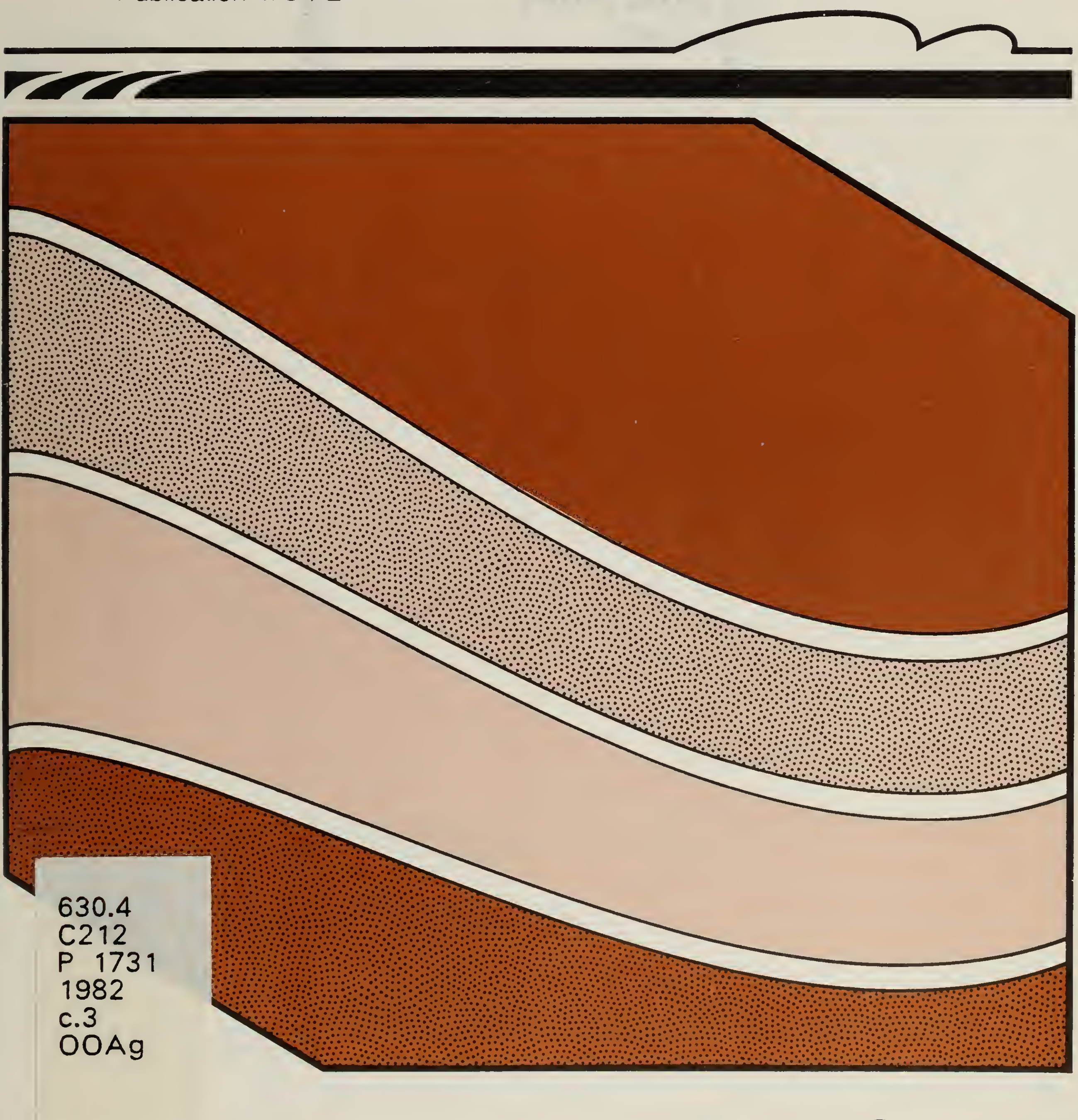
Acid soils and agricultural liming practice

