5.0–7.5	7.0
Zinnia	4.5–7.5	5.0–7.5	6.5–7.0
Balsam	4.5–7.5	5.5–7.5	6.5
Phlox	4.5–7.5	5.0–7.5	6.5
Scarlet sage	4.5–7.5	5.0–7.5	5.5–6.0
Castor bean	4.5–7.5	5.0–7.5	7.0
Lupine	4.5–7.5	5.0–7.5	5.5–6.0
African marigold	4.5–7.5	5.0–7.5	5.5–6.5
Nasturtium	4.5–7.5	5.5–7.5	7.0
Portulaca	4.5–7.5	5.0–7.5	5.5–6.0
French marigold	4.5–7.5	5.0–7.5	7.0
Petunia	4.5–7.5	5.0–7.5	5.5–6.0
Cosmos	4.5–7.5	5.0–7.5	5.5–6.0
Ageratum	4.5–7.5	4.5–7.5	7.0

* H_2SO_4 used to create more acidity and lime used to reduce acidity.

The plants are more tolerant to acidity in order of listing. A reaction of pH 6.0 to 7.0 is given as favorable to most garden flowers.

Table 7. RESPONSE OF CROPS ON SOILS* OF VARIOUS pH
Ohio Station Bulletin 470 and 497

Crop	pH range studied	Favorable pH range	pH of maximum yield
Red clover	4.5–8.0	6.0–8.0	7.0
Mammoth clover	4.5–8.0	6.0–8.0	7.0
Alsike clover	4.5–8.0	7.0–8.0	7.0
Sweet clover	4.5–8.0	7.0–8.0	7.0
Alfalfa	4.5–8.0	6.0–8.0	8.0
Soybeans	4.5–8.0	5.5–8.0	8.0
Timothy	4.5–8.0	6.0–8.0	8.0
Corn†	4.5–8.0	7.0–8.0	8.0

* Reaction of the soil adjusted with aluminum sulphate and lime.
† The nonlegume corn may have given better yields at the higher pH, because it followed legumes which had made more growth and therefore enriched the soil to a greater extent at the higher pH.

