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FARMING ACID SOILS

IN ALBERTA AND NORTHEASTERN BRITISH COLUMBIA [1]

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Soil acidity causes low crop yields every year on many farms in Alberta and northeastern British Columbia. Alfalfa is one of the most sensitive crops, and its yield is usually reduced when the soil pH is 6.0 or lower. Yields of most other crops are also reduced when soil pH is less than 5.6. About one-fifth of the cultivated soil in Alberta and northeastern British Columbia is acid, having a pH value of 6.0 or less. The proportion of acid soils, however, varies from area to area; the Peace River region has the highest proportion and southern Alberta the lowest.

Some crops have a high tolerance for soil acidity and they are the most suitable crops to grow if soil acidity is not corrected by liming. However, most of the main crops in Alberta and northeastern British Columbia are susceptible to soil acidity, and liming is therefore important.

The yields given in this publication were obtained from many small-plot experiments on farms in Alberta and northeastern British Columbia. These results indicate the improvements that can be expected in field-scale operations. Yields from liming in farm operations were not available for this publication, because the use of lime in farming is just beginning. Soil acidity in Alberta and northeastern British Columbia has been recognized as a problem only since the early 1960's. Extensive research has shown that liming is the practical economic solution to the problem.

Liming is only part of good management for acid soils. It does not replace other soil and crop management practices.

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WHAT IS AN ACID SOIL?

The scale used to measure soil reaction is pH. The reaction is alkaline when the pH value is above 7.0, neutral at 7.0, and acid below 7.0. In practical terms, soils between pH 6.5 and 7.5 are considered neutral. In Alberta and northeastern British Columbia, soil acidity of pH 6.1 to 6.9 has little effect on crops. Hence, for this region pH 6.0 is considered to be the upper value for acid soils.

Poor growth of crops on acid soils is related to many factors. The occurrence of toxic quantities of aluminum is a major cause of damage to crops by soil acidity. Also, manganese may be present in acid soils in quantities large enough to be toxic to some crops. Low soil pH in itself affects the growth of legume crops, alfalfa in particular, by decreasing the ability of *Rhizobium* bacteria to form nodules on the roots. The nodules take up atmospheric nitrogen and convert it for use by the legumes so that the soil and fertilizer nitrogen are not needed. Soils with pH 5.6 to 6.0 do not ordinarily contain toxic quantities of aluminum and manganese, but the low pH restricts nitrogen fixation and thus decreases the yield of alfalfa.

OCCURRENCE OF ACID SOILS

The distribution of acid soils in Alberta and northeastern British Columbia (the Peace River district of B.C.) is shown in Figure 1. Acid soils occur most frequently in central Alberta and in the Peace River region of Alberta and British Columbia.

The proportion of acid soils in an area or soil zone can be misleading for the individual farmer. A farm can have neutral soil even though it is in an area of predominantly acid soils. The opposite can also happen. Pockets of acid soil of 1 sq mile (2.5 km^2) or less can occur in a neutral soil area. The poor growth of a sensitive crop such as alfalfa may indicate an acid soil condition. However, a soil test is the only reliable way of determining whether a soil is acid or not.

TOLERANCE OF VARIOUS CROPS FOR SOIL ACIDITY

Crops vary greatly in their tolerance for soil acidity (Figure 2). But the cause of the variation is rather complex, because toxic quantities of aluminum occur in some acid soils but not in others. Fortunately, a soil test for aluminum can be used to predict the reduction in yields that the aluminum toxicity causes. Manganese toxicity can also reduce the yields of some crops, particularly those of rapeseed. But not enough information is available for predicting yield reductions caused by excess manganese, as shown in a soil test.

Legume crops, especially alfalfa, have a low tolerance for soil acidity (Figure 3). Red clover (Altaswede) is more tolerant than alsike clover (Aurora). Grasses, in general, are more tolerant of soil acidity than are legumes.

Cereal and oilseed crops vary greatly in their tolerance for soil acidity (Figure 4). Oats are very tolerant, wheat and rapeseed are moderately tolerant, and barley is the least tolerant. Figure 5 shows the much greater tolerance of oats than of barley. However, barley varieties differ in sensitivity to soil acidity. In tests on a very strongly acid soil, Olli barley grew much better than did Galt barley (Figure 6). But where that soil was limed, Galt barley produced the better yields. It is usually difficult to obtain high yields of barley on strongly to very strongly acid soils without first liming the soil. The search continues for high-yielding barley varieties that are tolerant of soil acidity.