Agriculture Canada

Publication 1731/E



Canada

Acid soils and agricultural liming practice

Prepared by K. Bruce MacDonald
Land Resource Research Institute
Ottawa, Ontario
March 1981
On behalf of
Expert Committee on Soil Management

PUBLICATION 1731, available from
Communications Branch, Agriculture Canada,
Ottawa K1A 0C7

Cat. No. A53—1731/1982E ISBN: 0-662-11855-3
Printed 1982 6M—4:82

Également disponible en français sous le titre
Les sols acides et le chaulage en agriculture.
This publication replaces publication #869 Liming and Other Soil Amendments.

Contents

Introduction/5

Sources of acidity/5
- Naturally occurring sources/5
- Man-induced sources/5

Management of soil acidity/7
- Liming materials/8
- Rate of reaction of limestone in soil/9
- Effectiveness of liming materials — the agricultural index/9
- Federal requirements for liming materials/12

Lime application/13
- Assessing soil requirements/13
- Assessing crop requirements/14
- Effect of liming on nutrient availability/15

Liming — part of a complete soil management program/15

Other publications/16

Introduction

Soil acidity, or soil pH, is a measure of the quantity of hydrogen ions, or acidity, in the soil. It is measured on a pH scale, which has values ranging from 0 to 14. On the pH scale a change of 1 pH unit represents a 10-fold change in acidity and 2 pH units represent a 100-fold change in acidity. In soils, the normal pH levels range from 3.5 to 8.5.

Soil acidity, or pH, is a soil characteristic that affects many aspects of crop growth and nutrient availability. For example, the development of leaf and petal color in some ornamental plants is related to soil pH. The severity of diseases such as potato scab and the rate of soil organism processes such as nitrification and crop residue decay are frequently affected by soil pH.

Soils with a pH value in the range of 6.5–7.5 are neutral in reaction, those with lower pH values are acidic in reaction, and those with higher pH values are alkaline in reaction. The lower the number, the more acid is the soil. The higher the number, the more alkaline is the soil.

The pH values of some common items are as follows: pure water, 7.0; lemon juice, 2.6; fresh milk, 6.6–6.9; mild soap solution, 8.5–10.0.

Sources of acidity

Naturally occurring sources

Soil pH and the sensitivity to change of the acid level in the soil are a result of the mineral and organic matter which make up the soil. Soils with a relatively high concentration of calcium and magnesium tend to have a pH near neutrality. When these soils contain free particles of calcium or magnesium carbonates (limestone) they resist pH change until these materials have been dissolved and leached out. The tendency for soils to become acid is a natural process resulting from leaching losses of calcium and magnesium and to a lesser extent from losses of sodium and potassium.

Man-induced sources

Growing crops and decomposing crop residues also produce acids in the soils. Man has speeded this process up greatly by:

i) the use of fertilizer materials, particularly nitrogen-containing materials, which add to the acidity level of soils. Table 1 lists some common fertilizer materials and shows the quantities of lime required to neutralize the acidity which they generate.
ii) acid additions (both wet and dry) from the atmosphere, commonly referred to as acid rain. Acidification from this source can lead to

TABLE 1 Lime required to neutralize the acidity generated by some common fertilizer materials

Material	Analysis	Lime (100% calcium carbonate) required* for each 100 kg of fertilizer material**	Lime (100% calcium carbonate) required for each kg of nitrogen (N) supplied in the fertilizer material
Ammonium nitrate	34-0-0	60	1.8
Urea	46-0-0	81	1.8
Anhydrous ammonia	82-0-0	148	1.8
Nitrogen solution	28-0-0	50	1.8
Aqua ammonia	20-0-0	36	1.8
Ammonium sulfate	21-0-0	110	5.4
Mono ammonium phosphate (MAP)	11-55-0	65	5.0
Di-ammonium phosphate (DAP)	18-46-0	90	5.0
Superphosphate	0-20-0	0	0
Triple superphosphate	0-46-0	0	0
Muriate of potash	0-0-60	0	0
Sulfate of potash	0-0-50	0	0
Sulfate of potash magnesia	0-0-21-10 Mg	0	0

Adapted from Andrews *The response of crops and soils to fertilizers and manures*. 2nd ed.; 1954.