Table 8. DATA ON THE USE OF LIMESTONE BY THE OREGON AGRICULTURAL EXPERIMENT STATION

Soil type, location, crop, and treatment	Duration of test	Yield per acre		Gain or loss	Reaction value, fall 1938, pH
		Treated	Untreated		
	Years	*Tons*	*Tons*	*Tons*	
Willamette Silty Clay Loam—College Farm, Old Rotation Field—					
Corn					
Check	2	....	4.4	....	....
Lime, 3 tons	....	5.70	4.4	1.3	....
Lime, 6 tons	....	6.53	4.4	2.13	....
Lime, 9 tons	....	7.00	4.4	2.60	....
Lime, 12 tons	....	6.12	4.4	1.72	....
Barley		*Bushels*	*Bushels*	*Bushels*	
Check	4	....	35.57	....	....
Lime, 6 tons	4	42.70	35.57	7.13	....
Lime, 9 tons	4	44.79	35.57	9.22	....
Lime, 12 tons	4	45.63	35.57	10.06	....
Lime, 3 tons	3	36.01	35.57	–0.44	....
Willamette Silty Clay Loam—Irrigation Field—					
Corn Silage		*Tons*	*Tons*	*Tons*	
Check	6	....	5.93	....	6.60
Lime, 2 tons; manure, 10 tons	6	8.76	5.93	2.83	6.89
Manure, 10 tons	6	7.69	5.93	1.76	....
Clover Hay					
Check	5	....	3.44	....	6.60
Lime, 2 tons; manure, 10 tons	5	3.72	3.44	0.28	6.89
Manure, 10 tons	5	5.04	3.44	1.60	....
Wheat		*Bushels*	*Bushels*	*Bushels*	
Check	5	....	48.33	....	6.60
Lime, 2 tons; manure, 10 tons	5	56.09	48.33	7.76	6.89
Manure, 10 tons	5	56.58	48.33	8.25	....
Chehalis Loam—East Farm—					
Potatoes		*Bushels*	*Bushels*	*Bushels*	
Check	10	....	169.14	....	....
Lime, 1 ton; superphosphate, 200 pounds; manure, 6 tons	....	219.28	....	50.14	....
Manure, 6 tons	....	247.60	201.89	45.71	....
Manure, 6 tons; superphosphate, 200 pounds	....	....	....	....	....
Sulphur, 50 pounds; lime, 200 pounds	....	268.57	257.86	10.71	....
Sulphur, 50 pounds	....	258.67	266.65	–7.98	....
Clover Hay		*Tons*	*Tons*	*Tons*	
Check	3	....	0.74	....	....
Lime, 1 ton; superphosphate, 200 pounds; manure, 6 tons	....	1.34	0.74	0.60	....
Manure, 6 tons; superphosphate, 200 pounds	....	1.51	0.90	0.61	....
Sulphur, 50 pounds; lime, 200 pounds	....	1.76	1.27	0.49	....
Sulphur, 50 pounds	....	1.70	1.43	0.27	....
Clover seed		*Bushels*	*Bushels*	*Bushels*	
Check	10	....	1.10	....	....
Lime, 1 ton; superphosphate, 200 pounds; manure, 6 tons	....	2.16	1.10	1.06	....
Superphosphate, 200 pounds; manure, 6 tons	....	2.61	1.68	0.93	....
Sulphur, 30 pounds; lime, 200 pounds	....	3.47	2.61	0.86	....
Sulphur, 50 pounds	....	3.65	2.93	0.72	....

Table 8. DATA ON THE USE OF LIMESTONE BY THE OREGON AGRICULTURAL EXPERIMENT STATION (*Continued*)

Soil type, location, crop, and treatment	Duration of test	Yield per acre		Gain or loss	Reaction value, fall 1938, pH
		Treated	Untreated		
Barley		*Bushels*	*Bushels*	*Bushels*	
Check	10	....	33.59	....	....
Lime, 1 ton; superphosphate, 200 pounds; manure, 6 tons	....	44.91	33.59	11.32	....
Superphosphate, 200 pounds; manure, 6 tons	....	44.58	38.79	5.79	....
Sulphur, 50 pounds; lime, 200 pounds	11	37.28	36.31	0.97	....
Sulphur, 50 pounds	11	36.90	36.90	0.00	....
Tobacco	*Years*	*Tons*	*Tons*	*Tons*	
Check	1	....	9.29	....	....
Superphosphate, 200 pounds; manure, 6 tons; lime, 1 ton	....	12.61	9.29	3.32	....
Manure, 6 tons; superphosphate, 200 pounds	....	11.96	9.71	2.25	....
Sulphur, 50 pounds; lime, 200 pounds	....	4.31	7.38	–3.07	....
Sulphur, 50 pounds	....	6.72	7.82	–1.10	....
Willamette Silty— *Fertility Experiment Field—*					
Legume clover or vetch, mostly clover		*Tons*	*Tons*	*Tons*	
Check	15	....	3.67	....	6.11
Lime, 1 ton	15	3.82	3.67	0.15	6.52
Lime, 2 tons	15	3.77	3.71	0.06	6.85
Lime, 3 tons	15	3.76	3.75	0.01	7.01
Lime, 2 tons; manure, 15 tons	15	4.34	3.75	0.59	6.83
Lime, 2 tons; superphosphate, 250 pounds; manure, 15 tons	15	4.18	3.68	0.50	7.03
Lime, 2 tons; rock phosphate, 600 pounds; manure, 15 tons	15	4.24	3.60	0.64	7.00
Wheat		*Bushels*	*Bushels*	*Bushels*	
Check	15	....	45.47	....	6.11
Lime, 1 ton	15	47.70	45.47	2.23	6.52
Lime, 2 tons	15	48.43	47.44	0.99	6.85
Lime, 3 tons	15	48.40	49.41	–1.01	7.01
Lime, 2 tons; manure, 15 tons	15	48.91	49.41	–0.50	6.83
Lime, 2 tons; superphosphate, 250 pounds; manure, 15 tons	15	48.39	48.27	0.12	7.03
Lime, 2 tons; rock phosphate, 600 pounds; manure, 15 tons	15	48.53	46.63	1.90	7.00
Corn silage		*Tons*	*Tons*	*Tons*	
Check	16	....	7.10	....	6.11
Lime, 1 ton	16	7.39	7.10	0.29	6.52
Lime, 2 tons	16	7.57	7.29	0.28	6.85
Lime, 3 tons	16	7.35	7.48	–0.13	7.01
Lime, 2 tons; manure 15 tons	16	8.45	7.48	0.97	6.83
Lime, 2 tons; superphosphate, 250 pounds; manure, 15 tons	16	8.16	7.31	0.85	7.03
Lime, 2 tons; rock phosphate, 600 pounds; manure, 15 tons	16	8.24	7.13	1.11	7.00
Melborne Silt Loam— *Astoria* Branch Experiment Station—*					
Peas and oats hay		*Tons*	*Tons*	*Tons*	
Check	1	....	1.95	....	....
Lime, 3 tons	1	2.40	1.99	0.41	....
Lime, 2 tons; superphosphate, 300 pounds	1	1.87	2.03	–0.16	....
Lime, 2 tons; KCl, 160 pounds	1	1.95	2.07	–0.12	....