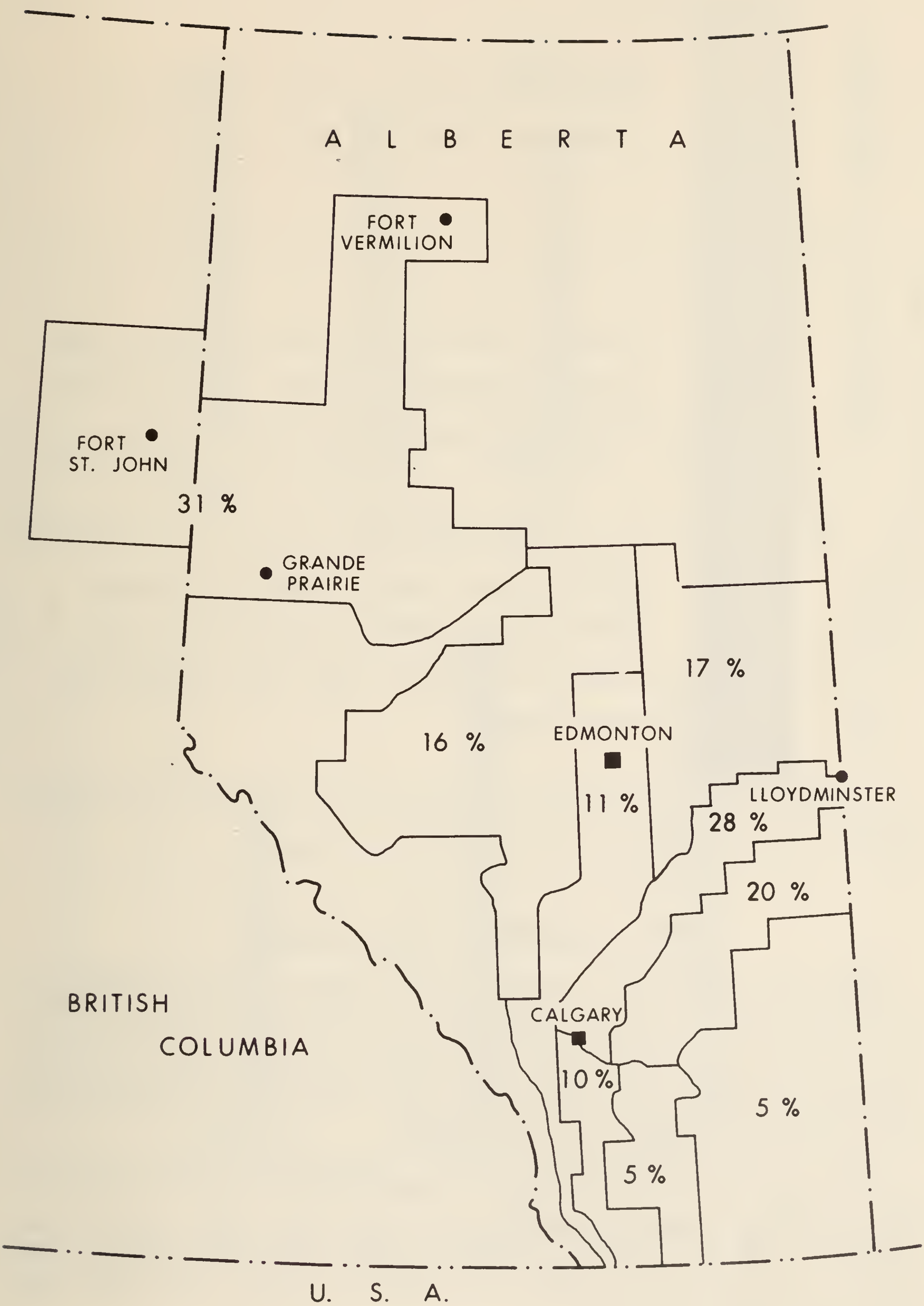

Figure 1. Percentage of cultivated acid soils with pH below 6.1 in various areas of Alberta and northeastern British Columbia.