* Figures are in kg if fertilizer is measured in kg. If fertilizer units are lbs then these figures remain correct but are read as lbs.

** This figure can be compared to the 23–63 kg/ha of lime required to neutralize the acidifying effects of precipitation in regions receiving relatively high rates of acid depositions.

amounts of sulfur and other acid-forming materials being added to the soil at such a rate that from 28 to 63 kg/ha of calcium carbonate is required annually to neutralize the acidifying effect. (This topic is dealt with in detail in Land Resource Research Institute Contribution No. 98, *Sensitivity of agricultural land to long-term acid precipitation in Eastern Canada.*) Acid rain will cause soils susceptible to shifts in pH to become acid more readily.

iii) intensifying crop production;
iv) improving drainage.

The development of acid conditions in soils is often a two-step process. First, all the basic compounds (calcium and magnesium carbonates, in particular) are consumed in neutralizing the developing acidity with little resultant change in soil pH, and second, the pH value decreases and the degree of acidity increases as the concentration of hydrogen ion increases. It is this latter stage that results in changes in nutrient availability, microbial processes, etc.

The map shows areas in Eastern Canada where the surface soil is susceptible to pH change from one or more of the acidifying processes. (Similar areas in Western Canada are much more localized. See, for example, *Acid soils in West Central Saskatchewan* or *Farming acid soils in Alberta and Northeastern British Columbia*. Complete references are listed under Other publications.) Management of the sensitive soils must include liming. The moderately sensitive areas represent soils in which the reserves of carbonates of calcium and magnesium have been depleted or were never present and, while they are generally not so acidic as to restrict crop growth, they will require liming in the near future to maintain their level of productivity. The nonsensitive regions represent areas in which calcium and magnesium levels in the soil are sufficient to neutralize the acidic materials that are currently being applied.

Because of localized soil variability, this map cannot be directly related to specific farms or fields. It is very generalized and at best gives regional trends. Landowners should determine the acidity level of their soil regardless of which soil area it falls into.

Management of soil acidity

There are two main ways to manage soil acidity. One way is to grow crops that are tolerant of soil acidity. However, under this management the soil will continue through natural and man-induced processes to become increasingly acidic. As the soil pH value decreases, it will drop below the range suitable for tolerant crops. The second way, a long-term solution, is to apply appropriate kinds and amounts of lime to the soil.

Liming materials

The term *lime*, used in the agricultural sense, refers to any of a great variety of materials that are usually composed of the oxide, hydroxide, or carbonate of calcium, or calcium and magnesium, used as a soil amendment to decrease soil acidity. The most common liming material is ground limestone. It may consist of only calcium carbonate (calcitic limestone) or a mixture of calcium and magnesium carbonates (dolomitic limestone). Other liming materials are marl, hydrated lime, pulpmill by-products, and industrial sugar refinery limestone waste.

Equal weights of different liming materials may not have the same ability to neutralize soil acidity. This is due to differences in the chemical composition of the material and its purity. The amount of acid a given quantity of limestone will neutralize when totally dissolved is called its neutralizing value. Pure calcium carbonate ($CaCO_3$) is used as a standard to compare the effectiveness of liming materials. It has a neutralizing value of 100. The neutralizing value for other materials is expressed as a percentage of the neutralizing value of pure calcium carbonate.

Dolomitic limestone. Dolomitic limestone consists of a mixture of magnesium and calcium carbonates. It can receive this designation with as little as 5% magnesium carbonate. The proportion of magnesium carbonate ($MgCO_3$) in the sample affects its neutralizing value; for example, a sample that contains 30% magnesium carbonate and the remainder calcium carbonate has a neutralizing value of 109, i.e., 100 kg of dolomite will neutralize the same amount of acidity as 109 kg of calcium carbonate.