* These data were provided by H. B. Howell, in charge of the Astoria Branch Experiment Station.

Table 8. DATA ON THE USE OF LIMESTONE BY THE OREGON AGRICULTURAL EXPERIMENT STATION (*Continued*)

Soil type, location, crop, and treatment	Duration of test	Yield per acre		Gain or loss	Reaction value, fall 1938, pH
		Treated	Untreated		
Clover-Timothy hay		*Tons*	*Tons*	*Tons*	
Check	4	-------	2.17	-------	-------
Lime, 3 tons	4	3.79	2.17	1.62	-------
Lime, 2 tons; superphosphate, 300 pounds	4	3.40	2.07	1.33	-------
Lime, 2 tons; KCl. 160 pounds	4	3.88	1.97	1.91	-------
Manure (check)	4	-------	3.77	-------	-------
Lime, 2 tons; manure, 15 tons	4	4.05	3.66	0.39	-------
Superphosphate, 300 pounds; lime, 2 tons; manure, 15 tons	----	3.62	3.55	0.07	-------
Lime, 2 tons; KCl, 160 pounds; manure, 15 tons	4	3.90	3.44	0.46	-------
Rutabagas		*Tons*	*Tons*	*Tons*	
Check	1	-------	0.73	-------	-------
Lime, 3 tons	----	9.65	0.73	8.92	-------
Lime, 2 tons; superphosphate, 300 pounds	----	20.42	0.73	19.69	-------
Lime, 2 tons; KCl, 160 pounds	----	10.12	0.73	9.39	-------
Manure, 15 tons (check)	----	-------	22.52	-------	-------
Lime, 2 tons; manure, 15 tons	----	33.83	23.27	10.56	-------
Superphosphate, 200 pounds; lime, 2 tons; manure, 15 tons	----	35.80	23.99	11.81	-------
Lime, 2 tons; KCl, 160 pounds; manure, 15 tons	----	32.97	24.71	8.26	-------

GENERAL FACTS

Limestone deposits in Oregon. Limestone deposits of considerable extent occur in Southern Oregon and in the Wallowa and Snake River regions of Eastern Oregon. Few deposits are found in the humid northwestern part of the state, including the Willamette Valley, where acid soils occur. A deposit is located at Dallas, Oregon. Transportation is a major item in cost of agricultural lime for northwestern Oregon.