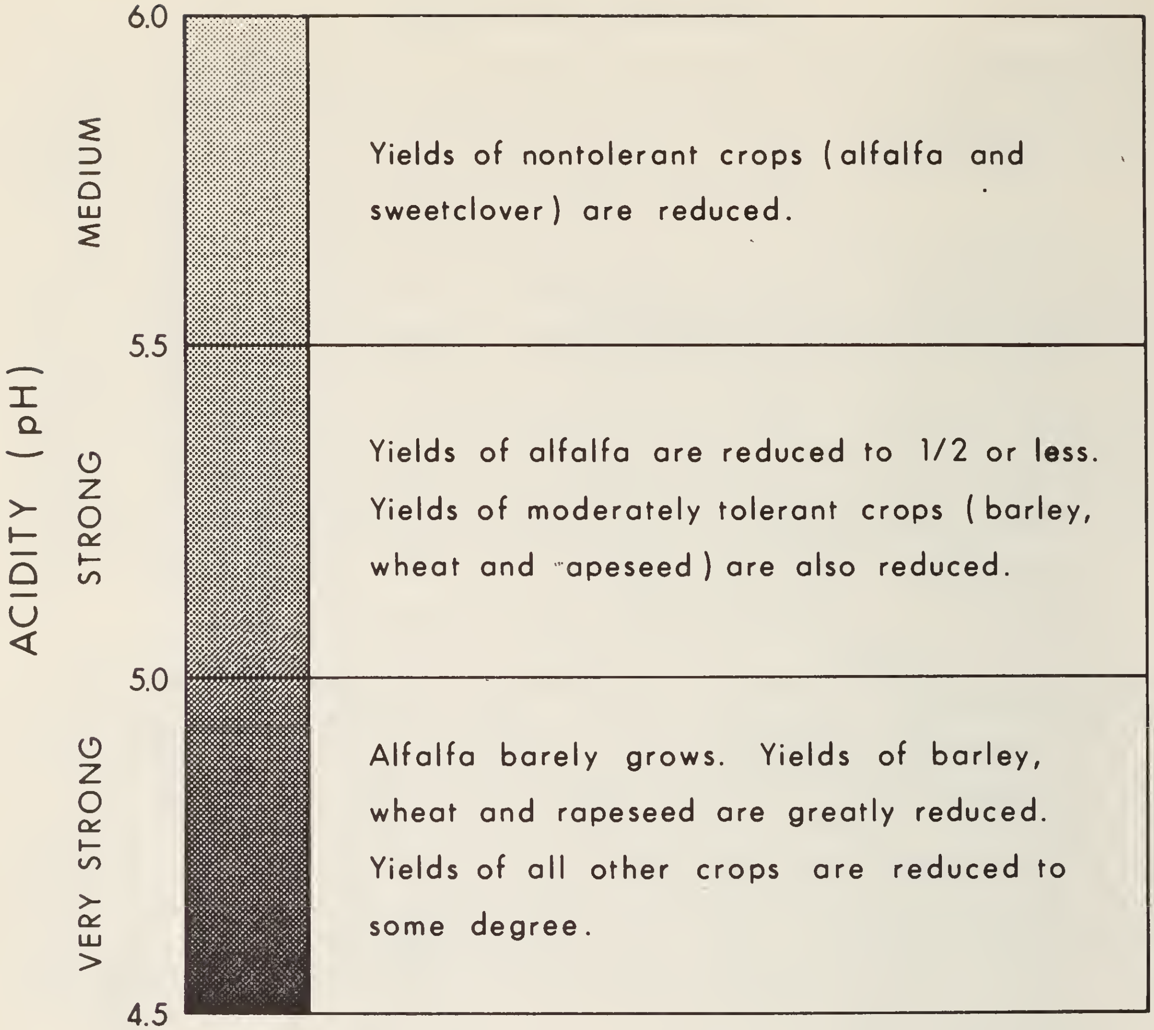

Figure 2. Tolerances of crops for soil acidity at different pH levels.

HOW TO CORRECT SOIL ACIDITY

There are two main ways to contend with soil acidity. One way, as discussed in the previous section, is to grow crops that are tolerant of soil acidity. The other way is to lime the soil so that acid-sensitive crops can be grown. A combination of the two can be used in order to give an overall wider range of crops. Grow crops tolerant of soil acidity on a portion of your farm, and apply lime to the rest of the land so that the sensitive crops can also be grown.

Lime is a material that sweetens the soil or decreases acidity (by increasing the pH). The most common liming material is ground limestone. It may consist of only calcium carbonate (calcitic limestone), or a mixture of calcium carbonate and magnesium carbonate (dolomitic limestone). Other liming materials are marl, hydrated lime, pulpmill by-products, and industrial slag. Marl is often used in areas where natural deposits are found.

The effectiveness of a liming material depends on its calcium carbonate equivalence and its fineness. The calcium carbonate equivalence is the potential ability of a material to neutralize acidity compared with chemically pure calcium carbonate. Although finely ground material reacts more rapidly with the soil than

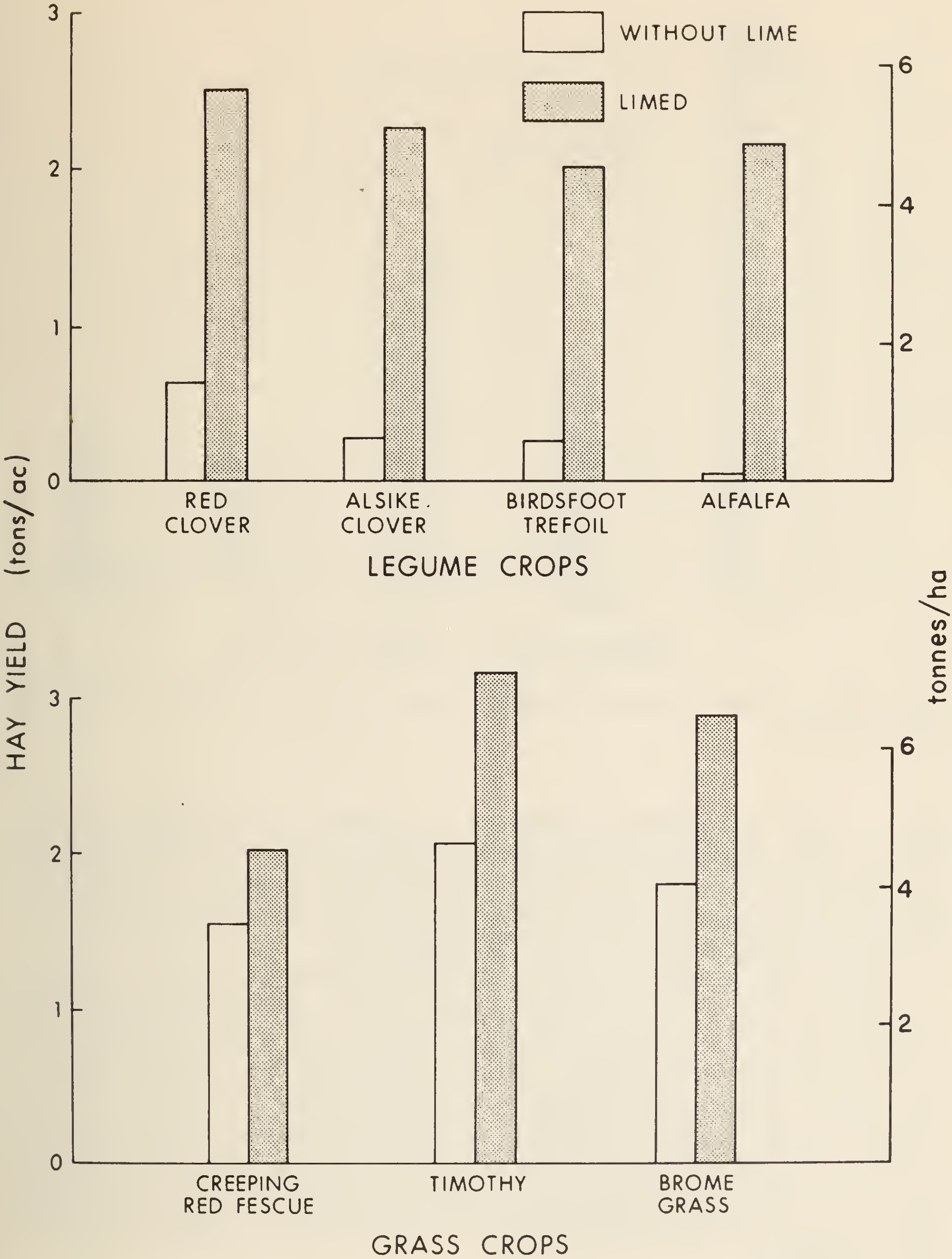

Figure 3. Average yields of legume and grass crops grown on two very strongly acid soils, with and without lime.

does coarsely ground material, very fine material is difficult to spread. Lime fine enough so that one-half passes a 60-mesh sieve (0.25-mm openings) reacts quickly with the soil and is easy to spread.