The amount of calcium and magnesium added to the soil with a limestone application can be calculated as follows: 1000 kg of dolomitic limestone, which contains 30% magnesium carbonate, contains 30% of 1000 kg, or 300 kg, of magnesium carbonate. Of this, 29%, or 86 kg, is elemental magnesium. If the limestone contains 66% calcium carbonate, 66% of 1000 kg, or 660 kg, is calcium carbonate; 40% of this, or 264 kg, is elemental calcium.

Calcitic limestone. Calcitic limestone contains mostly calcium carbonate and usually less than 5% magnesium carbonate. Impurities reduce the amount of lime provided; for example, 1000 kg of calcitic limestone 91% pure would provide 1000 kg × 91%, or 910 kg, calcium carbonate; 40% of this, or 364 kg, would be elemental calcium.

Marl. Marl is a water deposited material that has not yet solidified and therefore does not require crushing. It consists largely of calcium carbonate with some clay, sand, and organic matter present as impurities. A marl containing between 80 and 90% calcium carbonate is of good quality. When such a deposit is accessible and the costs of digging and hauling are not prohibitive, marl can be an effective source of lime. In many instances, marl will be lumpy and variable in effective size in the natural state — thus it may be difficult to handle and spread uniformly.

Indurated marl. Indurated marl is a hard, rocklike material with a honeycombed structure, deposited by waters of streams and springs rich in calcium carbonate. It is usually necessary to crush this type of marl before it can be evenly distributed on the soil.

Shells, mussel, and oyster muds. Along seacoasts, shells of various crabs, lobsters, and other shellfish, as well as muds containing varying quantities of mussel, oyster, and clam shells can often be obtained at little or no cost. Because the shells themselves are composed almost entirely of calcium carbonate, they can be used to advantage on acid soils, but unless they are crushed, or ground, their action is very slow.

Choice of a liming material should not be made on the basis of cost alone because the cheapest limestone may not meet the soil requirements. Choose a limestone that will raise the soil pH to the required level and also provide a proper balance of calcium and magnesium in the soil.

Where magnesium is required as a crop nutrient, dolomitic limestone should be used. Adding magnesium to other liming materials to equal that contained in dolomitic limestone would make the price of such a mixture prohibitive. If the soil magnesium level is already adequate, calcitic limestone may be used to raise the soil pH to the required level. On soils with very high magnesium levels the use of dolomitic limestone is not recommended because it will further increase the soil magnesium levels. *Selection of a liming material should be based on soil test recommendations which show the relative status of magnesium and calcium in your soil.*

Rate of reaction of limestone in soil

Liming materials neutralize soil acidity at different rates because of their fineness of grind, chemical composition, and hardness. Chemical composition and hardness have only a minor effect on reaction rates; the main factor is the degree of fineness. The finer a limestone is ground, the more quickly it will react when thoroughly mixed with the soil because of the increase in surface area of the limestone particles. This, in turn, means much more contact by the soil particles and soil solution with the limestone particles and, consequently, more rapid neutralization of soil acidity.

Effectiveness of liming materials — the agricultural index

Some means of combining neutralizing value and particle size is required to measure the overall effectiveness of limestone for neutralizing acid soils and to compare the relative values of different liming materials.

For this purpose a measure called the agricultural index has been developed.

$$\text{Agricultural index} = \frac{\text{neutralizing value} \times \text{fineness rating}}{100}$$

Sensitive - Surface soil exchangeable bases are less than 6 meq/100 g soil (or more than 25% of exchangeable bases could be depleted in 25 years).

Moderately sensitive - Surface soil exchangeable bases are 6 - 15 meq/100 g soil (or 10 - 25% of exchangeable bases could be depleted in 25 years).