Use of agricultural lime in Oregon. Use of agricultural lime in Oregon has increased from approximately 2,500 tons in 1933 to nearly 25,000 tons in 1938. It is estimated that a quarter million tons a year would be needed to correct and maintain favorable reactions for crop land in northwestern Oregon. Some things that have aided increased use include:

1. A milling-in-transit freight rate is available for the state lime industry at Salem.
2. Encouragement has been given by the state and recently soil building payments have been made on AAA contracts to the amount of $2.00 per 800 pounds of 90 per cent lime carbonate in counties where the cost is more than $5.00 a ton.
3. Use of chicken grit as a by-product of this industry has been helpful in financing the industry.
4. Trucking flax to Salem has permitted some lime to be trucked home on the back haul at low cost. Introduction of large trucks for delivery from Oswego and Dallas plants has been favorable to increased lime use in those areas.

Increased use of agricultural lime may be encouraged:

1. By a publicity and sales campaign.
2. By a decreased cost resulting from increased production and use, including industrial uses.
3. By special transportation rates.
4. By flotation method of separating impurities from lime carbonate.

State Lime Law. The State Lime Law requires that a statement be attached indicating (a) number of pounds in each package or bulk shipment; (b) name of particular form of lime, as ground limestone, lime hydrate, etc.; (c) name and address of the manufacturer; and (d) the guaranteed minimum percentage of neutralizing value, expressed in terms of calcium carbonate, and percentage of material that will pass respectively 100-mesh, 50-mesh, and 10-mesh sieves. The law requires that no label or chemical is to be used other than those specified. Producers are registered with the State Department of Agriculture.

Authorized dealers. The dealers licensed to sell lime in the State of Oregon in 1938 by the State Department of Agriculture were:

Pacific Lime Company, Limited, Blubber Bay, British Columbia, Canada

United States Gypsum Company, Chicago, Illinois

Beaver Portland Cement Co., 603 Lumbermens' Bldg., Portland, Oregon

Limestone Products, Inc., Dallas, Ore. (66% $CaCO_3$ + 4% $MgCO_3$)

Beaver Portland Cement, W. B. Sullivan—dealer, 324 N. Commercial Street, Salem, Oregon

State Lime Plant, Route 6, Box 1, Salem, Oregon (98% pure)

John H. McKenzie, 2718 S. W. Kelley Avenue, Portland, Oregon

Montgomery Ward & Company, Inc., Portland, Oregon

Oregon Portland Cement Company, Oswego and Portland, Ore. (96%)

American Keene Cement & Plaster Company, Salt Lake City, Utah

Nephi Plaster and Manufacturing Company, Salt Lake City, Utah

Pacific Portland Cement Company, San Francisco, California

Standard Gypsum Company, San Francisco, California

Spokane Portland Cement Company, Spokane, Washington

Northwest Lime Company, Enterprise, Oregon

Roche Harbor Lime & Cement Co., Roche Harbor, Washington

Composition and cost of brands. The composition and price of a few leading brands as of August 3, 1938, are indicated below:

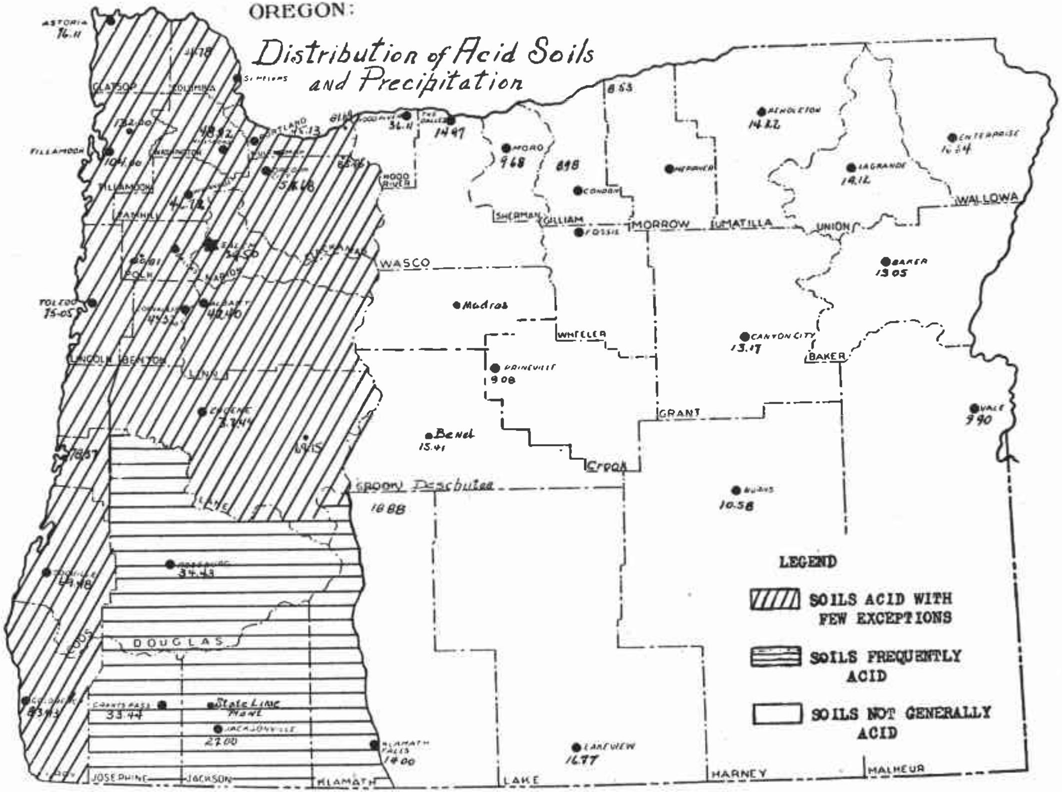
Horsehead Lime Company, Williams
- 99.32% calcium carbonate
- .04% magnesium carbonate
- $4.50 per ton at plant

Oregon Portland Cement Company, Oswego
- 96% calcium carbonate
- 1% magnesium carbonate
- $6.50 per ton within 50 miles of Oswego

State Lime Industry, Salem
- 98% calcium carbonate (reported February 12, 1938)
- $5.95 per ton in bulk at plant

Limestone Products Company, 1500 W. Lovejoy, Portland
Dallas Ground Limestone
- 66% calcium carbonate
- 4% magnesium carbonate
- $3.00 per ton in bulk
- $4.25 per ton in sacks

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



OREGON:
Distribution of Acid Soils and Precipitation
LEGEND
SOILS ACID WITH FEW EXCEPTIONS
SOILS FREQUENTLY ACID
SOILS NOT GENERALLY ACID
CLATSOP
COLUMBIA
TILLAMOOK
WASHINGTON
YAMHILL
POLK
LINCOLN
BENTON
LINN
LANE
DOUGLAS
COOS
JOSEPHINE
JACKSON
KLAMATH
WASCO
SHERMAN
GILLIAM
MORROW
UMATILLA
UNION
WALLOWA
WHEELER
BAKER
GRANT
Crook
Deschutes
LAKE
HARNEY
MALHEUR
Madras
Bend
15.41
State Line
Astoria
76.11
Pendleton
14.22
La Grande
14.12
Baker
13.05
Canyon City
13.17
Prineville
9.08
Burns
10.58
Vale
9.90
Lakeview
16.77
Klamath Falls
14.00
Roseburg
34.43
Grants Pass
33.44
Jacksonville
27.00
Eugene
37.44
Toledo
75.05
Moro
9.68
The Dalles
14.47
Hood River
36.11

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