An application of lime lasts at least 7 years, and probably 10 years or more,

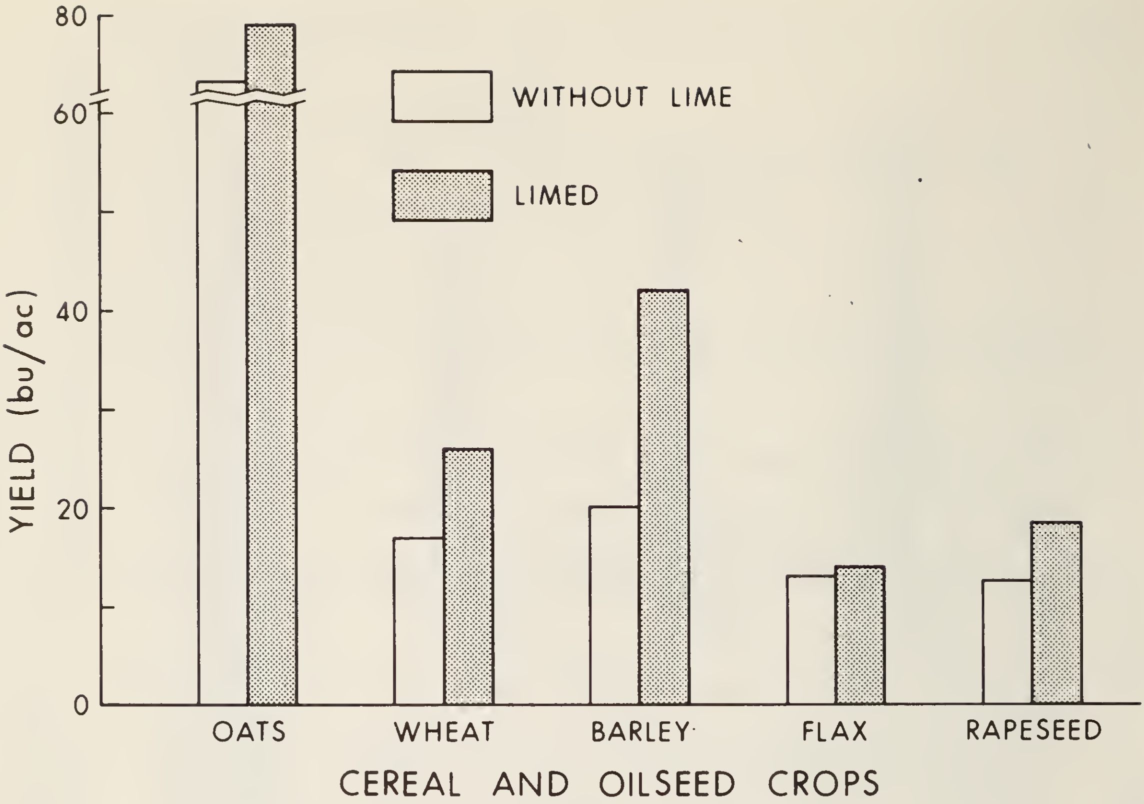

Figure 4. Average yields of cereal and oilseed crops grown on two very strongly acid soils, with and without lime.

under the soil and climatic conditions in Alberta and northeastern British Columbia. The rainfall in the region is comparatively low and soils are generally fine textured, discouraging the downward movement of lime. For subsequent applications, the amount of lime required to restore the soil to the desired pH level will be substantially less than for the initial application.

Fertilizer applications can acidify the soil. For example, it takes 110 lb (50 kg) of ground limestone to neutralize the acidity caused by a 100-lb (45-kg) application of ammonium sulfate, one of the most acidifying fertilizers. By comparison, urea, ammonium nitrate, and anhydrous ammonia require 84, 59, and 148 lb (38, 27, and 67 kg) of limestone to neutralize the acidity caused by 100 lb (45 kg) of fertilizer material. Calcium and magnesium, which are components of lime, are used as nutrients by plants, especially legumes. A 200-lb (90-kg) application of ground limestone is needed to replenish the nutrients removed by a 2-ton (1.8-tonne) alfalfa hay crop. However, very little calcium and magnesium are taken up by cereal and oilseed crops.

RESPONSE OF CROPS TO LIME

Because crops vary in their tolerance for soil acidity, they vary in their response to lime. Alfalfa, one of the least tolerant crops, is one of the most responsive to lime. Increases in yields of alfalfa by liming were evaluated from 28 field experiments conducted throughout Alberta and northeastern British Columbia. (Yields for alfalfa and other crops are presented in the figures and tables.)

Figure 5. Comparison of the growth of oats and barley on a very strongly acid soil. Barley (barely visible) is in front of the white stakes. Crops in the far background are on neutral soil.

Figure 6. Comparison of the growth, *left*, of Galt and, *right*, of Olli barley on a very strongly acid soil. Nonlimed soil is in the foreground and limed soil is in the background.

Figure 7. Response of alfalfa to lime on a soil with pH 5.4.

Figure 8. Response of alfalfa to lime on a soil with pH 4.9. Alfalfa is in the foreground, and red clover is in the background.