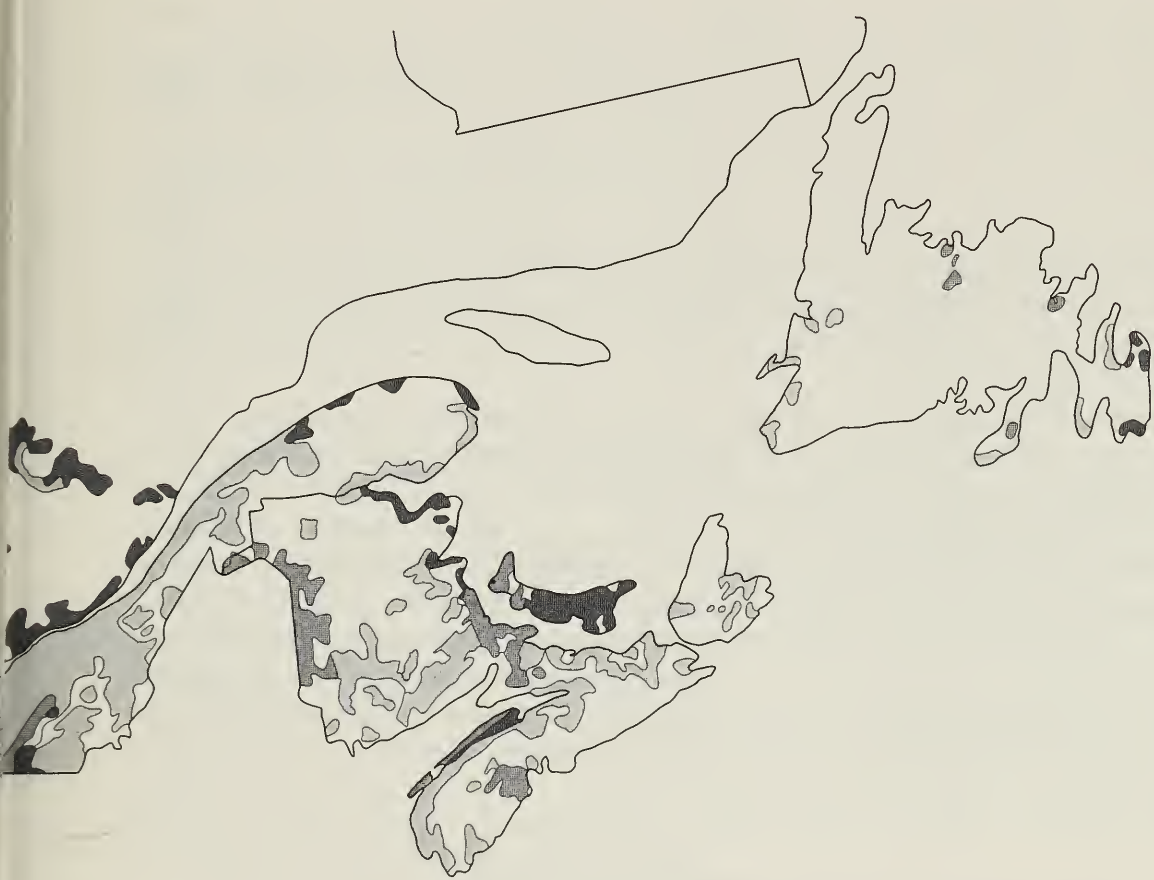
Non sensitive - Surface soil exchangeable bases exceed 15 meq/100 g soil (or less than 10% of exchangeable bases could be depleted in 25 years).

Unclassified - Non agricultural land.

SENSITIVITY OF AGRICULTURAL LAND TO LONG-TERM ACIDIFICATION, EASTERN CANADA. (THE ASSUMED INTENSITY OF ACIDIFICATION IS EQUIVALENT TO A LINE REQUIREMENT OF 60 kg/ha PER YEAR.)

Note: Due to cartographic generalization, areas shown as agricultural land may include non agricultural land.