Alfalfa responded well to applications of lime on a strongly acid soil with pH 5.4 (Figure 7). On a very strongly acid soil with pH 4.9 the growth of alfalfa was very poor when no lime was applied (Figure 8). The alfalfa plants were pale green in color, and the stand was patchy. Soil acidity weakened the plants so that they became prone to winterkilling and thus the stands thinned out and weeds invaded the field. However, good stands of alfalfa were obtained when these soils were limed.

At pH 5.5, liming increased the yield of alfalfa by more than 60 percent (Figure 9). The lime applications in these experiments raised the pH, on the average, to 6.5. In many areas of Canada and the United States, soils are limed to pH 6.5 and even to pH 7.0 for growing alfalfa. But tests in Alberta and northeastern British Columbia have shown that nearly all the benefit from lime on yields of alfalfa is gained from raising the pH to just above 6.0.

Red clover is much more tolerant of soil acidity than is alfalfa (Table 1). At pH 5.0 and lower, red clover yielded an average of 2 tons/ac (4.4 tonnes/ha), whereas alfalfa yielded less than 1 ton (2.2 tonnes). When the pH was between 5.1 and 6.0, alfalfa yields were about the same as those for red clover (about 2 tons/ac; 4.4 tonnes/ha). In this range red clover barely responded to lime, but alfalfa yields were increased to about 3 tons/ac (6.6 tonnes/ha) by liming. As a result, on the average, alfalfa yielded about 1 ton (2.2 tonnes) more on the limed soils than red clover did on the unlimed soils. In a few tests, red clover yields on unlimed soils were similar to alfalfa yields on limed soils. But, in general, for high yields of hay, red clover is not a good substitute for alfalfa on limed acid soil.

For predicting increases in yields of alfalfa hay from liming, soil pH is the most useful indicator. For most other crops, however, soluble aluminum (as determined by a soil test) is the best indicator. The relationship between yields of barley and the amount of aluminum in the soil is shown in Figure 10. For soils with 4 parts per million (ppm) of soluble aluminum, liming increased the yield of Galt barley by 13 bu/ac (700 kg/ha). In general, the response of barley to lime was slight when the soil contained less than 2 ppm of aluminum. These soils usually have a pH above 5.5. Barley responded well to applications of lime on soil with 45 ppm of aluminum (Figure 11).

TABLE 1. YIELDS OF RED CLOVER AND ALFALFA ON VARIOUS SOILS

			Average yields of hay (tons/ac)		
Crop	Soil pH	No. of sites	Without lime	Limed	Increase from lime
Red clover	5.0 and lower	6	2.0	3.0	1.0
	5.1 to 5.5	13	1.8	1.9	0.2
	5.6 to 6.0	7	2.3	2.4	0.1
Alfalfa	5.0 and lower	6	0.8	3.2	2.4
	5.1 to 5.5	13	1.6	2.7	1.1
	5.6 to 6.0	8	2.2	3.2	1.0

NOTE: The information is based on the results of 28 field experiments. 1 ton/ac is equivalent to 2.2 tonnes/ha.

Olli barley is about two-thirds as responsive as Galt barley to liming. A downward adjustment therefore needs to be made in Figure 10 in order to determine the expected yield increases for Olli barley. The percentage yield increases for wheat and rapeseed (Figure 4) were about one-half those for barley (averaged for three varieties of each crop). Therefore, a downward adjustment in Figure 10 needs to be made to estimate the expected yield increases for wheat and rapeseed from liming. Because high rates of nitrogen fertilizer were applied, the increases in yields of barley given in Figure 10 probably underestimate the increases that would be expected under farming conditions. Hence, the crops did not benefit from nitrogen released from the organic matter as a result of liming.

ECONOMICS OF LIMING

The return on money invested in liming depends largely on the sensitivity of the crops to soil acidity. Because alfalfa is a very sensitive crop, the cost of liming soils having a pH of 5.7 or lower is paid for in the second year of production by the increases in yields of alfalfa hay (Table 2). No precise figures are available for returns on alfalfa hay when soils having a pH of 5.8 to 6.0 are limed and therefore that pH range has not been included in the table.

The returns on barley (Table 3) are not as large as those on alfalfa hay. Even so, the lime application is paid for by two crops of barley. As already mentioned, large quantities of nitrogen fertilizer were applied to the barley, and therefore the barley did not benefit from nitrogen released from the soil. In separate field experiments, large but temporary increases in release of soil nitrogen were noted as a result of liming. The amounts released varied from 30 to 100 lb/ac (34 to 112 kg/ha) over 3 years. This is an added bonus on returns from liming for production of barley, wheat, rapeseed, and grass crops.

In Table 2 and 3, the cost of lime is listed at $32 per ton. The actual cost may vary slightly for each farm. Also, the prices of crops each year may differ from those given in the tables. However, you can work out your own calculations for expected returns on your investment by using your own liming costs and prices for

TABLE 2. NET RETURNS FROM LIMING FOR ALFALFA PRODUCTION (ANNUAL YIELD IS 2 TONS OF HAY/AC)

	Lime		Annual increase			Alfalfa production (net returns/ac)	
Soil pH	Tons/ ac	Cost/ ac	Tons/ ac	Value/ ac	Years to pay for lime	After 5 years	After 10 years
5.7	1.0	$32	0.40	$20	2	$ 68	$168
5.5	1.5	$48	0.80	$40	2	$152	$352
5.3	2.0	$64	1.10	$56	2	$216	$496
5.1	2.5	$80	1.34	$68	2	$260	$600
4.9	3.0	$96	1.68	$84	2	$324	$744

NOTE: The calculations in this table are based on 1 ton of applied lime costing $32, and 1 ton of hay worth $50.
1 ton/ac is equivalent to 2.2 tonnes/ha.

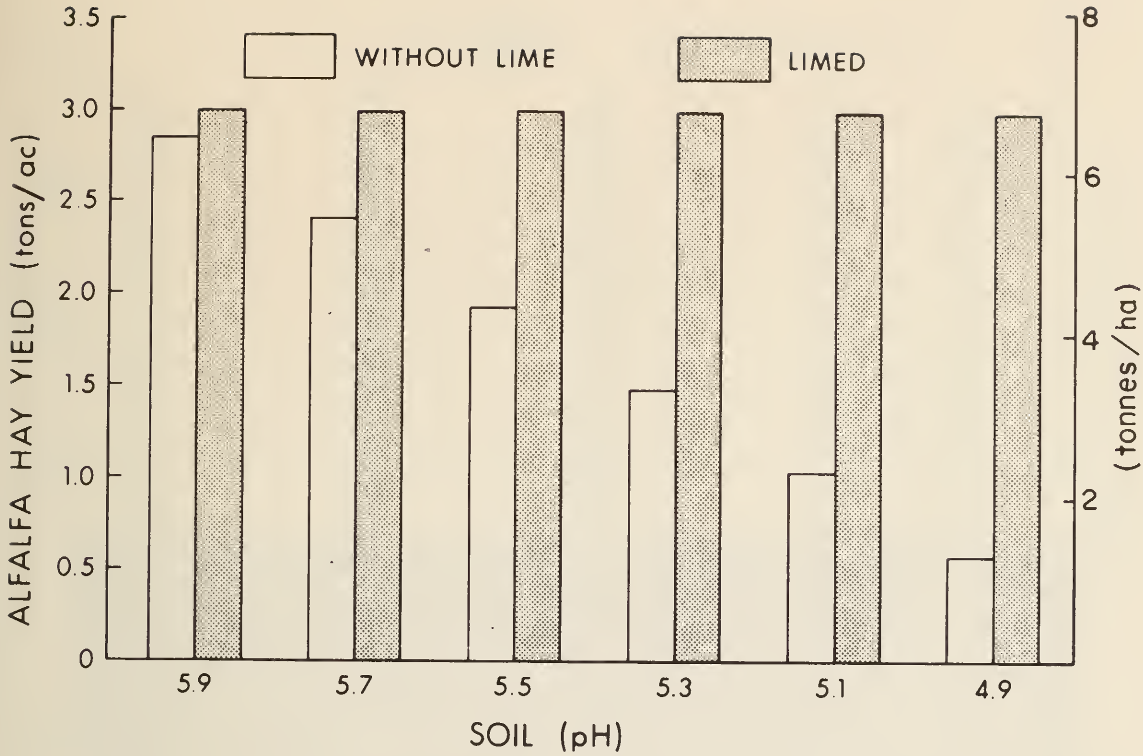

Figure 9. Response of alfalfa to lime at various pH levels.

farm crops. For crops such as wheat, rapeseed, alsike clover, and bromegrass, you can estimate your returns by referring to figures 3 and 4, and by adjusting the yield increases in comparison with those of alfalfa and barley.

Because an application of lime persists a long time in the soil, liming in this region is considered to be a capital expense. Hence, a lime application made on land that needs lime increases the value of the land. Tables 2 and 3 show the large net returns on investment that accrue over the years from the application of lime.

TABLE 3. NET RETURNS FROM LIMING FOR BARLEY PRODUCTION (ANNUAL YIELD IS 41 BU OF BARLEY/AC)

Amount of soil aluminum (parts per million)	Lime		Annual increase		Years to pay for lime	Barley production (net returns/ac)	
	Tons/ ac	Cost/ ac	Bu/ ac	Value/ ac		After 5 years	After 10 years
1	0.5	$16	5	$10	2	$ 34	$ 96
2	1.0	$32	8	$16	2	$ 48	$128
4	1.5	$48	13	$26	2	$ 82	$212
6	2.0	$64	16	$32	2	$ 96	$256
8	2.5	$80	18	$36	3	$100	$280

NOTE: The calculations in this table are based on 1 ton of applied lime costing $32, and barley worth $2/bu.
The average yield of barley in Alberta was 41 bu/ac for the 5-year period 1968-1972.
1 bushel of barley weighs 22 kg.
1 bu/ac is equivalent to 54 kg/ha.