Soil information compiled by C. Wang, Land Resource Research Institute, Research Branch, Agriculture Canada, Ottawa. The cultivated land areas shown were generalized from data at scale 1:50,000 by Claire Gosson, Geographical Services Directorate, Survey and Mapping Branch, Department of Energy, Mines and Resources, Ottawa.



Map compiled and drawn by Cartography Section, Land Resource Research Institute, Research Branch, Agriculture Canada.

A limestone that will neutralize 90% as much acid as pure calcium carbonate has a neutralizing value of 90. For a sample such as this, the fineness rating is calculated from the percentage of the material that will pass through Nos. 10 and 60 mesh Tyler screens as follows:

Particle size	% of sample		Effectiveness factor	
Coarser than No. 10 sieve	10	×	0	= 0
Passing through a No. 10 sieve but retained on a No. 60 sieve	40	×	0.4	= 16
Passing through a No. 60 sieve	50	×	1.0	= 50
			Fineness rating	66

By multiplying the percentage of a limestone sample in each of the three size categories by the effectiveness factor for that size fraction, a fineness rating is established for any sample of agricultural lime. The effectiveness factor used in this calculation gives an indication of how readily a particular sized particle will react with the soil. These factors imply that particles which are retained on a No. 10 mesh Tyler screen (2 mm) are totally ineffective and will not react for many years, those which pass through a No. 10 sieve but are retained on a No. 60 mesh Tyler screen are 40% effective and will react in 1–2 years, and that those which pass through a No. 60 Tyler screen are completely effective and available the year of application.

The limestone sample, used as an example, with a neutralizing value of 90 and a fineness rating of 66 would have an agricultural index of $90 \times 66/100 = 59.4$, or approximately 60.

The agricultural index can be used to compare the relative value of two different limestones for neutralization of soil acidity. For example, to compare the limestone from the example calculation (agricultural index of 60), referred to as limestone A, with one with an index of 90, referred to as limestone B, the rate of A must be $90/60 \times$ the rate of B to give equivalent effects. Similarly, to be equally cost effective, limestone A must be available, delivered, and spread on the farm at $60/90 \times$ the cost of limestone B.

Federal requirements for liming materials

Liming materials sold or offered for sale in Canada must meet the basic requirements set forth under the Fertilizers Act and Fertilizers Regulations. The Plant Products and Quarantine Directorate of the Food Production and Inspection Branch of Agriculture Canada is responsible for ensuring that sellers meet the terms of the Fertilizers Act and Fertilizers Regulations.

Under the Act and Regulations, all liming materials must conform to prescribed standards (merit, safety, and value) and be packaged and labeled as prescribed. All liming material product labels must carry the following minimal information:

- product name
- guaranteed analysis of all active ingredients
- a net-content statement
- cautions, where necessary
- name and address of the responsible packager.

Specific guarantees required for liming materials are for minimum amounts of calcium and magnesium, minimum neutralizing value expressed as calcium carbonate equivalent, and fineness guarantees for the percentages passing through Nos. 10 and 100 mesh Tyler screens. As with all fertilizers and soil conditioners, the units of measurement used on labels for liming materials must be metric.

Lime application

Assessing soil requirements

Soil-testing laboratories will provide a lime requirement test on request. The rate of lime needed varies with the soil pH, organic matter content, and clay content. The actual amount recommended may vary from 1 to 13 t/ha.

Fields that are not uniform in crop growth, texture, color, drainage, or organic matter content are not likely to be uniform in lime requirement. Each section that appears different should be sampled separately. Liming is a fairly large expenditure, and it is important that lime be applied to land that needs it most. The field should be divided into smaller areas based on observations of crop growth differences. Patterns of poorer growth, particularly of nontolerant crops, can be used as an aid in mapping out the sampling areas.

In general, the soil factors of importance in determining lime needs include (i) soil pH, (ii) amount of chemically held acidity in the soil, (iii) depth of cultivation, (iv) desired pH for the crop to be grown, and (v) soil texture. Table 2 gives example lime requirements to achieve various shifts in soil pH on soils of various textures.

One of the important considerations in the application of limestone is the depth of normal cultivation practices. The deeper the zone of soil with favorable conditions for plant growth, the greater will be the rooting depth. Crops with restricted roots produce poor yields. Unless the limestone is thoroughly mixed with the soil to full cultivation depth, only a part of the rooting zone will be favorable for plant growth. Twice as much

TABLE 2 Limestone required to change the pH of the plow layer (18 cm) of soils of various textures

Texture of plow layer	Desired pH	Soil pH before liming 4.5	5.5
		Tonnes of lime required per hectare	
Clay loam	6.5	13	8
	6.0	11	4
	5.5	8	0
Loam	6.5	11	7
	6.0	9	4
	5.5	7	0
Fine Sandy loam	6.5	9	4
	6.0	7	2
	5.5	4	0
Sandy loam	6.5	7	3
	6.0	5	2
	5.5	3	0

lime is required to correct the acidity of the cultivated layer of a soil plowed 20 cm deep as is needed to correct the acidity of a soil plowed 10 cm deep. It should be noted that when the surface soil is adequately limed, liming of the subsoil has little effect on yields. Consequently, cultivation to depths deeper than normal to incorporate lime is generally not warranted.

Lime compounds may be applied whenever the land can support a tractor or truck; fall or early spring are usually the most convenient times. The liming material should be incorporated by cultivation to ensure even distribution in the surface soil. Where large applications are used (6 t/ha or more) a split application is recommended, with deep tillage after the first application and shallower tillage after the second. Depths of tillage required for good crop growth may differ according to the particular area of Canada.

Assessing crop requirements

The degree to which soil acidity should be neutralized depends on the crop to be grown. Sensitive crops, such as alfalfa, trefoil, clovers, and soybeans, have bacteria living in nodules on the roots of the crops. These bacteria take nitrogen from the air and change it into a form that plants can use. The bacteria thrive best at pH values above 6.0 in most soils. Hence, pH values above 6.0 are generally best for these legume crops.

Legumes such as red clover and alsike clover, in exception to this generalization, grow well at pH 5.5 or lower. More tolerant crops such as broccoli, brussels sprouts, apples, cereals, and grasses can be grown successfully on soils having a pH value in the range of 5.5–7.5. This again is a generalization and within this group specific crops vary with regard to their sensitivity to soil acidity.

Potato scab is more prevalent at soil pH values above 5.5 than at lower pH levels. Black root rot in tobacco is more prevalent at pH values above 6.4. Some plants such as rhododendrons, blueberries, and cranberries grow well at pH values below 6.0 and appear to suffer from iron and/or manganese deficiencies at higher pH values. There is also evidence that fungi associated with healthy root development on these plants require soil with a low pH value.

Effect of liming on nutrient availability

Acid soils are relatively low in calcium and frequently low in magnesium, but usually have adequate amounts of each of these elements to supply the requirements of growing crop. Liming materials are occasionally required to supply calcium and magnesium as plant nutrients as well as to perform their role in neutralizing soil acidity.

Phosphorus in soils is commonly considered to be most available at pH values near 6.5, with its availability decreasing at both lower and higher pH values. However, soil test and fertilizer response studies in many areas indicate that frequently soils with high pH values contain adequate amounts of plant-available phosphorus.

Aluminum, iron, manganese, boron, copper, and zinc are more soluble in acid than in neutral or slightly alkaline soils. When a soil is made less acid by liming, the solubility of each of these elements decreases. Except for aluminum, these elements are essential to plant growth, but only in very small amounts. In acid soils, manganese in particular may be toxic and result in reduced crop yields. Deficiencies of these micronutrients can reduce yields. Aluminum is not needed for plant growth and, although it is not likely to be toxic at pH values above 5.5, at lower pH levels it is frequently toxic. Molybdenum is one element essential for plants that is less soluble in acid soils.