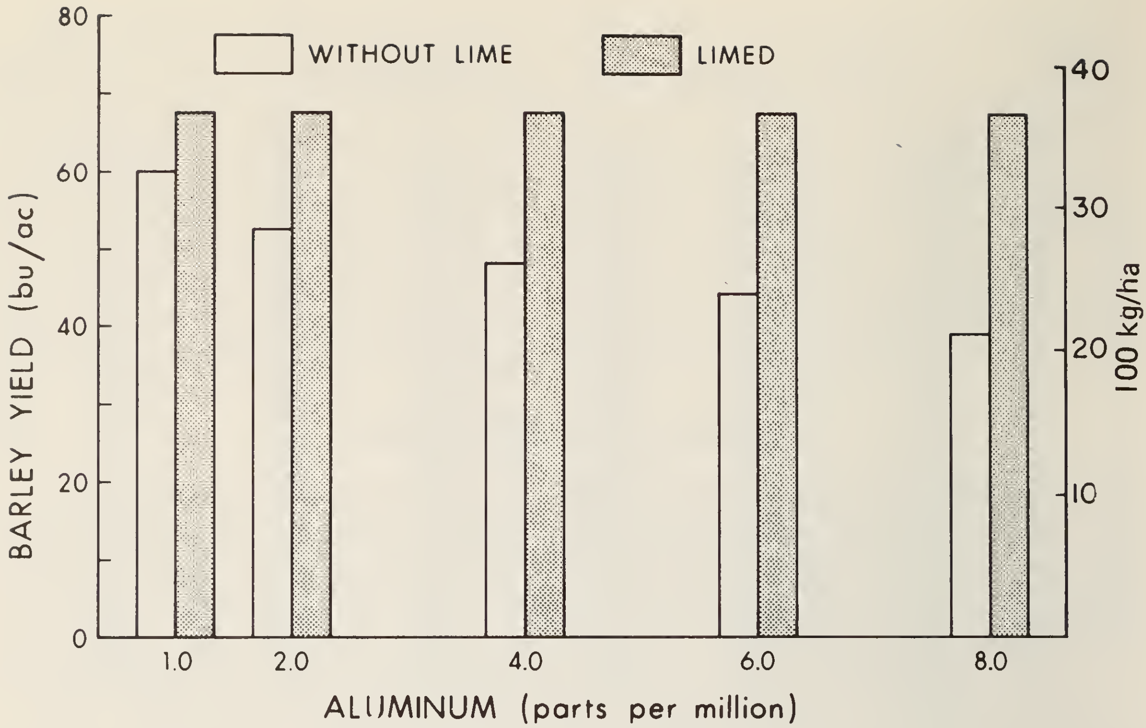

Figure 10. Response of Galt barley to lime on soils containing various amounts of soluble aluminum.

DETERMINING SOIL ACIDITY AND LIME REQUIREMENTS

You can *not* tell by the appearance of a soil whether or not it is acid, although the kinds of plants that grow there naturally give some indication. *The only sure way to find out if a soil is acid is to have it analyzed.* Samples of farm soil are analyzed in Alberta by the Alberta Soil and Feed Testing Laboratory, Edmonton; and in British Columbia by the B.C. Soil Testing Laboratory, Kelowna. The pH of the soil sample is entered on the soil analysis report sheet that is sent to you. If the pH is 5.5 or lower, the soil is analyzed for soluble aluminum and those results are also entered on the report. If the soil pH is 5.6 to 5.9 and you have indicated that you intend to grow alfalfa, the amount of lime that is required to bring the soil pH to 6.2 is entered. If the pH of the soil sample is 5.5 or lower, two lime recommendations are given. One is the amount of lime needed to rid the soil of toxic quantities of aluminum for the purpose of growing grain crops, particularly barley, wheat, and rapeseed. The other is the amount of lime required to bring the soil to pH 6.2 for the purpose of also growing alfalfa and, of course, any other crop.

The amount of lime needed increases as the soil acidity increases. Also, more lime is needed for soils of high organic matter content than for soils low in organic matter. Clayey soils need more lime than sandy soils. The actual amount recommended could be anywhere from 1/2 ton/ac (1 tonne/ha) to 6 tons (13 tonnes). The usual amount required for growing cereal and oilseed crops on soils that have toxic quantities of aluminum is about 1 ton of ground limestone per ac (2.2 tonnes/ha). For soils of pH 5.5, an application of 1 ton/ac (2.2 tonnes/ha) generally corrects the acidity for growing alfalfa.

Figure 11. Response of barley to lime on a soil with 45 parts per million of aluminum.

Figure 12. A tractor-drawn dribble-type lime spreader.

Be careful in taking soil samples that are to be used to determine lime needs or whether you can grow tolerant crops. The problems of soil acidity may first be brought to your attention when you receive the results of the pH tests of the soil samples sent to the laboratory for finding fertilizer recommendations. If so, your soil analysis report will suggest that you resample the field in more detail. Separate samples should be taken in different parts of the field where crop growth is poor and where crop growth is good. Or, the field can be divided into several smaller blocks, about 10 ac (4 ha) each, for separate sampling. Each sample submitted to the laboratory should be made up of 10-15 subsamples from each part of the field. Instructions and advice on taking soil samples may be obtained from your district agriculturist. Liming is expensive and lime should be applied first to the land that needs it most.

WHERE TO BUY LIME AND HOW TO APPLY IT

Ask your district agriculturist for the name of the agent who sells lime. Because equipment that is available for applying lime varies from one region to another, this information should also be obtained from your district agriculturist.

Because lime must be applied at a much higher rate than fertilizer, most fertilizer spreaders do not apply a high enough rate of lime. But some truck-mounted or trailer-type cyclone spreaders are designed for applying both lime and fertilizer. The tractor-drawn dribble-type lime spreader (Figure 12) is small and therefore is most useful for liming rather small areas. A truck-mounted cyclone lime spreader is shown in Figure 13.