Liming — part of a complete soil management program

For soils that are susceptible to acidification (i.e., those with a pH value of less than 6.0 and have no free carbonates of calcium and/or magnesium), liming must be an integral part of the soil management program for sustained crop production. Crops must be selected that are tolerant of the existing soil pH, and the pH must be adjusted and managed to meet crop requirements. Even soils supporting tolerant crops such as potatoes may require periodic liming to prevent the soil pH from decreasing to levels where crop growth is reduced.

Liming does not replace other management practices. As well as any requirement for lime, productive soils require adequate additions of crop nutrients through fertilizers, crop residues, or manure. Timeliness of cultural operations remains important in order to make optimal use of soil, labor, and climatic resources and to produce crops of high yield and quality. Normal pest control practices and selection of recommended crop varieties and species are still requisites to successful production operations.

In conjunction with other good management practices, the use of lime when needed results in some direct benefits to the farmer:

- Lime application decreases the solubility of aluminum and manganese and reduces or eliminates their toxic effects.
- Lime application increases the availability of phosphorus and molybdenum to the plant.

In this direct way and also in indirect ways, the use of lime where required will increase the efficiency of applied fertilizer.

- Liming of acid soils promotes microbial activity resulting in the increased release of organic nitrogen, sulfur, and phosphorus through the more rapid decomposition of organic matter.
- Liming of acid soils tends to promote better soil structure and tilth by increasing crop residues and through chemical effects of decreasing acidity and increasing calcium and magnesium concentration.

Watch for areas where soil acidity is reaching levels that restrict plant growth. When these conditions arise proper liming practices following guidelines from soil-testing laboratories will result in continued high levels of crop production.

Other publications

Wang, C.; Coote, D. R. Sensitivity classification of agricultural land to long-term acid precipitation in Eastern Canada. Ottawa, Ont.: Land Resource Research Institute Contribution No. 98. 1981.

Coote, D. R.; Siminovitch, D.; Singh, S. S.; Wang, C. The significance of acid rain to agriculture in Eastern Canada. Ottawa, Ont.: Land Resource Research Institute Contribution No. 119. Chemistry and Biology Research Institute Contribution No. 1236. 1981.

Atlantic Soil Fertility Committee. Atlantic soils need lime. Departments of Agriculture of New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland.

Conseil des Productions végétales du Québec. Rapport de la journée d'information sur la chaux agricole. Québec: Ministère de l'Agriculture, des Pêcheries et de l'Alimentation; 1980.

Bates, T. E.; Lane, T. H. Soil acidity and liming. Guelph, Ont.: Ministry of Agriculture and Food, c/o University of Guelph. Fact Sheet, Agdex 534; 1979.

Rostad, H. P. W. Acid soils in West Central Saskatchewan. Saskatoon, Sask.: Saskatchewan Institute of Pedology. Map, Publ. M64; 1981.

Alberta Soils Advisory Committee. Soil quality criteria for agriculture. Alberta: prepared under the sponsorship of Western Canada Soil Coordinating Committee. Published by Agric. Can.; 1979.

Alberta Agriculture. Crop production on acid soils. Edmonton, Alta.: Alberta Agriculture. Leaflet.

Hoyt, P. B.; Nyborg, M.; Penney, D. C. Farming acid soils in Alberta and Northeastern British Columbia. Ottawa, Ont.: Agric. Can. Publ. 1521; 1974.

Field Crops Branch. Soil reaction. Victoria, B.C.: British Columbia Department of Agriculture; 1974.

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)
WEIGHT			
ounce	x 28	gram	(g)
pound	x 0.45	kilogram	(kg)
short ton (2000 lb)	x 0.9	tonne	(t)
TEMPERATURE			
degrees Fahrenheit	(°F-32) x 0.56 or (°F-32) x 5/9	degrees Celsius	(°C)
PRESSURE			
pounds per square inch	x 6.9	kilopascal	(kPa)
POWER			
horsepower	x 746 x 0.75	watt kilowatt	(W) (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			
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)