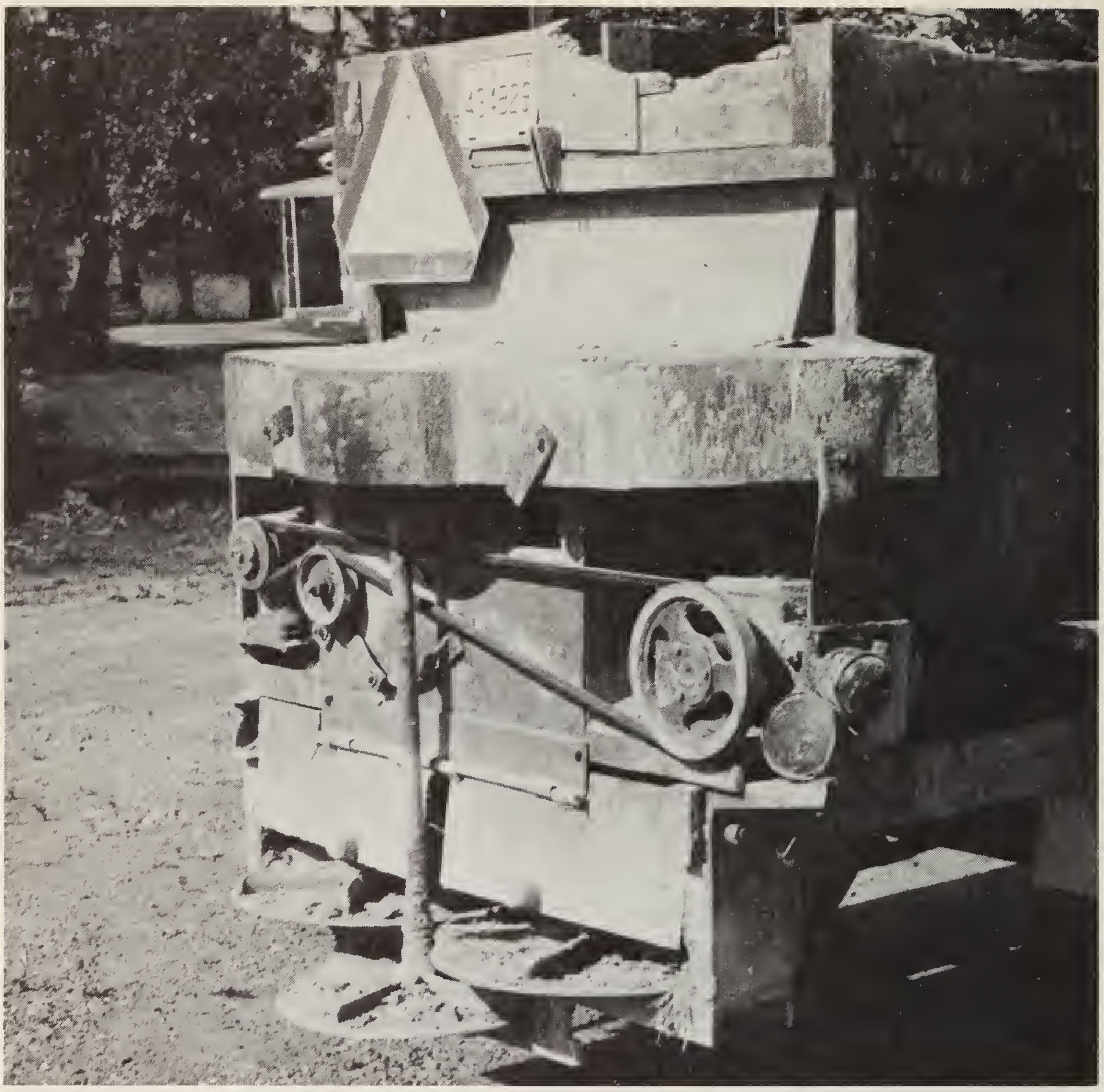

Figure 13. A truck-mounted cyclone lime spreader (Courtesy B.C. Dept. of Agriculture).

Lime can be applied at any time during the year when the ground can support a tractor or truck. To obtain the most benefit from the lime, it should be thoroughly mixed with the soil to a depth of 4-5 in. (10-13 cm).

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MORE INFORMATION

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CONVERSION FACTORS FOR METRIC SYSTEM

Imperial units	Approximate conversion factor	Results in:	
LINEAR			
inch	x 25	millimetre	(mm)
foot	x 30	centimetre	(cm)
yard	x 0.9	metre	(m)
mile	x 1.6	kilometre	(km)
AREA			
square inch	x 6.5	square centimetre	(cm^2)
square foot	x 0.09	square metre	(m^2)
acre	x 0.40	hectare	(ha)
VOLUME			
cubic inch	x 16	cubic centimetre	(cm^3)
cubic foot	x 28	cubic decimetre	(dm^3)
cubic yard	x 0.8	cubic metre	(m^3)
fluid ounce	x 28	millilitre	(mℓ)
pint	x 0.57	litre	(ℓ)
quart	x 1.1	litre	(ℓ)
gallon	x 4.5	litre	(ℓ)
bushel	x 0.36	hectolitre	(hℓ)
WEIGHT			
ounce	x 28	gram	(g)
pound	x 0.45	kilogram	(kg)
short ton (2000 lb)	x 0.9	tonne	(t)
TEMPERATURE			
degree fahrenheit	°F-32 x 0.56 (or °F-32 x 5/9)	degree Celsius	(°C)
PRESSURE			
pounds per square inch	x 6.9	kilopascal	(kPa)
POWER			
horsepower	x 746	watt	(W)
	x 0.75	kilowatt	(kW)
SPEED			
feet per second	x 0.30	metres per second	(m/s)
miles per hour	x 1.6	kilometres per hour	(km/h)
AGRICULTURE			
bushels per acre	x 0.90	hectolitres per hectare	(hℓ/ha)
gallons per acre	x 11.23	litres per hectare	(ℓ/ha)
quarts per acre	x 2.8	litres per hectare	(ℓ/ha)
pints per acre	x 1.4	litres per hectare	(ℓ/ha)
fluid ounces per acre	x 70	millilitres per hectare	(mℓ/ha)
tons per acre	x 2.24	tonnes per hectare	(t/ha)
pounds per acre	x 1.12	kilograms per hectare	(kg/ha)
ounces per acre	x 70	grams per hectare	(g/ha)
plants per acre	x 2.47	plants per hectare	(plants/ha)

Examples: 2 miles x 1.6 = 3. 2 km; 15 bu/ac x 0.90 = 13.5 hℓ/ha